A02

R程式語言的基礎: 物件

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本章大綱&學習目標

- R程式變數(Variables)命名法及語法
- Rounding of Numbers
- 向量 (Vectors)
  - 向量運算、規律的序列、邏輯向量、字元向量、遺失值
- 因子 (Factors)、陣列 (Arrays)、矩陣 (Matrices)
- 表列 (List)、資料框 (Data Frame) 、時間日期
- 物件的模式(Mode)、類別 (Class)、屬性 (Attributes)
- 查詢物件之模式、類別、屬性、結構及可取用的元素。
- 存取物件內之元素

R變數命名法

- Case sensitive
  - `A` and `a` are different
- All alphanumeric symbols are allowed (`A-Z, a-z, 0-9`)
  - "`.`", "`_`".
- Name must start with "." or a letter.

- 錯誤命名
  - `3x`
  - `3_x`
  - `3-x`
  - `3.x`
  - `.3variable`
- 正確命名
  - `x_3`
  - `x3`
  - `x.3`
  - `taiwan.taipei.x3`
  - `.variable`

Google's R Style Guide
https://google.github.io/styleguide/Rguide.xml

Function name: Make function names verbs.
GOOD : `CalculateAvgClicks`
BAD : `calculate_avg_clicks`
BAD : `calculateAvgClicks`

Variable name:
GOOD : `avg.clicks`
OK: `avgClicks`
BAD : `avg_Clicks`

File names: be meaningful.
GOOD: `predict_ad_revenue.R`
BAD: `foo.R`

R語法

- Assignments

```
> x <- 5
> x = 5
> x
> (x <- 5)
[1] 5
> assign("x", 2)
> 2 -> x
> a <- b <- c <- 6
```

Assignment: 建議使用 **<-**, 而不是 **=**
https://google.github.io/styleguide/Rguide.xml
Google's R Style Guide

- x <- expressions

```
> x <- 3+5
```

- ; or new line

```
> x <- 5 ; y <- 7
```

or

```
> x <- 5
> Y <- 7
```

- Comment

```
> # how are you?
```

- "+" : If a comment is not complete at the end of a line, R will give a different prompt.

```
> x <-
+ 5
```

提示符號(prompt)

```
> (y <- 1:5)
[1] 1 2 3 4 5
> sum(y)
[1] 15
> options(prompt = 'hmwu> ', continue = "+   ")
hmwu> sum(y^2)
[1] 55
hmwu> options(prompt = '> ', continue = "+   ")
>
```

物件 (Objects)

- Variables, arrays of numbers, character strings, functions,...

```
> x <- 3+5
> y <- 7
> objects()
[1] "x" "y"

> ls()
[1] "x" "y"

> rm(x, y)
> rm(list = ls())

> objects()
character(0)
```

儲存R物件所佔用的記憶體估計:

```
object.size(x)
print(object.size(x), units = "Mb")
```

```
> n <- 10000
> p <- 200
> myData <- matrix(rnorm(n*p), ncol = p, nrow=n)
> print(object.size(myData), units = "Mb")
15.3 Mb
```

```
> os <- function(x){
+    print(object.size(x), units = "Mb")
+ }
> os(myData)
15.3 Mb
```

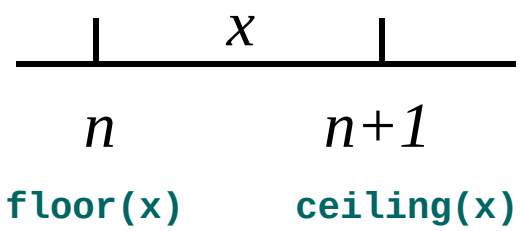
物件 (Objects)

```
> x <- 2 # x is a vector of length 1
> x <- vector() # x is a vector of 0 length
> x <- matrix() # x is a matrix of 1 column, 1 row
> x <- 'Hello Dolly' # x is a vector containing 1 string
> x <- c('Hello', 'Dolly') # x is a vector with 2 strings
> x <- function(){} # x is a function that does nothing
```

- The vectors are atomic objects — all of their elements must be of the same mode.
- Most other types of objects in R are more complex than vectors. They may consist of collections of vectors, matrices, data frames and functions.
- When an object is created (for example with the assignment <-), R must allocate memory for the object.
- The amount of memory allocated depends on the mode of the object.

Rounding of Numbers

- **ceiling**: the **smallest integers** not less than the corresponding elements of x.
- **floor**: the **largest integers** not greater than the corresponding elements of x.



- **trunc**: **the integers** formed by truncating the values in x toward 0.
- **round**: rounds the values in its first argument to the specified number of decimal places (default 0).

```
> (x <- c(pi, 1/3, -1/3, -pi))
[1]  3.1415927  0.3333333 -0.3333333 -3.1415927
> ceiling(x)
[1]  4  1  0 -3
> floor(x)
[1]  3  0 -1 -4
> trunc(x)
[1]  3  0  0 -3
> round(x, 2)
[1]  3.14  0.33 -0.33 -3.14
> round(x, 5)
[1]  3.14159  0.33333 -0.33333 -3.14159
```

```
> # checking if a number is an integer
> (x <- c(1/3, 2, -4, 1.5))
[1]  0.3333333  2.0000000 -4.0000000  1.5000000
> ceiling(x) == floor(x)
[1] FALSE  TRUE  TRUE FALSE
```

設定數值顯示位數 (1)

```
> getOption("digits") # digits: controls the number (1~22, default 7) of
digits to print when printing numeric values.
[1] 7
> x1 <- c(-10, -0.00001, 0, 0.00001, 10)
> x2 <- c(-10, -0.00001, 0, 0.00001, 10, pi)
> x3 <- c(-12, -0.12345, 0, 0.12345, 12)
> x4 <- c(1.810032e+09, 1.810032e-09, 10, pi, 0.0001, -0.0000005)
> x1 # same as print(x1)
[1] -1e+01 -1e-05  0e+00  1e-05  1e+01
> x2
[1] -10.000000  -0.000010   0.000000   0.000010  10.000000   3.141593
> x3
[1] -12.00000  -0.12345   0.00000   0.12345  12.00000
> x4
[1]  1.810032e+09  1.810032e-09  1.000000e+01  3.141593e+00 -5.000000e-07
> cat(x1, "\n")
-10 -1e-05 0 1e-05 10
> cat(x2, "\n")
-10 -1e-05 0 1e-05 10 3.141593
> cat(x3, "\n")
-12 -0.12345 0 0.12345 12
> cat(x4, "\n")
1810032000 1.810032e-09 10 3.141593 -5e-07
```

設定數值顯示位數 (2)

```
> op <- options();
> str(op) # nicer printing
List of 72
 $ add.smooth                          : logi TRUE
...
> options(digits = 3) # try options(digits = 1) or options(digits = 5)
> x1 # same as print(x1)
[1] -1e+01 -1e-05  0e+00  1e-05  1e+01
> x2
[1] -10.00000  -0.00001   0.00000   0.00001  10.00000   3.14159
> x3
[1] -12.000  -0.123   0.000   0.123  12.000
> x4
[1]  1.81e+09  1.81e-09  1.00e+01  3.14e+00 -5.00e-07
> cat(x1, "\n")
-10 -1e-05 0 1e-05 10
> cat(x2, "\n")
-10 -1e-05 0 1e-05 10 3.14
> cat(x3, "\n")
-12 -0.123 0 0.123 12
> cat(x4, "\n")
1.81e+09 1.81e-09 10 3.14 -5e-07
> options(op)  # reset (all) initial options
> options("digits") # or getOption("digits")
$digits
[1] 7
```

See also:

```
> getOption( "scipen" )
# (penalty) print numeric values in
fixed (scipen = positive integer)
notation or exponential (negative
integer) notation. Fixed notation
will be preferred unless it is more
than scipen digits wider.
> options(scipen = 100, digits = 4)
> options(scipen = 999) # do not
show scientific notation
```

向量 (Vector)

- 向量(vector): 同樣屬性(數字或文字)的資料的集合
- **c( )**: 串連多個字串 (combine values into a vector or list)

```
> x1 <- c(10, 5, 3, 6, 2.7)
> x1
[1] 10.0  5.0  3.0  6.0  2.7
>
> assign("x2", c(10, 5, 3, 6, 2.7))
> x2
[1] 10.0  5.0  3.0  6.0  2.7
>
> c(10, 5, 3, 6, 2.7) -> x3
> x3
[1] 10.0  5.0  3.0  6.0  2.7
>
> length(x1)
[1] 5
>
> c(1,7:9)
[1] 1 7 8 9
> c(1:5, 10.5, "next")
[1] "1" "2" "3" "4" "5" "10.5" "next"
```

