# Matrices and Arrays

# Matrices

R supports the creation of 2d data structures (rows and columns) of atomic vector types. Generally these are formed via a call to `matrix()`.

```
matrix(1:4, nrow=2, ncol=2)
```

```
##      [,1] [,2]
## [1,]    1    3
## [2,]    2    4
```

```
matrix(LETTERS[1:6], 2)
```

```
##      [,1] [,2] [,3]
## [1,] "A"  "C"  "E"
## [2,] "B"  "D"  "F"
```

```
matrix(c(TRUE, FALSE), 2, 2)
```

```
##       [,1]  [,2]
## [1,]  TRUE  TRUE
## [2,] FALSE FALSE
```

```
matrix(6:1 / 2, ncol = 2)
```

```
##      [,1] [,2]
## [1,]  3.0  1.5
## [2,]  2.5  1.0
## [3,]  2.0  0.5
```

# Data ordering

Matrices in R use column major ordering (data is sorted in column order not row order).

```
(m = matrix(1:6, nrow=2, ncol=3))
```

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

```
c(m)
```

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

```
(n = matrix(1:6, nrow=2, ncol=3))
```

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

```
c(n)
```

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

When creating the matrix we can populate the matrix via row, but that data will still be stored in column major order.

```
(x = matrix(1:6, nrow=2, ncol=3, byrow = TRUE))
```

```
##      [,1] [,2] [,3]
## [1,]    1    2    3
```

```
(y = matrix(1:6, nrow=3, ncol=2, byrow=TRUE))
```

```
##      [,1] [,2]
## [1,]    1    2
```

# Matrix structure

```
m = matrix(1:4, ncol=2, nrow=2)
```

```
typeof(m)
```

```
## [1] "integer"
```

```
class(m)
```

```
## [1] "matrix" "array"
```

```
mode(m)
```

```
## [1] "numeric"
```

```
attributes(m)
```

```
## $dim
## [1] 2 2
```

Matrices (and arrays) are just atomic vectors with a `dim` attribute attached (they do not have a class attribute).

```
n = letters[1:6]
dim(n) = c(2L, 3L)

n
```

```
##      [,1] [,2] [,3]
## [1,] "a"  "c"  "e"
```

```
o = letters[1:6]
attr(o,"dim") = c(2L, 3L)

o
```

```
##      [,1] [,2] [,3]
## [1,] "a"  "c"  "e"
```

# Data Frames

# Data Frames

A data frame is how R handles heterogeneous tabular data (i.e. rows and columns) and is one of the most commonly used data structure in R.

```
(df = data.frame(
  x = 1:3,
  y = c("a", "b", "c"),
  z = c(TRUE)
))
```

```
##   x y    z
## 1 1 a TRUE
## 2 2 b TRUE
## 3 3 c TRUE
```

R represents data frames using a list of equal length vectors.

```
str(df)
```

```
## 'data.frame':    3 obs. of  3 variables:
##  $ x: int  1 2 3
##  $ y: chr  "a" "b" "c"
##  $ z: logi  TRUE TRUE TRUE
```

# Data Frame Structure

```
typeof(df)
```

```
## [1] "list"
```

```
class(df)
```

```
## [1] "data.frame"
```

```
attributes(df)
```

```
## $names
## [1] "x" "y" "z"
##
## $class
## [1] "data.frame"
##
## $row.names
## [1] 1 2 3
```

```
str(unclass(df))
```

```
## List of 3
##  $ x: int [1:3] 1 2 3
```

# Build your own data.frame

```
df = list(x = 1:3, y = c("a", "b", "c"), z = c(TRUE, TRUE, TRUE))
```

```
attr(df,"class") = "data.frame"
df
```

```
## [1] x y z
## <0 rows> (or 0-length row.names)
```

```
attr(df,"row.names") = 1:3
df
```

```
##   x y    z
## 1 1 a TRUE
## 2 2 b TRUE
## 3 3 c TRUE
```

```
str(df)
```

```
## 'data.frame':    3 obs. of  3 variables:
##  $ x: int  1 2 3
##  $ y: chr  "a" "b" "c"
##  $ z: logi  TRUE TRUE TRUE
```

```
is.data.frame(df)
```

```
## [1] TRUE
```

# Strings (Characters) vs Factors

Previous to R v4.0.0, the default behavior of data frames was to convert character data into factors. Sometimes this was useful, but mostly it wasn't.