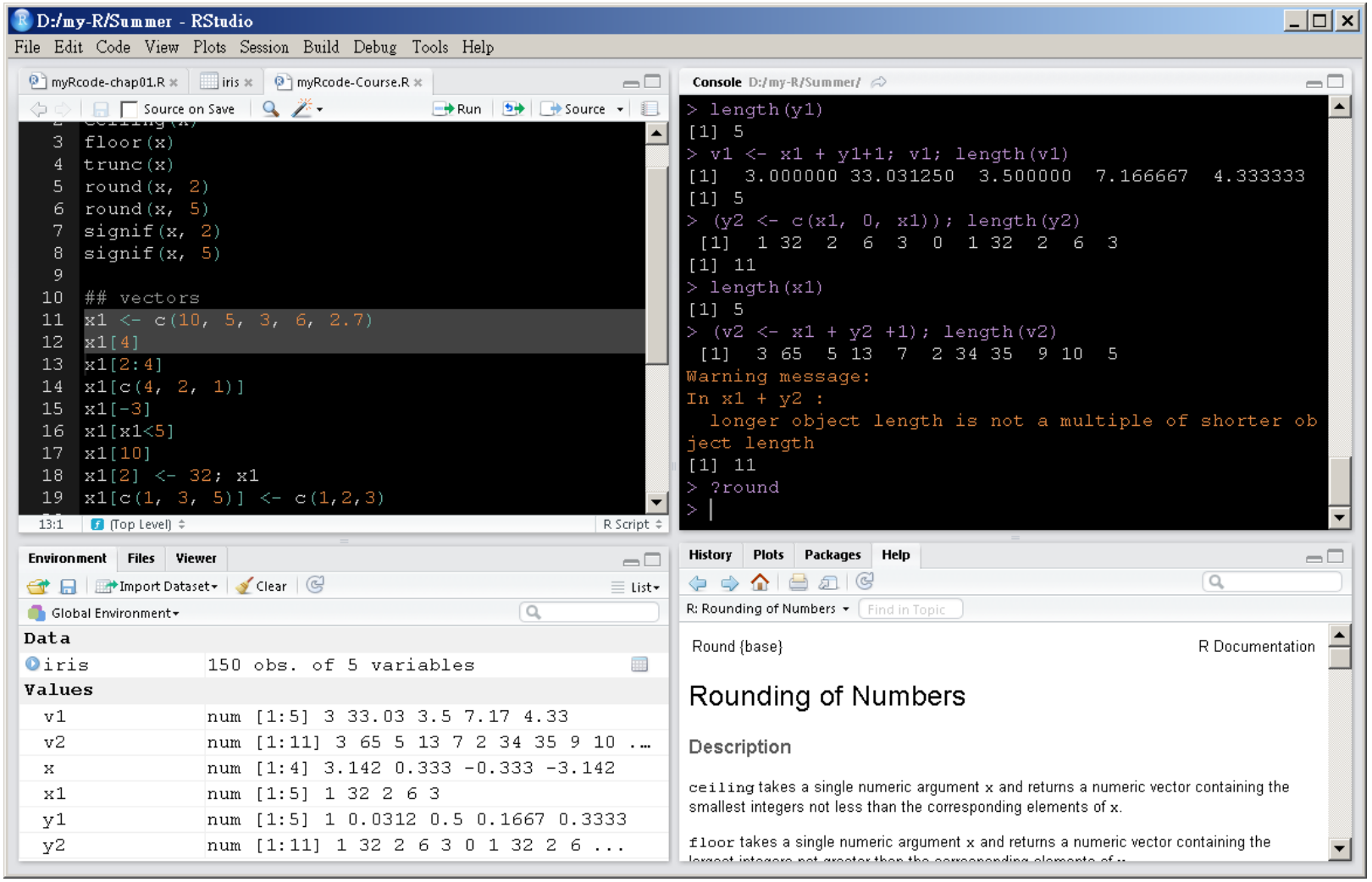
```
> x1[4]
[1] 6
> x1[2:4]
[1] 5 3 6
> x1[c(4, 2, 1)]
[1]  6  5 10
> x1[-3]
[1] 10.0  5.0  6.0  2.7
> x1[x1<5]
[1] 3.0 2.7
> x1[10]
[1] NA
> x1[2] <- 32; x1
[1] 10.0 32.0  3.0  6.0  2.7
> x1[c(1, 3, 5)] <- c(1,2,3)
> x1
[1]  1 32  2  6  3
```

向量 (Vectors)

```
> (y1 <- 1/x1)
[1] 0.1000000 0.2000000 0.3333333 0.1666667 0.3703704
> length(y1)
[1] 5
>
> v1 <- x1 + y1+1; v1; length(v1)
[1] 11.100000  6.200000  4.333333  7.166667  4.070370
[1] 5
>
> (y2 <- c(x1, 0, x1)); length(y2)
 [1] 10.0  5.0  3.0  6.0  2.7  0.0 10.0  5.0  3.0  6.0  2.7
 [1] 11
>
> length(x1)
[1] 5
> (v2 <- x1 + y2 + 1); length(v2)
 [1] 21.0 11.0  7.0 13.0  6.4 11.0 16.0  9.0 10.0  9.7 13.7
Warning message:
In x1 + y2 :
  longer object length is not a multiple of shorter object length
[1] 11
```

x1 repeated 2.2 times, y2 repeated one time, 1 repeated 11 times

課堂練習1



注意: 打完一行程式，就立刻執行，查看結果

向量運算 (Vector Arithmetic)

一些簡單的數學計算:

- +, -, *, /, ^
- log(x), logb(x, b)
- pi, exp(x),
- sin(pi/2), cos(pi), tan(pi/4),
- abs(x), sqrt(x),
- length(x)
- prod(x)
- choose(n, k)
- factorial(x)

一些簡單的統計運算:

- max(x), min(x)
- pmax(x), pmin(x)
- range(x)
  - c(min(x), max(x))
- mean(x)
  - sum(x)/length(x)
- var(x), cov(x)
  - sum((x-mean(x))^2)/(length(x)-1)
- sqrt(var(x))
- median(x)
- summary(x)
- cor(x, y)

其它函式應用

- sort(x)#排序，由小到大。
- rank(x)#排序等級。
- order(x)#排序後，各個元素的原始所在位置。

```
> ?mean
查看 mean的用法
mean(x, trim = 0, na.rm = FALSE, ...)
```

課堂練習2

```
> x <- c(1.58, -0.29,  0.59, -0.38,  0.72)
> max(x)
[1] 1.58
> min(x)
[1] -0.38
> range(x)
[1] -0.38  1.58
> c(min(x), max(x))
[1] -0.38  1.58
> mean(x)
[1] 0.444
> sum(x)/length(x)
[1] 0.444
```

```
> var(x)
[1] 0.65143
> sum( (x-mean(x))^2)/(length(x)-1)
[1] 0.65143
> sqrt(var(x))
[1] 0.8071121
> median(x)
[1] 0.59
> summary(x)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 -0.380  -0.290   0.590   0.444   0.720   1.580
> sort(x)
[1] -0.38 -0.29  0.59  0.72  1.58
> rank(x)
[1] 5 2 3 1 4
> order(x)
[1] 4 2 3 5 1
```

規律的序列 (Regular Sequences)

```
> x <- c(1,2,3,4,5,6,7,8,9,10)
> x <- 1:10
> y <- 10:2
> 2*1:10 #The colon operator has high priority with an expression
 [1]  2  4  6  8 10 12 14 16 18 20
>
> n <- 10
> 1:n-1
 [1] 0 1 2 3 4 5 6 7 8 9
> 1:(n-1)
[1] 1 2 3 4 5 6 7 8 9
>
> width <- 1
> seq(from = 2, to = 5, by = width)
[1] 2 3 4 5
>
> 2:5
[1] 2 3 4 5
> s1 <- seq(-5, 5, by = 0.2) # -5.0 -4.8 -4.6 ... 4.8  5.0
> s2 <- seq(length = 51, from = -5, by = 0.2) # -5.0 -4.8 -4.6 ...
4.8  5.0
```

規律的序列 (Regular Sequences)

```
> rep(x, times=5)
 [1]  1  2  3  4  5  6  7  8  9 10  1  2  3  4  5  6  7  8
[19]  9 10  1  2  3  4  5  6  7  8  9 10  1  2  3  4  5  6
[37]  7  8  9 10  1  2  3  4  5  6  7  8  9 10
>
> rep(x, each=5)
 [1]  1  1  1  1  1  2  2  2  2  2  3  3  3  3  3  4  4  4
[19]  4  4  5  5  5  5  5  6  6  6  6  6  7  7  7  7  7  8
[37]  8  8  8  8  9  9  9  9  9 10 10 10 10 10
>
> rep(1:4, each=5)
 [1] 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 4

> rep(LETTERS[1:4], 3)
 [1] "A" "B" "C" "D" "A" "B" "C" "D" "A" "B" "C" "D"
>
> rep(LETTERS[1:4], length.out=3)
[1] "A" "B" "C"
```

課堂練習3: 造出規律的序列

- 1 2 2 3 3 3 4 4 4 4 5 5 5 5 5
- 5 4 4 3 3 3 2 2 2 2 1 1 1 1 1
- 1 2 3 1 2 3 1 2 3
- Fibonacci number (可能需要用到**for**):
0 1 1 2 3 5 8 13 21 34 55 ...
- 1 2 3 4 5 2 3 4 5 3 4 5 4 5 5
- 1 6 13 22 33 46 ...
- 1 2 3 4 9 8 27 16 ...

```
> seq(from=1, by=1:5, len=5)
[1]  1  3  7 13 21
> seq(from=1, by=1, len=5)
[1] 1 2 3 4 5
> seq(from=1, by=2, len=5)
[1] 1 3 5 7 9
> seq(from=1, by=3, len=5)
[1]  1  4  7 10 13
> seq(from=1, by=4, len=5)
[1]  1  5  9 13 17
> seq(from=1, by=5, len=5)
[1]  1  6 11 16 21
>
```

rev, **sequence**

Ex: 將[0, 2]分成20等份的子區間。
- 取左端點
- 取右端點
- 取子區間之中點

([a, b]之partition, 用於Riemann Sum)

邏輯向量 (Logical Vectors)

- **TRUE, FALSE**
- **T, F**
- Logical operators
  - `<, <=, >, >=, ==, !=`
- c1,c2: logical expression
  - `c1&c2`: intersection “and”
  - `c1|c2`: union “or”

```
> x <- c(12, 4, 7, 20, 13)
> x < 15
[1]  TRUE  TRUE  TRUE FALSE  TRUE
> x <= 15
[1]  TRUE  TRUE  TRUE FALSE  TRUE
> x > 13
[1] FALSE FALSE FALSE  TRUE FALSE
> x >= 10
[1]  TRUE FALSE FALSE  TRUE  TRUE
> x == 12
[1]  TRUE FALSE FALSE FALSE FALSE
> x != 20
[1] TRUE TRUE TRUE FALSE TRUE
> (x = 3)
[1] 3
```

```
> (x > 10)
[1] TRUE FALSE FALSE  TRUE  TRUE
> x != 20
[1]  TRUE  TRUE  TRUE FALSE  TRUE
> (x > 10) & (x != 20)
[1]  TRUE FALSE FALSE FALSE  TRUE
> (x > 10) | (x != 20)
[1] TRUE TRUE TRUE TRUE TRUE
```

```
> (x >= 10)
[1]  TRUE FALSE FALSE  TRUE  TRUE
> 1*(x >= 10)
[1] 1 0 0 1 1
> (x >= 15)
[1] FALSE FALSE FALSE  TRUE FALSE
> 2*(x >= 15)
[1] 0 0 0 2 0
```

遺失值 (Missing Values)

- **NA**: not available, missing values

```
> z <- c(1:3, NA)
> z
[1]  1  2  3 NA
> ind <- is.na(z)
> ind
[1] FALSE FALSE FALSE  TRUE
```

- A vector of the same length as x all of whose values are NA

```
> x == NA
[1] NA NA NA NA NA
```

- **NaN**: not a number, missing values

```
> 0/0
[1] NaN
> Inf - Inf
[1] NaN
```

See also: `na.fail(x)`, `na.pass(x)`, `na.omit(x)`, `na.exclude(x)`

`is.na(xx)` is **TRUE** both for **NA** and **NaN** values
`is.nan(xx)` is only **TRUE** for **NaN**s

練習: NA, NaN and Inf

```
> x <- c(NA, 0 / 0, Inf - Inf, Inf, 5) # Inf is a number.
> x
[1]  NA NaN NaN Inf   5
> y <- data.frame(x, is.na(x), is.nan(x), x == Inf, x == 5)
> y
    x is.na.x. is.nan.x. x....Inf x....5
1  NA     TRUE     FALSE       NA     NA
2 NaN     TRUE      TRUE       NA     NA
3 NaN     TRUE      TRUE       NA     NA
4 Inf    FALSE     FALSE     TRUE  FALSE
5   5    FALSE     FALSE    FALSE   TRUE
> colnames(y) <- c("x", "is.na(x)", "is.nan(x)", "x == Inf", "x == 5")
> y
    x is.na(x) is.nan(x) x == Inf x == 5
1  NA     TRUE     FALSE       NA     NA
2 NaN     TRUE      TRUE       NA     NA
3 NaN     TRUE      TRUE       NA     NA
4 Inf    FALSE     FALSE     TRUE  FALSE
5   5    FALSE     FALSE    FALSE   TRUE
```

字元向量 (Character Vectors)

- Character strings are entered using either
  - double (“) quotes or
  - single (‘) quotes
- Character strings are printed using double quotes.

```
> (x <- "x-values")
[1] "x-values"
> (y <- "New iteration results")
[1] "New iteration results"
> (answer1 <- c("a1", "a2", "b1", "b3"))
[1] "a1" "a2" "b1" "b3"
> (answer2 <- c('a1', 'a2', 'b1', 'b3'))
[1] "a1" "a2" "b1" "b3"
> (answer3 <- c('a', "a2", 3))
[1] "a"  "a2" "3"
```

```
> (answer4 <- c('My name is "Hank"'))
[1] "My name is \"Hank\""
> (answer5 <- c("My name is 'Hank'"))
[1] "My name is 'Hank'"
```

```
> paste("A", 1:6, sep = "")
[1] "A1" "A2" "A3" "A4" "A5" "A6"
> paste("Today is", date())
[1] "Today is Wed Sep 24 13:26:20 2028"
> labs <- paste(c("X", "Y"), 1:10, sep = "")
> labs
 [1] "X1"  "Y2"  "X3"  "Y4"  "X5"  "Y6"  "X7"  "Y8"  "X9"  "Y10"
```

跳脫字元 (Escape Character)

- Escape Character:
  - `\n`: new line.
  - `\t`: tab.
  - `\b`: backspace.

```
> cat("How are you?", "\n", "I'm fine.", "\n")
How are you?
 I'm fine.
> cat("How are you?", "\t", "I'm fine.", "\n")
How are you?     I'm fine.
> cat("How are you?", "\b\b\b", "I'm fine.")
How are yo I'm fine.>
```

NOTE: `"\"` is entered and printed as `"\\"`

```
> setwd("c:\\temp\\mydata")
```

索引向量: Index Vector [ ]

- A logical vector

```
> x <- c(7, 2, 4, 9, NA, 4)
> x[2]
[1] 2
> x[5]
[1] NA
> x[0]
numeric(0)
> x[10]
[1] NA
> y <- x[!is.na(x)]
> y
[1] 7 2 4 9 4
> (x+1)[(!is.na(x))&(x>0)] -> z
> z
[1]  8  3  5 10  5
```

- A vector of positive integral quantities

```
> rep(c(1,2,2,1), times=3)
 [1] 1 2 2 1 1 2 2 1 1 2 2 1
> c("x","y")[rep(c(1,2,2,1), times=3)]
 [1] "x" "y" "y" "x" "x" "y" "y" "x" "x" "y" "y" "x"
```

索引向量: Index Vector [ ]

- A vector of negative integral quantities

```
> x <- c(7, 2, 4, 9, NA, 4)
> x[-2]
[1]  7  4  9 NA  4
> x[-(1:3)]
[1]  9 NA  4
```

```
> x <- c(7, 2, 4, 9, NA, 4)
> x[is.na(x)] <- 0
> x
[1] 7 2 4 9 0 4
> y <- c(-7, 2, 4, 9, 0, -4)
> abs(y)
[1] 7 2 4 9 0 4
> y[y<0] <- - y[y<0]
> y
[1] 7 2 4 9 0 4
```

A vector of character strings

```
> fruit <- c(5, 10, 1, 20)
> fruit
[1]  5 10  1 20
> names(fruit) <- c("orange", "banana", "apple", "peach")
> fruit
orange banana  apple  peach
     5     10      1     20
> lunch <- fruit[c("apple", "orange")]
> lunch
 apple orange
     1      5
```

課堂練習4

```
> x <- c(A = 5, B = 3, third = 10)
> x
    A     B third
    5     3    10
> x[1]
A
5
> x["A"]
A
5
> x[c("third", "B")]
third     B
   10     3
> x[c(3, 1)]
third     A
   10     5
> names(x)
[1] "A"     "B"     "third"
> names(x) <- c("AA", "BB", "CC")
> x
AA BB CC
 5  3 10
```

```
> # compare two "char" strings
> "A" < "B"
[1] TRUE
> "Hank" <= "Tom"
[1] TRUE
> "201" < "1"
[1] FALSE
> c("201", "001") < "1"
[1] FALSE  TRUE
> c("1", "A", "a") < "a"
[1]  TRUE FALSE FALSE
> # compare T/F
> TRUE < FALSE
[1] FALSE
> T > F
[1] TRUE
> # compare T/F, char, numeric
> 1 < "a"
[1] TRUE
> "a" < FALSE
[1] TRUE
```

```
> 1 > T
[1] FALSE
> 1 < T
[1] FALSE
> 1 == T
[1] TRUE
```

```
> 0 < F
[1] FALSE
> 0 > F
[1] FALSE
> 0 == F
[1] TRUE
```

因子 (Factors)

- The levels of factors are stored in alphabetical order.

```
> scores <- c(60, 49, 90, 54, 54, 48, 61, 61, 51, 49, 49)
> gender <- c("f", "f", "m", "f", "m", "m", "m", "m", "f", "f", "m")
> levels(gender)
NULL
> gender.f <- factor(gender)
> gender.f
 [1] f f m f m m m m f f m
Levels: f m
> levels(gender.f)
[1] "f" "m"
> table(gender.f)
gender.f
f m
5 6
```

```
> levels(gender.f) <- c("女", "男")
> gender.f
 [1] 女 女 男 女 男 男 男 男 女 女 男
Levels: 女 男
> (scores.mean <- tapply(scores, gender.f, mean))
  女   男
52.6 60.5
```

```
> grade <- as.factor(c("B", "F", "A", "C", "A", "C", "B", "A", "F", "D"))
> levels(grade)
[1] "A" "B" "C" "D" "F"
> grade2 <- ordered(grade, levels = rev(levels(grade)))
> grade2
 [1] B F A C A C B A F D
Levels: F < D < C < B < A
```

```
> grade2[which(grade2 >= "B")]
[1] B A A B A
Levels: F < D < C < B < A
```