Either way it is important to know what type/class you are working with. This behavior can be changed using the `stringsAsFactors` argument to `data.frame` and related functions (e.g. `read.csv`, `read.table`, etc.).

```
df = data.frame(x = 1:3, y = c("a", "b", "c"), stringsAsFactors = TRUE)
df
```

```
##   x y
## 1 1 a
## 2 2 b
## 3 3 c
```

```
str(df)
```

```
## 'data.frame':    3 obs. of  2 variables:
##  $ x: int  1 2 3
##  $ y: Factor w/ 3 levels "a","b","c": 1 2 3
```

# Length Coercion

For data frames on creation the lengths of the component vectors will be coerced to match, however if they not multiples then there will be an error (previously this produced a warning).

```
data.frame(x = 1:3, y = c("a"))
```

```
##   x y
## 1 1 a
## 2 2 a
## 3 3 a
```

```
data.frame(x = 1:3, y = c("a","b"))
```

```
## Error in data.frame(x = 1:3, y = c("a", "b")): arguments imply differing number of rows: 3, 2
```

```
data.frame(x = 1:3, y = character())
```

```
## Error in data.frame(x = 1:3, y = character()): arguments imply differing number of rows: 3, 0
```

# Subsetting

# Subsetting in General

R has three subsetting operators (`[`, `[[`, and `$`). The behavior of these operators will depend on the object (class) they are being used with.

In general there are 6 different types of subsetting that can be performed:

- Positive integer
- Negative integer
- Logical value
- Empty / NULL
- Zero valued
- Character value (names)

# Positive Integer subsetting

Returns elements at the given location(s)

```
x = c(1,4,7)
y = list(1,4,7)
```

```
x[1]
```

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

```
x[c(1,3)]
```

```
## [1] 1 7
```

```
x[c(1,1)]
```

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

```
x[c(1.9,2.1)]
```

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

```
str( y[1] )
```

```
## List of 1
##  $ : num 1
```

```
str( y[c(1,3)] )
```

```
## List of 2
##  $ : num 1
##  $ : num 7
```

```
str( y[c(1,1)] )
```

```
## List of 2
##  $ : num 1
##  $ : num 1
```

```
str( y[c(1.9,2.1)] )
```

```
## List of 2
##  $ : num 1
##  $ : num 4
```

Note - R uses a 1-based indexing scheme

# Negative Integer subsetting

Excludes elements at the given location(s)

```
x = c(1,4,7)
```

```
x[-1]
```

```
## [1] 4 7
```

```
x[-c(1,3)]
```

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

```
x[c(-1,-1)]
```

```
## [1] 4 7
```

```
y = list(1,4,7)
```

```
str( y[-1] )
```

```
## List of 2
##  $ : num 4
##  $ : num 7
```

```
str( y[-c(1,3)] )
```

```
## List of 1
##  $ : num 4
```

```
x[c(-1,2)]
```

```
## Error in x[c(-1, 2)]: only 0's may be mixed with negative subscripts
```