因子 (Factors)

```
> MyLetter <- c("C", "D", "A", "K", "A",  "I", "J", "I", "K", "H",  "A", "K",
"K", "B", "E", "H",  "G", "L", "H", "H", "I", "K", "B", "D")
> MyLetter.factor <- factor(MyLetter)
> MyLetter.factor
 [1] C D A K A I J I K H A K K B E H G L H H I K B D
Levels: A B C D E G H I J K L
> table(MyLetter.factor)
MyLetter.factor
A B C D E G H I J K L
3 2 1 2 1 1 4 3 1 5 1
> MyLetter.ordered <- factor(MyLetter, levels = c("A", "B", "C",  "D", "E", "F",
"G", "H", "I", "J", "K", "L"), ordered = TRUE)
> MyLetter.ordered[1] < MyLetter.ordered[2]
[1] TRUE
> table(MyLetter.ordered)
MyLetter.ordered
A B C D E F G H I J K L
3 2 1 2 1 0 1 4 3 1 5 1
```

陣列 (Arrays)

- An array is a multiply subscripted collection of data entries.

```
> z <- 1:30
> z
 [1]  1  2  3  4  5  6  7  8  9 10 11
12 13 14 15 16 17 18 19 20 21 22 23 24
25 26 27 28
[29] 29 30
>
> dim(z) <- c(3,5,2)
> z
, , 1

     [,1] [,2] [,3] [,4] [,5]
[1,]    1    4    7   10   13
[2,]    2    5    8   11   14
[3,]    3    6    9   12   15

, , 2

     [,1] [,2] [,3] [,4] [,5]
[1,]   16   19   22   25   28
[2,]   17   20   23   26   29
[3,]   18   21   24   27   30
```

```
> z[1,3,2]
[1] 22
>
> z[1,1,]
[1]  1 16
>
> z[1,,2]
[1] 16 19 22 25 28
>
> z[1,1:2,1]
[1] 1 4
>
> z[-1,,]
, , 1

     [,1] [,2] [,3] [,4] [,5]
[1,]    2    5    8   11   14
[2,]    3    6    9   12   15

, , 2

     [,1] [,2] [,3] [,4] [,5]
[1,]   17   20   23   26   29
[2,]   18   21   24   27   30
```

陣列 (Arrays)

```
> x <- array(1:20, dim=c(4,5))
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
>
> i <- array(c(1:3, 3:1), dim=c(3,2))
> i
     [,1] [,2]
[1,]    1    3
[2,]    2    2
[3,]    3    1
>
> x[i] <- 0
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    0   13   17
[2,]    2    0   10   14   18
[3,]    0    7   11   15   19
[4,]    4    8   12   16   20
```

```
> x <- c(1,2,3,4,5)
> x
[1] 1 2 3 4 5
> z <- array(x, dim=c(3,4))
> z
     [,1] [,2] [,3] [,4]
[1,]    1    4    2    5
[2,]    2    5    3    1
[3,]    3    1    4    2
>
> t(z) #transpose
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    1
[3,]    2    3    4
[4,]    5    1    2
```

See also: **aperm {base}**: Array Transposition

課堂練習5: interval data

```
> temperature
          January.a January.b February.a February.b
AnQing          1.8       7.1        2.1        7.2
BaoDing        -7.1       1.7       -5.3        4.8
BeiJing        -7.2       2.1       -5.9        3.8
BoKeTu        -23.4     -15.5      -24.0      -14.0
ChangChun     -16.9      -6.7      -17.6       -6.8
> tempArray <- array(0, dim=c(5,2,2))
> tempArray[,,1] <- as.matrix(temperature[,c(1,3)])
> tempArray[,,2] <- as.matrix(temperature[,c(2,4)])
> tempArray
, , 1

      [,1]  [,2]
[1,]   1.8   2.1
[2,]  -7.1  -5.3
[3,]  -7.2  -5.9
[4,] -23.4 -24.0
[5,] -16.9 -17.6

, , 2

      [,1]  [,2]
[1,]   7.1   7.2
[2,]   1.7   4.8
[3,]   2.1   3.8
[4,] -15.5 -14.0
[5,]  -6.7  -6.8
```

```
> colnames(tempArray) <- c("January", "February")
> rownames(tempArray) <- rownames(temperature)
> dimnames(tempArray)[[3]] <- c("min", "max")
> dimnames(tempArray)
[[1]]
[1] "AnQing"    "BaoDing"   "BeiJing"   "BoKeTu"
"ChangChun"

[[2]]
[1] "January"  "February"

[[3]]
[1] "min" "max"
> tempArray
, , min

          January February
AnQing        1.8      2.1
BaoDing      -7.1     -5.3
BeiJing      -7.2     -5.9
BoKeTu      -23.4    -24.0
ChangChun   -16.9    -17.6

, , max

          January February
AnQing        7.1      7.2
BaoDing       1.7      4.8
BeiJing       2.1      3.8
BoKeTu      -15.5    -14.0
ChangChun    -6.7     -6.8
```

matrix(): 矩陣

- A matrix is an array with two subscripts.

```
> x <- 1:20
> A <- matrix(x, ncol=4)
> A
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
> A.1 <- matrix(x, ncol=4, byrow=TRUE)
> A.1
     [,1] [,2] [,3] [,4]
[1,]    1    2    3    4
[2,]    5    6    7    8
[3,]    9   10   11   12
[4,]   13   14   15   16
[5,]   17   18   19   20
> nrow(A)
[1] 5
> ncol(A)
[1] 4
```

```
> dim(A)
[1] 5 4
> diag(A)
[1]  1  7 13 19
>
> B <- matrix(x+2, ncol=4)
> A * B #element by element product
     [,1] [,2] [,3] [,4]
[1,]    3   48  143  288
[2,]    8   63  168  323
[3,]   15   80  195  360
[4,]   24   99  224  399
[5,]   35  120  255  440
> A %*% t(B) #matrix product
     [,1] [,2] [,3] [,4] [,5]
[1,]  482  516  550  584  618
[2,]  524  562  600  638  676
[3,]  566  608  650  692  734
[4,]  608  654  700  746  792
[5,]  650  700  750  800  850
```

```
> x <- 4
> diag(x) #identity matrix
```

矩陣 (Matrices)

```
> apply(mat, 1, mean) # row means
[1]  9 10 11 12
> apply(mat, 2, mean) # column means
[1]  2.5  6.5 10.5 14.5 18.5
> apply(mat, 1, var) # row variances
[1] 40 40 40 40
> apply(mat, 2, var) # column variances
[1] 1.666667 1.666667 1.666667 1.666667 1.666667
>
> mean(mat)
[1] 10.5
> var(mat)
         [,1]     [,2]     [,3]     [,4]     [,5]
[1,] 1.666667 1.666667 1.666667 1.666667 1.666667
[2,] 1.666667 1.666667 1.666667 1.666667 1.666667
[3,] 1.666667 1.666667 1.666667 1.666667 1.666667
[4,] 1.666667 1.666667 1.666667 1.666667 1.666667
[5,] 1.666667 1.666667 1.666667 1.666667 1.666667
> summary(mat)
       V1              V2              V3              V4              V5
 Min.   :1.00   Min.   :5.00   Min.   : 9.00   Min.   :13.00   Min.   :17.00
 1st Qu.:1.75   1st Qu.:5.75   1st Qu.: 9.75   1st Qu.:13.75   1st Qu.:17.75
 Median :2.50   Median :6.50   Median :10.50   Median :14.50   Median :18.50
 Mean   :2.50   Mean   :6.50   Mean   :10.50   Mean   :14.50   Mean   :18.50
 3rd Qu.:3.25   3rd Qu.:7.25   3rd Qu.:11.25   3rd Qu.:15.25   3rd Qu.:19.25
 Max.   :4.00   Max.   :8.00   Max.   :12.00   Max.   :16.00   Max.   :20.00
```

```
> mat <- matrix(1:20, ncol=5)
> mat
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
> id <- mat[, 2] > 5
> id
[1] FALSE  TRUE  TRUE  TRUE
> mat[id, ]
     [,1] [,2] [,3] [,4] [,5]
[1,]    2    6   10   14   18
[2,]    3    7   11   15   19
[3,]    4    8   12   16   20
```

矩陣的索引

```
> (y <- array(1:15, dim=c(3, 5)))
> dim(y)
[1] 3 5

> x <- matrix(1:15, 3, 5)
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    4    7   10   13
[2,]    2    5    8   11   14
[3,]    3    6    9   12   15
> x[1]
[1] 1
> x[6]
[1] 6
>
> x <- matrix(1:15, 3, 5, byrow=TRUE)
> x
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    2    3    4    5
[2,]    6    7    8    9   10
[3,]   11   12   13   14   15
> x[1]
[1] 1
> x[6]
[1] 12
```

```
> y[2, 4]
[1] 11
> y[1,]
[1]  1  4  7 10 13
> y[,1]
[1] 1 2 3
> y[2:3, ]
     [,1] [,2] [,3] [,4] [,5]
[1,]    2    5    8   11   14
[2,]    3    6    9   12   15
> y[-2,]
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    4    7   10   13
[2,]    3    6    9   12   15
> y[,-2]
     [,1] [,2] [,3] [,4]
[1,]    1    7   10   13
[2,]    2    8   11   14
[3,]    3    9   12   15
> dimnames(y)
NULL
> rownames(y)
NULL
> colnames(y)
NULL
```