# Logical Value Subsetting

Returns elements that correspond to TRUE in the logical vector. Length of the logical vector is coerced to be the same as the vector being subsetted.

```
x = c(1,4,7,12)
```

```
x[c(TRUE,TRUE,FALSE,TRUE)]
```

```
## [1]  1  4 12
```

```
x[c(TRUE,FALSE)]
```

```
## [1] 1 7
```

```
y = list(1,4,7,12)
```

```
str( y[c(TRUE,TRUE,FALSE,TRUE)] )
```

```
## List of 3
##  $ : num 1
##  $ : num 4
##  $ : num 12
```

```
str( y[c(TRUE,FALSE)] )
```

```
## List of 2
##  $ : num 1
##  $ : num 7
```

```
x[x %% 2 == 0]
```

```
## [1]  4 12
```

# Empty Subsetting

Returns the original vector, this is not the same as subsetting with `NULL`

```
x = c(1,4,7)
```

```
x[]
```

```
## [1] 1 4 7
```

```
x[NULL]
```

```
## numeric(0)
```

```
y = list(1,4,7)
```

```
str(y[])
```

```
## List of 3
##  $ : num 1
##  $ : num 4
##  $ : num 7
```

```
str(y[NULL])
```

```
##  list()
```

# Zero subsetting

Returns an empty vector (of the same type), this is the same as subsetting with `NULL`

```
x = c(1,4,7)
```

```
x[0]
```

```
## numeric(0)
```

```
y = list(1,4,7)
str(y[0])
```

```
##  list()
```

0s can be mixed with either positive or negative integers for subsetting

```
x[c(0,1)]
```

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

```
y[c(0,1)]
```

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

```
x[c(0,-1)]
```

```
## [1] 4 7
```

```
y[c(0,-1)]
```

```
## [[1]]
## [1] 4
##
## [[2]]
## [1] 7
```

# Character subsetting

If the vector has names, selects elements whose names correspond to the values in the character vector.

```
x = c(a=1, b=4, c=7)
```

```
x["a"]
```

```
## a
## 1
```

```
x[c("a","a")]
```

```
## a a
## 1 1
```

```
x[c("b","c")]
```

```
## b c
## 4 7
```

```
y = list(a=1,b=4,c=7)
```

```
str(y["a"])
```

```
## List of 1
##  $ a: num 1
```

```
str(y[c("a","a")])
```

```
## List of 2
##  $ a: num 1
##  $ a: num 1
```

```
str(y[c("b","c")])
```

```
## List of 2
##  $ b: num 4
##  $ c: num 7
```

# Out of bounds

```
x = c(1,4,7)
```

```
x[4]
```

```
## [1] NA
```

```
x[-4]
```

```
## [1] 1 4 7
```

```
x["a"]
```

```
## [1] NA
```

```
x[c(1,4)]
```

```
## [1]  1 NA
```

```
y = list(1,4,7)
```

```
str(y[4])
```

```
## List of 1
##  $ : NULL
```

```
str(y[-4])
```

```
## List of 3
##  $ : num 1
##  $ : num 4
##  $ : num 7
```

```
str(y["a"])
```

```
## List of 1
##  $ : NULL
```

```
str(y[c(1,4)])
```

```
## List of 2
```

# Missing

```
x = c(1,4,7)
```

```
x[NA]
```

```
## [1] NA NA NA
```

```
x[c(1,NA)]
```

```
## [1]  1 NA
```

```
y = list(1,4,7)
```

```
str(y[NA])
```

```
## List of 3
##  $ : NULL
##  $ : NULL
##  $ : NULL
```

```
str(y[c(1,NA)])
```

```
## List of 2
##  $ : num 1
##  $ : NULL
```

# The other subset operators (`[[` and `$`)

# Atomic vectors - [ vs. [[

`[[` subsets like `[` except it can only subset for a single value

```
x = c(a=1,b=4,c=7)
```

```
x[1]
```

```
## a
## 1
```

```
x[[1]]
```

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

```
x[["a"]]
```

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

```
x[[1:2]]
```

```
## Error in x[[1:2]]: attempt to select more than one element in vectorIndex
```

```
x[[TRUE]]
```

# Generic Vectors - [ vs. [[

Subsets a single value, but returns the value - not a list containing that value.

```
y = list(a=1, b=4, c=7:9)
```

```
y[2]
```

```
## $b
## [1] 4
```

```
str( y[2] )
```

```
## List of 1
##  $ b: num 4
```

```
y[[2]]
```

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

```
y[["b"]]
```

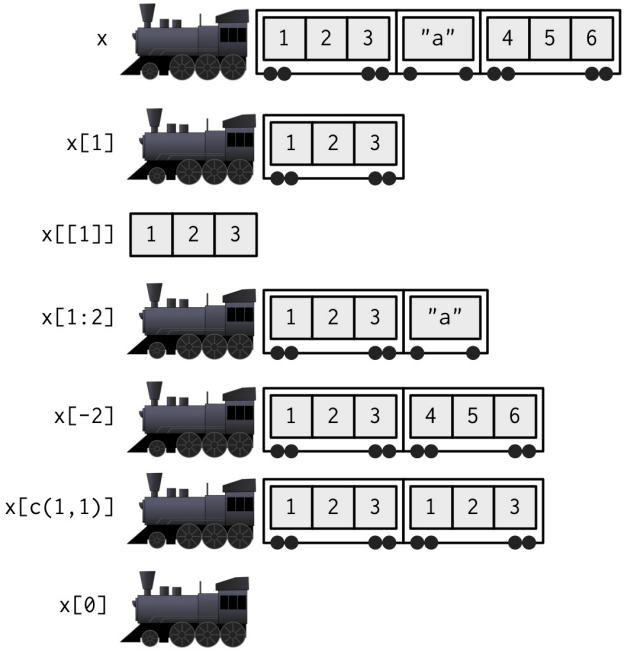
```
## [1] 4
```

```
y[[1:2]]
```

```
## Error in y[[1:2]]: subscript out of bounds
```