矩陣結合 (Forming Partitioned Matrices)

- **cbind()** and **rbind()**

```
> x <- c(1, 2, 3, 4, 5)
> y <- c(0.5, 0.4, 0.3, 0.2, 0.1)
> (z1 <- cbind(x,y))
     x   y
[1,] 1 0.5
[2,] 2 0.4
[3,] 3 0.3
[4,] 4 0.2
[5,] 5 0.1
> (z2 <- rbind(x,y))
  [,1] [,2] [,3] [,4] [,5]
x  1.0  2.0  3.0  4.0  5.0
y  0.5  0.4  0.3  0.2  0.1
```

```
> (A <- rbind(x,y))
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
[6,]    3    5    7    9
[7,]    4    6    8   10
```

```
> (x <- matrix(1:20, ncol=4, nrow=5))
     [,1] [,2] [,3] [,4]
[1,]    1    6   11   16
[2,]    2    7   12   17
[3,]    3    8   13   18
[4,]    4    9   14   19
[5,]    5   10   15   20
> (y <- matrix(3:10, ncol=4))
     [,1] [,2] [,3] [,4]
[1,]    3    5    7    9
[2,]    4    6    8   10
> (z <- matrix(rep(1:5, 2),nrow=5))
     [,1] [,2]
[1,]    1    1
[2,]    2    2
[3,]    3    3
[4,]    4    4
[5,]    5    5
```

```
> (B <- cbind(x,z))
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    1    6   11   16    1    1
[2,]    2    7   12   17    2    2
[3,]    3    8   13   18    3    3
[4,]    4    9   14   19    4    4
[5,]    5   10   15   20    5    5
```

常用矩陣運算

Some matrix functions	
t	Transpose
diag	Diagonal
%*%	Inner (dot) product of two vectors $x^t y$, matrix multiplication
%o%	Outer product of two vectors xy^t
crossprod, tcrossprod	Cross products $x^t y$ and xy^t of matrices
det	Determinant
solve	Inverse
eigen	Eigenvalues and eigenvectors
svd	Singular value decomposition
qr	QR decomposition
chol	Choleski decomposition

list(): 表列

- List is an object consisting of an ordered collection of objects known as its components.
- A list could consist of a numeric vector, a logical value, a matrix, a complex vector, a character array, a function, and so on.
- 許多 R統計函式回傳值皆是list。

```
> my.list <- list(name="George",
                  wife="Mary",
                  no.children=3,
                  child.ages=c(4,7,9))
> my.list
$name
[1] "George"

$wife
[1] "Mary"

$no.children
[1] 3

$child.ages
[1] 4 7 9
```

Construct list:

```
my.list <- list(name_1=object_1,…,name_m=object_m)
lst.ABC <- list(list.A, list.B, list.C)
```

see also: http://faculty.nps.edu/sebuttre/home/R/lists.html

表列 (List)

`lst[1]` vs `lst[[1]]`

- `[]:` a general subscripting.
- `[[]]:` the operator used to select a **single** element.
- `[1]:` a sublist of the **list** consisting of the first entry. (**name** are included in the sublist).
- `[[1]]:` first object in the list, **exclude name**.

```
> my.list
$name
[1] "George"

$wife
[1] "Mary"

$no.children
[1] 3

$child.ages
[1] 4 7 9
```

```
> my.list[[1]] # 傳回向量
[1] "George"
> my.list[[2]]
[1] "Mary"
> my.list[[4]][1]
[1] 4
>
> my.list$name # my.list[[1]]
# my.list[["name"]]
[1] "George"
> my.list$wife # my.list[[2]]
[1] "Mary"
> my.list$child.ages[1] # my.list[[4]][1]
[1] 4
> x <- "name"
> my.list[[x]]
[1] "George"
>
> my.list[1] # 傳回list
$name
[1] "George"
> my.list[2]
$wife
[1] "Mary"
```

```
> getElement(mylist, "name")
```

課堂練習6

```
my.list <- list(name=c("George", "John", "Tom"),
                wife=c("Mary", "Sue", "Nico"),
                no.children=c(3, 2, 0),
                child.ages=list(c(4,7,9), c(2, 5), NA))
```

```
> my.list$name
[1] "George" "John"   "Tom"
> my.list$wife
[1] "Mary" "Sue"  "Nico"
> my.list$no.children
[1] 3 2 0
> my.list$name[3]
[1] "Tom"
> my.list$name == "John"
[1] FALSE  TRUE FALSE
> my.list$child.ages
[[1]]
[1] 4 7 9

[[2]]
[1] 2 5

[[3]]
[1] NA
```

```
> my.list$child.ages[2]
[[1]]
[1] 2 5
> my.list$child.ages[[2]]
[1] 2 5
> my.list$child.ages[2][1]
[[1]]
[1] 2 5
> my.list$child.ages[[2]][1]
[1] 2
> my.list$child.ages[[2]][2]
[1] 5
> length(my.list)
[1] 4
```

```
> my.list[[c(2, 3)]]
[1] "Nico"
> my.list[c(2, 3)]
$wife
[1] "Mary" "Sue"  "Nico"

$no.children
[1] 3 2 0
```

資料框 (Data Frame)

- A data frame is a list with class "**data.frame**".
- Regarded as a matrix with column possibly of differing modes and attributes.

```
> my.matrix <- matrix(1:15, ncol=3)
> my.matrix
     [,1] [,2] [,3]
[1,]    1    6   11
[2,]    2    7   12
[3,]    3    8   13
[4,]    4    9   14
[5,]    5   10   15
> my.data <- data.frame(my.matrix)
> my.data
  X1 X2 X3
1  1  6 11
2  2  7 12
3  3  8 13
4  4  9 14
5  5 10 15
```

```
> my.data[1, ]
  X1 X2 X3
1  1  6 11
> my.data[2, 3]
[1] 12
> my.data$X1
[1] 1 2 3 4 5
> my.data[, "X1"]
[1] 1 2 3 4 5
> my.data["X1"]
  X1
1  1
2  2
3  3
4  4
5  5
> rownames(my.data)
[1] "1" "2" "3" "4" "5"
> row.names(my.data)
[1] "1" "2" "3" "4" "5"
> colnames(my.data)
[1] "X1" "X2" "X3"
> names(my.data)
[1] "X1" "X2" "X3"
```

資料框 (Data Frame)

```
> rownames(my.data) <- c(paste("s", 1:5, sep="."))
> colnames(my.data) <- c("A1", "A2", "A3")
> my.data
    A1 A2 A3
s.1  1  6 11
s.2  2  7 12
s.3  3  8 13
s.4  4  9 14
s.5  5 10 15
```

```
> attach(my.data)
> A1
[1] 1 2 3 4 5
> A2
[1]  6  7  8  9 10
> A3
[1] 11 12 13 14 15
> detach()
> A1
Error: object "A1" not found
```

```
> subjects <-c ('Chinese', 'Math', 'English')
> scores <- c(50, 90, 61)
> pass <- scores >= 60
> student <- data.frame(subjects, scores, pass)
> student
  subjects scores  pass
1  Chinese     50 FALSE
2     Math     90  TRUE
3  English     61  TRUE
> student["2",] # use row names to extract records for no.2
  subjects scores pass
2     Math     90 TRUE
> student[,"scores"] # use column names to extract values for "scores"
[1] 50 90 61
```

列資料選取

```
> index.1 <- iris[, "Species"] == "virginica"
> iris[index.1, ]
    Sepal.Length Sepal.Width Petal.Length Petal.Width   Species
101          6.3         3.3          6.0         2.5 virginica
102          5.8         2.7          5.1         1.9 virginica
...

> iris[Species == "virginica",]
    Sepal.Length Sepal.Width Petal.Length Petal.Width   Species
101          6.3         3.3          6.0         2.5 virginica
102          5.8         2.7          5.1         1.9 virginica
...

> iris[!(Species == "virginica"),]
    Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
1            5.1         3.5          1.4         0.2     setosa
2            4.9         3.0          1.4         0.2     setosa
...

> m <- mean(iris$Sepal.Length)
> index.3 <- iris[, "Sepal.Length"] > m
> iris[index.3, ]
    Sepal.Length Sepal.Width Petal.Length Petal.Width    Species
51           7.0         3.2          4.7         1.4 versicolor
52           6.4         3.2          4.5         1.5 versicolor
...
```

data.frame 欄位名稱

```
> # data.frame出來的資料欄位名稱，會根據input所放是何種類別物件有關。
>
> x1 <- rnorm(5)
> x2 <- rnorm(5)
> x1
[1]  1.8825035  0.2527107  0.5207440 -0.2923048  0.8582343
> class(x1)
[1] "numeric"
> data.frame(Var1=x1, Var2=x2)
        Var1       Var2
1  1.8825035  0.8957060
2  0.2527107 -1.9809223
3  0.5207440 -0.2122453
4 -0.2923048  0.4875996
5  0.8582343 -0.6821969
```

```
> y1 <- data.frame(rnorm(5))
> y2 <- data.frame(rnorm(5))
> y1
     rnorm.5.
1  0.08852351
2  1.98961669
3 -0.10708352
4 -0.29978350
5 -0.15617972
> class(y1)
[1] "data.frame"
> data.frame(Var1=y1, Var2=y2)
     rnorm.5. rnorm.5..1
1  0.08852351 -1.0302574
2  1.98961669 -0.2824586
3 -0.10708352  1.6422156
4 -0.29978350 -0.8494181
5 -0.15617972  0.3258587
```