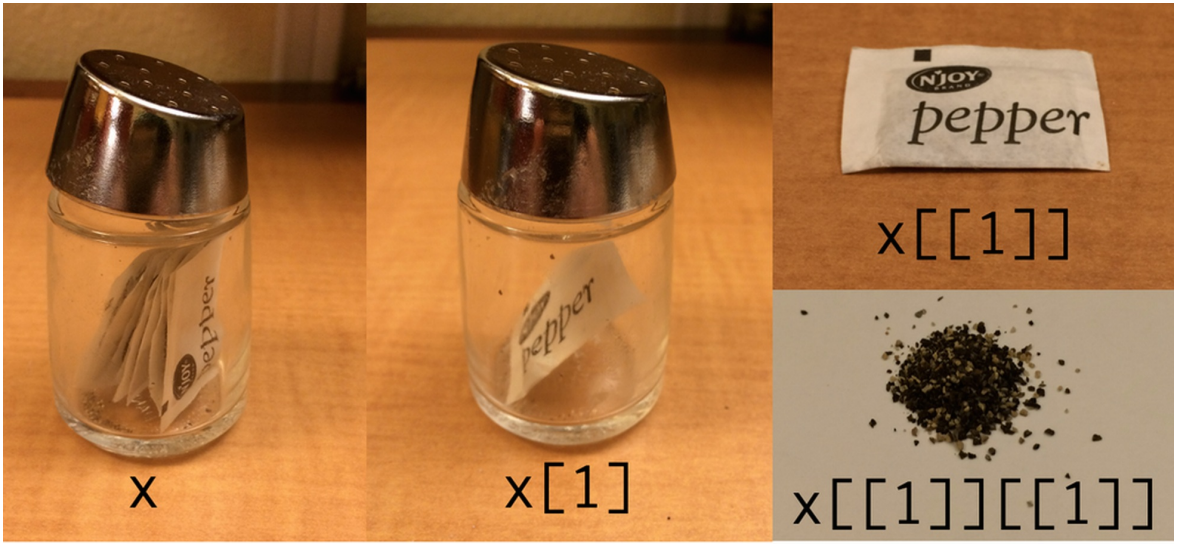
```
y[[2:1]]
```

# Hadley's Analogy (1)




From Advanced R - Chapter 4.3

# Hadley's Analogy (2)




**Hadley Wickham** @hadleywickham · 6h
Indexing lists in #rstats. Inspired by the Residence Inn

273 370 •••

# [[ vs. $

`$` is equivalent to `[[` but it only works for named lists and it uses partial matching for names

```
x = c("abc"=1, "def"=5)
```

```
x$abc
```

```
## Error in x$abc: $ operator is invalid for atomic vectors
```

```
y = list("abc"=1, "def"=5)
```

```
y[["abc"]]
```

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

```
y$abc
```

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

```
y$d
```

```
## [1] 5
```

# A common error

Why does the following code not work?

```
x = list(abc = 1:10, def = 10:1)
y = "abc"
```

```
x[[y]]
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

```
x$y
```

```
## NULL
```

The expression `x$y` gets directly interpreted as `x[["y"]]` by R, not the include of the `"`s, this is not the same as the expression `x[[y]]`.

# Subsetting Data Frames

# Subsetting

As data frames have 2 dimensions, we can subset on either the rows or the columns - the subsetting values are separated by a comma.

```
(df = data.frame(x = 1:3, y = c("A","B","C"), z = TRUE))
```

```
##   x y    z
## 1 1 A TRUE
## 2 2 B TRUE
## 3 3 C TRUE
```

```
df[1, ]
```

```
##   x y    z
## 1 1 A TRUE
```

```
str( df[1, ] )
```

```
## 'data.frame':    1 obs. of  3 variables:
##  $ x: int 1
##  $ y: chr "A"
##  $ z: logi TRUE
```

```
df[c(1,3), ]
```

```
##   x y    z
## 1 1 A TRUE
## 3 3 C TRUE
```

```
str( df[c(1,3), ] )
```

```
## 'data.frame':    2 obs. of  3 variables:
##  $ x: int  1 3
##  $ y: chr  "A" "C"
```

# Subsetting Columns

```
df
```

```
##   x y    z
## 1 1 A TRUE
## 2 2 B TRUE
## 3 3 C TRUE
```

```
df[, 1]
```

```
## [1] 1 2 3
```

```
str( df[, 1] )
```

```
##  int [1:3] 1 2 3
```

```
df[, 1:2]
```

```
##   x y
## 1 1 A
## 2 2 B
## 3 3 C
```

```
str( df[, 1:2] )
```

```
## 'data.frame':    3 obs. of  2 variables:
##  $ x: int  1 2 3
##  $ y: chr  "A" "B" "C"
```

```
df[, -3]
```

```
##   x y
## 1 1 A
```

```
str( df[, -3] )
```

```
## 'data.frame':    3 obs. of  2 variables:
##  $ x: int  1 2 3
```

# Subsetting both

```
df
```

```
##   x y    z
## 1 1 A TRUE
## 2 2 B TRUE
## 3 3 C TRUE
```

```
df[1, 1]
```

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

```
str( df[1, 1] )
```

```
##  int 1
```

```
df[1:2, 1:2]
```

```
##   x y
## 1 1 A
## 2 2 B
```

```
str( df[1:2, 1:2] )
```

```
## 'data.frame':    2 obs. of  2 variables:
##  $ x: int  1 2
##  $ y: chr  "A" "B"
```

```
df[-1, 2:3]
```

```
##   y    z
## 2 B TRUE
## 3 C TRUE
```

```
str( df[-1, 2:3] )
```

```
## 'data.frame':    2 obs. of  2 variables:
##  $ y: chr  "B" "C"
##  $ z: logi  TRUE TRUE
```

# Preserving vs Simplifying

Most of the time, R's `[` subset operator is a preserving operator, in that the returned object will always have the same type/class as the object being subset. Confusingly, when used with some classes (e.g. data frame, matrix or array) `[` becomes a simplifying operator (does not preserve type) - this behavior is instead controlled by the `drop` argument.