課堂練習

```
> class(iris)
[1] "data.frame"
> head(iris, 3)
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
> x1 <- iris[1]
> head(x1)
  Sepal.Length
1          5.1
2          4.9
3          4.7
4          4.6
5          5.0
6          5.4
> class(x1)
[1] "data.frame"
> x2 <- iris[[1]]
> head(x2)
[1] 5.1 4.9 4.7 4.6 5.0 5.4
> class(x2)
[1] "numeric"
> x3 <- iris["Sepal.Length"]
> class(x3)
[1] "data.frame"
> x4 <- iris[, "Sepal.Length"]
> class(x4)
[1] "numeric"
```

```
> iris.copy <- iris
> iris.copy[3] <- NULL
> head(iris.copy, 3)
  Sepal.Length Sepal.Width Petal.Width Species
1          5.1         3.5         0.2  setosa
2          4.9         3.0         0.2  setosa
3          4.7         3.2         0.2  setosa
>
> iris.copy <- iris
> iris.copy[[3]] <- NULL
> head(iris.copy, 3)
  Sepal.Length Sepal.Width Petal.Width Species
1          5.1         3.5         0.2  setosa
2          4.9         3.0         0.2  setosa
3          4.7         3.2         0.2  setosa
>
> iris$species
NULL
> iris$Species
  [1] setosa     setosa     setosa ...
[145] virginica  virginica  virginica
Levels: setosa versicolor virginica
```

課堂練習:
data.frame的變數是一矩陣類別

```
> iris.range <- aggregate(iris[, 1:4], by=list(iris[, 5]), range)
> str(iris.range)
'data.frame':   3 obs. of  5 variables:
 $ Group.1     : Factor w/ 3 levels "setosa","versicolor",..: 1 2 3
 $ Sepal.Length: num [1:3, 1:2] 4.3 4.9 4.9 5.8 7 7.9
 $ Sepal.Width : num [1:3, 1:2] 2.3 2 2.2 4.4 3.4 3.8
 $ Petal.Length: num [1:3, 1:2] 1 3 4.5 1.9 5.1 6.9
 $ Petal.Width : num [1:3, 1:2] 0.1 1 1.4 0.6 1.8 2.5
> iris.range
     Group.1 Sepal.Length.1 Sepal.Length.2 Sepal.Width.1 Sepal.Width.2 Petal.Length.1 Petal.Length.2 Petal.Width.1 Petal.Width.2
1     setosa           4.3           5.8          2.3          4.4           1.0           1.9          0.1          0.6
2 versicolor           4.9           7.0          2.0          3.4           3.0           5.1          1.0          1.8
3  virginica           4.9           7.9          2.2          3.8           4.5           6.9          1.4          2.5
> class(iris.range)
[1] "data.frame"
> iris.range$Sepal.Length
     [,1] [,2]
[1,]  4.3  5.8
[2,]  4.9  7.0
[3,]  4.9  7.9
> class(iris.range$Sepal.Length)
[1] "matrix"
> dim(iris.range)
[1] 3 5
> iris.range[,1:3]
     Group.1 Sepal.Length.1 Sepal.Length.2 Sepal.Width.1 Sepal.Width.2
1     setosa           4.3           5.8          2.3          4.4
2 versicolor           4.9           7.0          2.0          3.4
3  virginica           4.9           7.9          2.2          3.8
```

日期 Dates

- R以"Date" 類別表示(不包括時間)日期: 年月日。
- Internally, Date objects are stored as the number of days since **January 1, 1970**, using negative numbers for earlier dates.
- The **as.numeric** function can be used to convert a Date object to its internal form.

Code	Value
%d	Day of the month (decimal number)
%m	Month (decimal number)
%b	Month (abbreviated)
%B	Month (full name)
%y	Year (2 digit)
%Y	Year (4 digit)

```
> as.Date("1985-6-16")
[1] "1985-06-16"
> as.Date("2019/02/17")
[1] "2019-02-17"
> as.Date(1000, origin = "1900-01-01")
[1] "1902-09-28"
> as.Date("2/15/2011", format = "%m/%d/%Y")
[1] "2011-02-15"
>
> as.Date("April 26, 1993", format = "%B %d, %Y")
[1] "1993-04-26"
> as.Date("22JUN01", format = "%d%b%y")
[1] "2001-06-22"
> seq(as.Date('1976-7-4'), by = 'days', length = 10)
 [1] "1976-07-04" "1976-07-05" "1976-07-06" "1976-07-07" "1976-07-08" "1976-07-09" "1976-07-10"
 [8] "1976-07-11" "1976-07-12" "1976-07-13"
> seq(as.Date('2010-2-1'), to = as.Date('2010-4-1'), by='2 weeks')
[1] "2010-02-01" "2010-02-15" "2010-03-01" "2010-03-15" "2010-03-29"
```

請先執行!!

```
> (lct <- Sys.getlocale("LC_TIME"))
[1] "C"
> Sys.setlocale("LC_TIME", "C")
[1] "C"
```

日期時間

- R的"時間"用"POSIXct"或 "POSIXlt" 類別表示，
- 內部時間是以 "1970年1月1日" 起至今的秒數表示。
- (UTC, Universal Time, Coordinated, 世界協調時間)
- (GMT, Greenwich Mean Time, 格林威治標準時間)

```
> Sys.time()
[1] "2028-10-14 21:16:07 台北標準時間"
# extract date
> substr(as.character(Sys.time()), 1, 10)
[1] "2028-10-14"
# extract time
> substr(as.character(Sys.time()), 12, 19)
[1] "21:16:07"
> date()
[1] "Tue Oct 14 21:16:09 2028"
```

```
> now <- Sys.time()
> as.POSIXct(now)
[1] "2027-06-03 17:46:44 CST"
> as.POSIXlt(now)
[1] "2027-06-03 17:46:44 CST"
> class(now)
[1] "POSIXct" "POSIXt"
```

```
sec, min, hour,
mday (# day number within the month),
mon (#January=0),
year (#+1900),
wday (#day of the week starting at 0=sunday),
yday (#day of the year after 1 january=0)
```

```
> my.date <- as.POSIXlt(Sys.time())
> my.date
[1] "2028-10-14 21:18:31 台北標準時間"
> my.date$sec
[1] 31.304
> my.date$min
[1] 18
> my.date$hour
[1] 21
```

```
> my.date$mday
[1] 14
> my.date$mon
[1] 9
> my.date$year + 1900
[1] 2028
> my.date$wday
[1] 2
> my.date$yday
[1] 287
```

POSIXlt / POSIXct 類別

- Functions to convert between character representations and objects of classes "POSIXlt" and "POSIXct" representing calendar dates and times.
- Character input is first converted to class "POSIXlt" by strptime.
- Numeric input is first converted to "POSIXct".
- Any conversion that needs to go between the two date-time classes requires a time zone: conversion from "POSIXlt" to "POSIXct" will validate times in the selected time zone.

Code	Meaning	Code	Meaning
%a	Abbreviated weekday	%A	Full weekday
%b	Abbreviated month	%B	Full month
%c	Locale-specific date and time	%d	Decimal date
%H	Decimal hours (24 hour)	%I	Decimal hours (12 hour)
%j	Decimal day of the year	%m	Decimal month
%M	Decimal minute	%p	Locale-specific AM/PM
%S	Decimal second	%U	Decimal week of the year (starting on Sunday)
%w	Decimal Weekday (0=Sunday)	%W	Decimal week of the year (starting on Monday)
%x	Locale-specific Date	%X	Locale-specific Time
%y	2-digit year	%Y	4-digit year
%z	Offset from GMT	%Z	Time zone (character)

```
> as.POSIXct("1969-12-31 23:59:59", format = "%Y-%m-%d %H:%M:%S", tz = "UTC")
[1] "1969-12-31 23:59:59 UTC"
> as.POSIXlt(Sys.time(), "GMT")
[1] "2017-08-27 13:17:45 GMT"
```

strptime {base}: Date-time Conversion Functions to and from Character

```
> x1 <- c("20040227", "20050412", "19930922")
> strptime(x1, format="%Y%m%d")
[1] "2004-02-27 CST" "2005-04-12 CST" "1993-09-22 CST"
>
> x2 <- c("27/02/2004", "27/02/2005", "14/01/2003")
> strptime(x2, format="%d/%m/%Y")
[1] "2004-02-27 CST" "2005-02-27 CST" "2003-01-14 CST"
>
> x3 <- c("1jan1960", "2jan1960", "31mar1960", "30jul1960")
> strptime(x3, "%d%b%Y")
[1] "1960-01-01 CST" "1960-01-02 CST" "1960-03-31 CST" "1960-07-30 CDT"
```