```
df[1, ]
```

```
##   x y    z
## 1 1 A TRUE
```

```
str(df[1, ])
```

```
## 'data.frame':    1 obs. of  3 variables:
##  $ x: int 1
##  $ y: chr "A"
##  $ z: logi TRUE
```

```
df[1, , drop=TRUE]
```

```
## $x
## [1] 1
##
## $y
## [1] "A"
##
## $z
```

```
str(df[1, , drop=TRUE])
```

```
## List of 3
##  $ x: int 1
##  $ y: chr "A"
##  $ z: logi TRUE
```

```
df[, 1]
```

```
## [1] 1 2 3
```

```
df[, 1, drop=FALSE]
```

```
##   x
## 1 1
## 2 2
## 3 3
```

```
df[1:2, 1:2]
```

```
##   x y
## 1 1 A
## 2 2 B
```

```
df[1:2, 1:2, drop=TRUE]
```

```
##   x y
## 1 1 A
## 2 2 B
```

```
str(df[, 1])
```

```
##  int [1:3] 1 2 3
```

```
str(df[, 1, drop=FALSE])
```

```
## 'data.frame':    3 obs. of  1 variable:
##  $ x: int  1 2 3
```

```
str(df[1:2, 1:2])
```

```
## 'data.frame':    2 obs. of  2 variables:
##  $ x: int  1 2
##  $ y: chr  "A" "B"
```

```
str(df[1:2, 1:2, drop=TRUE])
```

```
## 'data.frame':    2 obs. of  2 variables:
##  $ x: int  1 2
##  $ y: chr  "A" "B"
```

# Subsetting and assignment

# Subsetting and assignment

Subsets can also be used with assignment to update specific values within an object (in-place).

```
x = c(1, 4, 7, 9, 10, 15)
```

```
x[2] = 2
x
```

```
## [1]  1  2  7  9 10 15
```

```
x %% 2 != 0
```

```
## [1]  TRUE FALSE  TRUE  TRUE FALSE  TRUE
```

```
x[x %% 2 != 0] = (x[x %% 2 != 0] + 1) / 2
x
```

```
## [1]  1  2  4  5 10  8
```

```
x[c(1,1)] = c(2,3)
x
```

```
## [1]  3  2  4  5 10  8
```

```
x = 1:6
```

```
x[c(2,NA)] = 1
x
```

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

```
x = 1:6
```

```
x[c(-1,-2)] = 3
x
```

```
## [1] 1 2 3 3 3 3
```

```
x = 1:6
```

```
x[c(TRUE,NA)] = 1
x
```

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

```
x = 1:6
```

```
x[] = 1:3
x
```

# Subsets of Subsets

```
( df = data.frame(a = c(5,1,NA,3)) )
```

```
##    a
## 1  5
## 2  1
## 3 NA
## 4  3
```

```
df$a[df$a == 5] = 0
df
```

```
##    a
## 1  0
## 2  1
## 3 NA
## 4  3
```

```
df[1][df[1] != 3] = -1
df
```

```
##    a
## 1 -1
## 2 -1
## 3 NA
```

# Exercise 2

Some data providers choose to encode missing values using values like `-999`. Below is a sample data frame with missing values encoded in this way.

```
d = data.frame(
  patient_id = c(1, 2, 3, 4, 5),
  age = c(32, 27, 56, 19, 65),
  bp = c(110, 100, 125, -999, -999),
  o2 = c(97, 95, -999, -999, 99)
)
```

- Task 1 - using the subsetting tools we've discussed come up with code that will replace the `-999` values in the `bp` and `o2` column with actual `NA` values. Save this as `d_na`.
- Task 2 - Once you have created `d_na` come up with code that translate it back into the original data frame `d`, i.e. replace the `NA`s with `-999`.