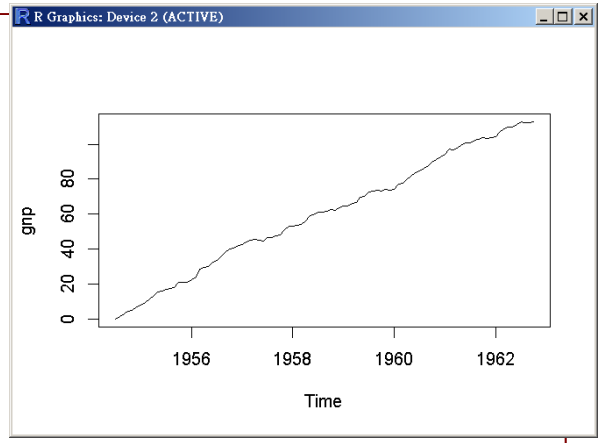
```
> dates <- c("02/27/92", "02/27/92", "01/14/92", "02/28/92", "02/01/92")
> times <- c("23:03:20", "22:29:56", "01:03:30", "18:21:03", "16:56:26")
> x <- paste(dates, times)
> strptime(x, "%m/%d/%y %H:%M:%S")
[1] "1992-02-27 23:03:20 CST" "1992-02-27 22:29:56 CST"
[3] "1992-01-14 01:03:30 CST" "1992-02-28 18:21:03 CST"
[5] "1992-02-01 16:56:26 CST"
```

See also: **Lubridate** Package, **Chron** Packag

時間序列物件: ts

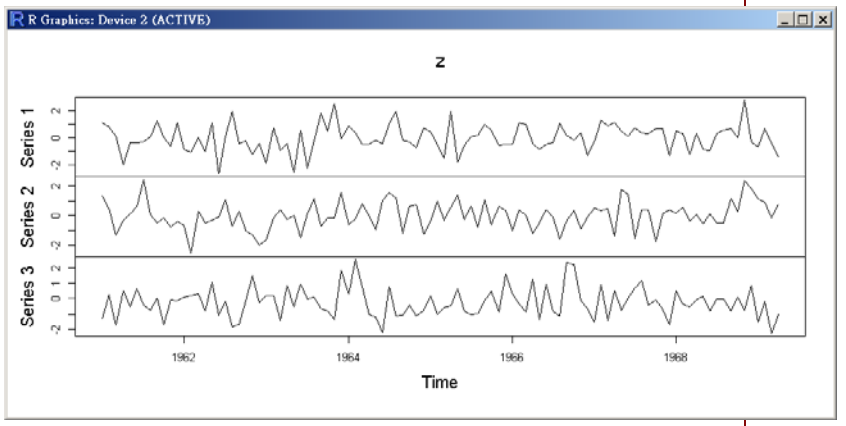
```
ts(data = NA, start = 1, end = numeric(), frequency = 1,
   deltat = 1, ts.eps = getOption("ts.eps"), class = , names = )
as.ts(x, ...)
is.ts(x)
```

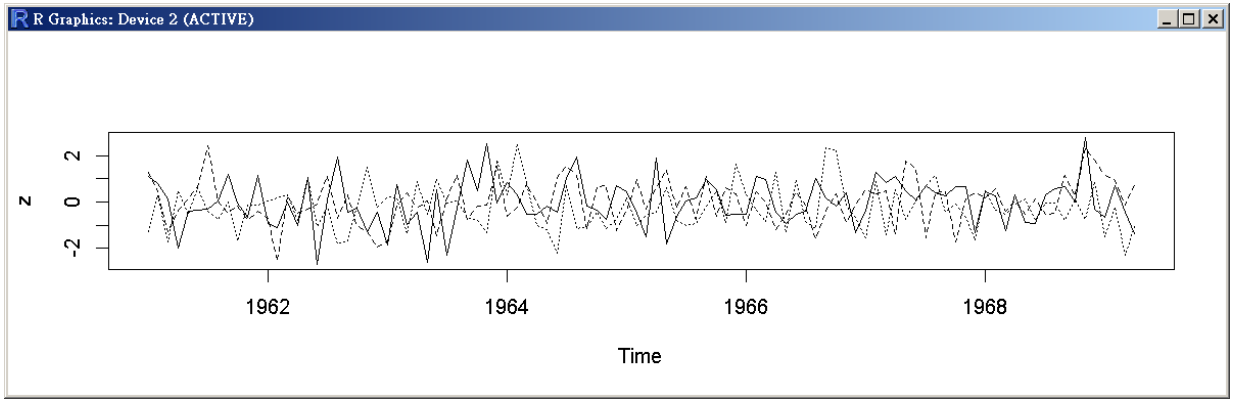
```
> ts(1:10, frequency = 4, start = c(1959, 2))
     Qtr1 Qtr2 Qtr3 Qtr4
1959         1    2    3
1960    4    5    6    7
1961    8    9   10
> my.ts <- ts(1:10, frequency = 7, start = c(12, 2))
> class(my.ts)
[1] "ts"
> print(my.ts, calendar = TRUE)
   p1 p2 p3 p4 p5 p6 p7
12     1  2  3  4  5  6
13  7  8  9 10
> gnp <- ts(cumsum(1+round(rnorm(100), 2)), start = c(1954, 7), frequency = 12)
> gnp
       Jan    Feb    Mar    Apr    May    Jun    Jul    Aug    Sep    Oct    Nov    Dec
1954                                            -0.12   1.62   3.13   4.36   4.78   6.81
1955   7.98   9.62  11.26  12.80  15.25  15.88  17.13  17.72  18.04  20.77  21.01  21.22
. . .
1962 104.41 106.88 108.87 109.82 109.62 111.52 112.70 112.29 112.48 112.84
> plot(gnp)
```



Multivariate ts

```
> z <- ts(matrix(rnorm(300), 100, 3), start = c(1961, 1), frequency = 12)
> head(z, 3)
         Series 1  Series 2   Series 3
[1,] -0.008998503 0.5389408 -0.9403586
[2,] -0.750712987 0.3026561 -0.1112974
[3,] -2.086179305 0.6752907  0.8359952
> tail(z, 3)
         Series 1   Series 2    Series 3
[98,]  1.6249153 -0.8999009  0.12837969
[99,]  0.6174681 -0.8451825  0.86245135
[100,] 0.5894715 -0.2738029 -0.05433789
>
> class(z)
[1] "mts"    "ts"     "matrix"
> plot(z)
> plot(z, plot.type = "single", lty = 1:3)
```





mode(object): 物件的模式

- **In R every "object" has a mode and a class**. The former represents how an object is stored in memory (numeric, character, list and function) while the later represents its abstract type.
- Mode: `"logical", "integer", "double", "complex", "raw", "character", "list", "expression", "name", "symbol" and "function".`

```
> mode(object)
```

- Vector must have their values all of the same mode.
  - Empty character string vector: `character(0)`.
  - Empty numeric vector: `numeric(0)`.

NOTE: Lists are of mode list. There are ordered sequences of objects which individually can be of any mode.

```
> (z <- 0:9)
 [1] 0 1 2 3 4 5 6 7 8 9
> mode(z)
[1] "numeric"
> (digits <- as.character(z))
 [1] "0" "1" "2" "3" "4" "5" "6" "7" "8" "9"
> mode(digits)
[1] "character"
> (d <- as.integer(digits))
 [1] 0 1 2 3 4 5 6 7 8 9
> mode(d)
[1] "numeric"
> (x <- z[1:5]>3)
 [1] FALSE FALSE FALSE FALSE  TRUE
> mode(x)
[1] "logical"
```

class(object): 物件的類別

- For simple vector, mode=class: **numeric, logical, character, list**.
- **matrix, array, factor, data.frame**

```
> x1 <- 10
> class(x1)
[1] "numeric"
> (x2 <- seq(1, 10, 2))
[1] 1 3 5 7 9
> class(x2)
[1] "numeric"
```

```
> my.f <-  formula(iris$Sepal.Length ~ iris$Sepal.Width)
> class(my.f)
[1] "formula"
> class(lm(my.f))
[1] "lm"
> class(aov(my.f))
[1] "aov" "lm"
```

```
> class(iris)
[1] "data.frame"
> (iris.sub <- iris[5:10, 1:4])
   Sepal.Length Sepal.Width Petal.Length Petal.Width
5           5.0         3.6          1.4         0.2
6           5.4         3.9          1.7         0.4
7           4.6         3.4          1.4         0.3
8           5.0         3.4          1.5         0.2
9           4.4         2.9          1.4         0.2
10          4.9         3.1          1.5         0.1
> class(iris.sub)
[1] "data.frame"
>
> class(as.matrix(iris.sub))
[1] "matrix"
```

```
> as.list(iris.sub)
$Sepal.Length
[1] 5.0 5.4 4.6 5.0 4.4 4.9

$Sepal.Width
[1] 3.6 3.9 3.4 3.4 2.9 3.1

$Petal.Length
[1] 1.4 1.7 1.4 1.5 1.4 1.5

$Petal.Width
[1] 0.2 0.4 0.3 0.2 0.2 0.1

> class(as.list(iris.sub))
[1] "list"
```

class(object): 物件的類別

```
> ex1 <- expression(1 + 0:9)  # expression object
> ex1
expression(1 + 0:9)
> eval(ex1)
 [1]  1  2  3  4  5  6  7  8  9 10
> class(ex1)
[1] "expression"
>
>
> hi <- function(){
+    cat("hello world!\n")
+ }
> hi()
hello world!
> class(hi) # function object
[1] "function"
```

```
> # data frames are stored in
memory as list but they are
wrapped into data.frame objects.
> d <- data.frame(V1 = c(1,2))
> class(d)
[1] "data.frame"
> mode(d)
[1] "list"
> typeof(d)
[1] "list"
```

```
> (r.dates <- strptime(c("27/02/2004", "27/02/2005"), format="%d/%m/%Y"))
[1] "2004-02-27 CST" "2005-02-27 CST"
> class(r.dates)
[1] "POSIXlt" "POSIXt"
```

"There is a special object called NULL. It is used whenever there is a need to indicate or specify that an object is absent. It should not be confused with a vector or list of zero length.

The NULL object has no type and no modifiable properties. There is only one NULL object in R, to which all instances refer. To test for NULL use is.null. You cannot set attributes on NULL. "

attributes(object): 物件的屬性

All objects except NULL can have one or more attributes attached to them.

- Select a specific attribute

```
> attr(object, name)
```

- Set a specific attribute

```
> attr(z, “dim”) <- c(10, 10)
```

```
> x <- matrix(1:10, ncol=2)
> x
     [,1] [,2]
[1,]    1    6
[2,]    2    7
[3,]    3    8
[4,]    4    9
[5,]    5   10
> attributes(x)
$dim
[1] 5 2

> attr(x, "dim")
[1] 5 2
> dim(x)
[1] 5 2
```

```
> x <- data.frame(matrix(1:10, ncol=2))
> x
  X1 X2
1  1  6
2  2  7
3  3  8
4  4  9
5  5 10
> attributes(x)
$names
[1] "X1" "X2"

$row.names
[1] 1 2 3 4 5

$class
[1] "data.frame"

> attr(x, "names")
[1] "X1" "X2"
> names(x)
[1] "X1" "X2"
```

```
> gender.f
 [1] 女 女 男 女 男 男 男 男 女 女 男
Levels: 女 男
> str(gender.f)
 Factor w/ 2 levels "女","男":
1 1 2 1 2 2 2 2 1 1 ...
> class(gender.f)
[1] "factor"
> attributes(gender.f)
$levels
[1] "女" "男"

$class
[1] "factor"
```

length(object): 物件的長度

```
> beta <- c(1, 3, 5, 2, 4, 6, 11, NA, NA, 22)
> length(beta)
[1] 10
> length(beta[!is.na(beta)])
[1] 8
>
> e <- numeric() # empty object
> e[3] <- 17
> length(e)
[1] 3
> e
[1] NA NA 17
>
> (alpha <- numeric(10))
 [1] 0 0 0 0 0 0 0 0 0 0
> length(alpha)
[1] 10
> alpha <- alpha[2*1:5]
> length(alpha)
[1] 5
> length(alpha) <- 3
> alpha
[1] 0 0 0
```

```
> myf <- formula(y ~ x1 + x2 + x3)
> length(myf)
[1] 3
> str(myf)
Class 'formula'  language y ~ x1 + x2 + x3
  ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
> myf[1]
`~`()
> myf[2]
y()
> myf[3]
(x1 + x2 + x3)()
> myf[4]
Error in if (length(ans) == 0L ...
  需要 TRUE/FALSE 值的地方有缺值
```

```
> mye <- expression(x, {y <- x^2; y+2}, x^y)
> length(mye)
[1] 3
> str(mye)
  expression(x, {     y <- x^2     y + 2 }, x^y)
```

```
> mye[1]
expression(x)
> mye[2]
expression({
    y <- x^2
    y + 2
})
> mye[3]
expression(x^y)
> mye[4]
expression(NULL)
```

str(object): 物件之結構

```
> x <- 1:12
> str(x)
 int [1:12] 1 2 3 4 5 6 7 8 9 10 ...
>
> ch <- letters[1:12]
> str(ch)
 chr [1:12] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l"
>
> str(iris)
'data.frame':   150 obs. of  5 variables:
 $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
 $ Sepal.Width : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
 $ Petal.Length: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
 $ Petal.Width : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
 $ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1  ...
>
> str(ls)  # try > str(str)
function (name, pos = -1L, envir = as.environment(pos), all.names = FALSE, pattern,
sorted = TRUE)
> str(str)
function (object, ...)
>
> myp <- plot(iris[,1], iris[,2])
> str(myp)
 NULL
```

```
> (x <- as.Date("1985-6-16"))
[1] "1985-06-16"
> str(x)
 Date[1:1], format: "1985-06-16"
> (y <- strptime("27/02/2004", format="%d/%m/%Y"))
[1] "2004-02-27 CST"
> str(y)
 POSIXlt[1:1], format: "2004-02-27"
```

str(object): 物件之結構

```
> my.f <-  iris$Sepal.Length ~ iris$Sepal.Width
> my.f
iris$Sepal.Length ~ iris$Sepal.Width
> str(my.f)
Class 'formula'  language iris$Sepal.Length ~ iris$Sepal.Width
  ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
```

```
> my.lm <- lm(my.f)
> my.lm

Call:
lm(formula = my.f)

Coefficients:
     (Intercept)  iris$Sepal.Width
          6.5262           -0.2234

> str(my.lm)
List of 12
 $ coefficients : Named num [1:2] 6.526 -0.223
 ...
 $ qr           :List of 5
...
  ..$ tol  : num 1e-07
...
 $ terms   :Classes 'terms', 'formula'  language iris$Sepal.Length ~ iris$Sepal.Width
  .. ..- attr(*, "variables")= language list(iris$Sepal.Length, iris$Sepal.Width)
...
 - attr(*, "class")= chr "lm"
```

```
> my.lm$qr$tol
[1] 1e-07
```

```
> attr(my.lm$terms, "variables")
list(iris$Sepal.Length, iris$Sepal.Width)
```

str(object): 物件之結構

```
> my.lm.s <- summary(my.lm)
> my.lm.s

Call:
lm(formula = my.f)

Residuals:
    Min      1Q  Median      3Q     Max
-1.5561 -0.6333 -0.1120  0.5579  2.2226

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)        6.5262     0.4789   13.63   <2e-16 ***
iris$Sepal.Width  -0.2234     0.1551   -1.44    0.152
---
Signif. codes:  0  '***'  0.001  '**'  0.01  '*'  0.05  '.'  0.1  ' '  1

Residual standard error: 0.8251 on 148 degrees of freedom
Multiple R-squared:  0.01382,   Adjusted R-squared:  0.007159
F-statistic: 2.074 on 1 and 148 DF,  p-value: 0.1519

> str(my.lm.s)
List of 11
 $ call         : language lm(formula = my.f)
 $ terms        :Classes 'terms', 'formula'  language iris$Sepal.Length ~ iris$Sepal.Width
  .. ..- attr(*, "variables")= language list(iris$Sepal.Length, iris$Sepal.Width)
  .. ..- attr(*, "factors")= int [1:2, 1] 0 1
 ...
 - attr(*, "class")= chr "summary.lm"
```

```
> mye <- expression(x, {y <- x^2; y+2}, x^y)
> mye
expression(x, {
    y <- x^2
    y + 2
}, x^y)
>
```

物件屬性強制轉換 (Coercing)

Table 2.4. Functions for testing (is) the attributes of different categories of object (arrays, lists, etc.) and for coercing (as) the attributes of an object into a specified form. Neither operation changes the attributes of the object.

Type	Testing	Coercing
Array	is.array	as.array
Character	is.character	as.character
Complex	is.complex	as.complex
Dataframe	is.data.frame	as.data.frame
Double	is.double	as.double
Factor	is.factor	as.factor
List	is.list	as.list
Logical	is.logical	as.logical
Matrix	is.matrix	as.matrix
Numeric	is.numeric	as.numeric
Raw	is.raw	as.raw
Time series (ts)	is.ts	as.ts
Vector	is.vector	as.vector

```
> as.numeric(factor(c(“a”, “b”, “c”)))
> as.numeric(c(“a”, “b”, “c”)) #don’t work
```

資料類別/格式轉換

```
> # converting rows of a matrix to elements of a list
> xy.matrix <- cbind(c(1, 2, 3), c(15, 16, 17))
> xy.matrix
     [,1] [,2]
[1,]    1   15
[2,]    2   16
[3,]    3   17
> class(xy.matrix)
[1] "matrix"
>
> xy.df <- data.frame(t(xy.location))
> xy.df
  X1 X2 X3
1  1  2  3
2 15 16 17
> class(xy.df)
[1] "data.frame"
>
> xy.list <- as.list(xy.df)
> xy.list
$X1
[1]  1 15

$X2
[1]  2 16

$X3
[1]  3 17
> class(xy.list)
[1] "list"
```

```
> Titanic
, , Age = Child, Survived = No

      Sex
Class  Male Female
  1st     0      0
  2nd     0      0
  3rd    35     17
  Crew    0      0

, , Age = Adult, Survived = No

      Sex
Class  Male Female
...
> class(Titanic)
[1] "table"
> data.frame(Titanic)
   Class    Sex   Age Survived Freq
1    1st   Male Child       No    0
2    2nd   Male Child       No    0
3    3rd   Male Child       No   35
4   Crew   Male Child       No    0
...
```