Programming for Data Analytics

9. The S3 Object System

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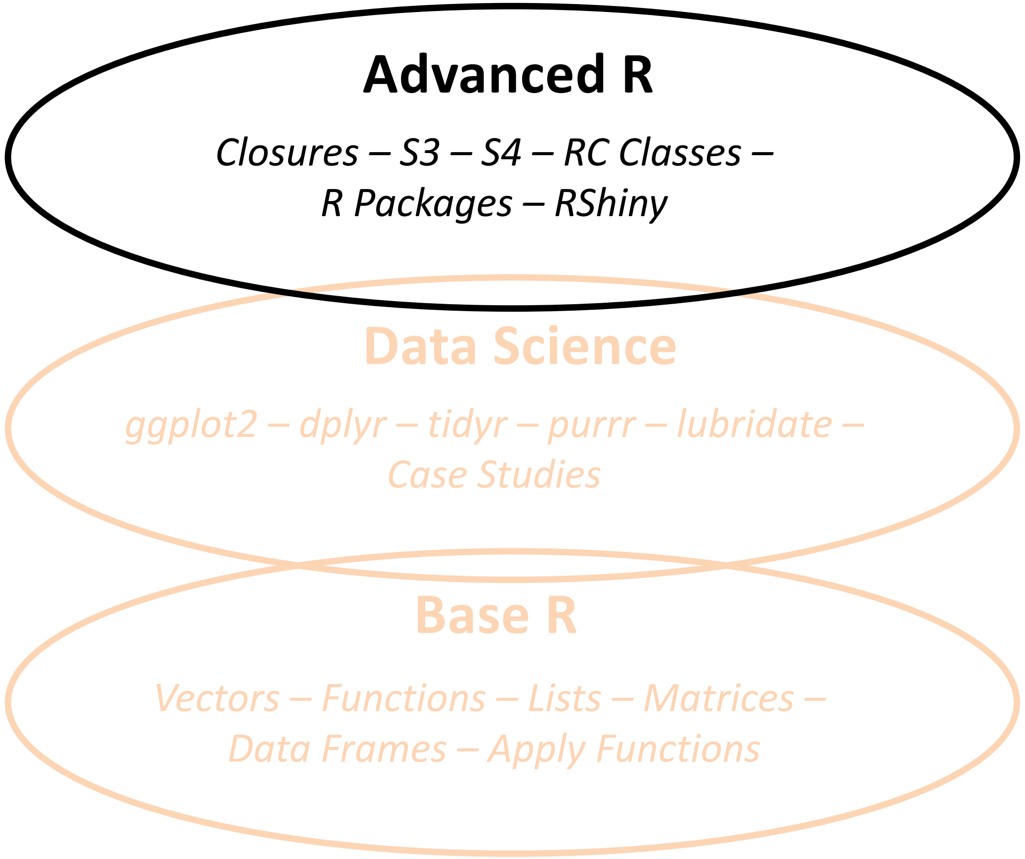
https://github.com/JimDuggan/CT5102

Overview

- Attributes
- S3 Classes
- Inheritance



Advanced R

Closures – S3 – S4 – RC Classes – R Packages – RShiny

Data Science

ggplot2 – dplyr – tidyr – purrr – lubridate – Case Studies

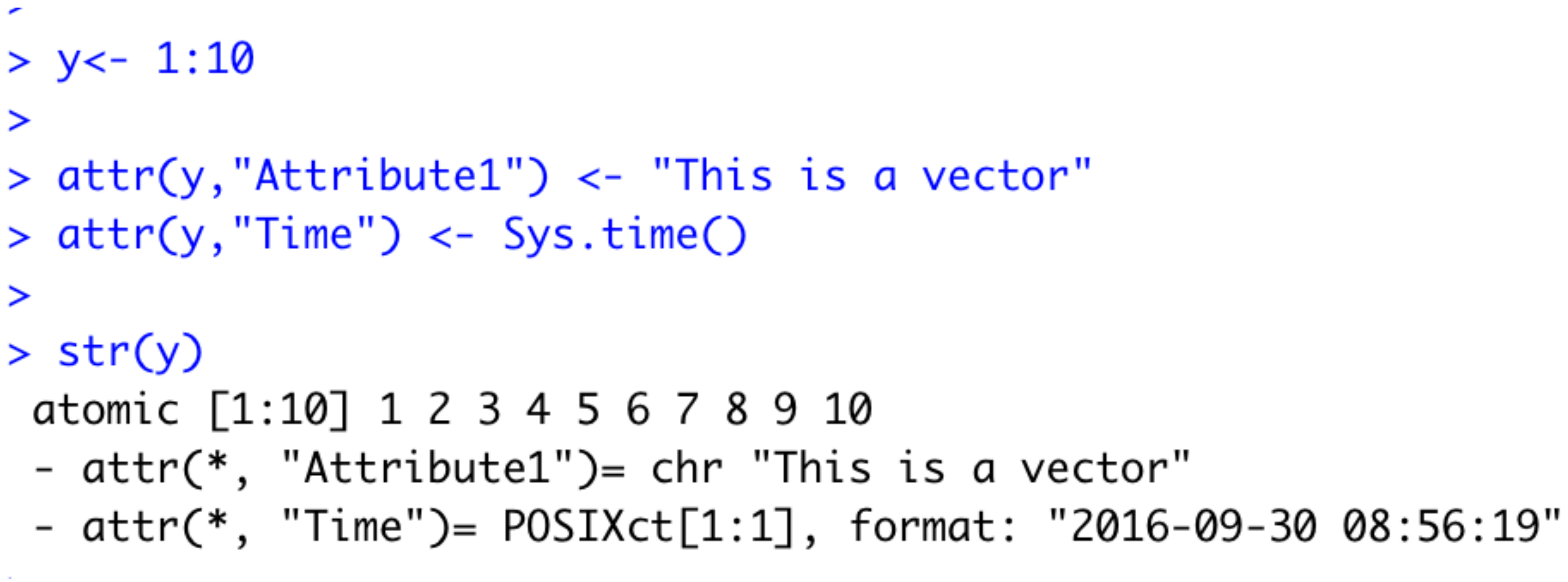
Base R

Vectors – Functions – Lists – Matrices – Data Frames – Apply Functions

(1) Attributes

- All objects can have arbitrary additional attributes, used to store meta-data about the object
- Attributes can be thought of as a named list (with unique names)
- Attributes can be accessed:
  - Individually with **attr()**
  - All at once with **attributes()**

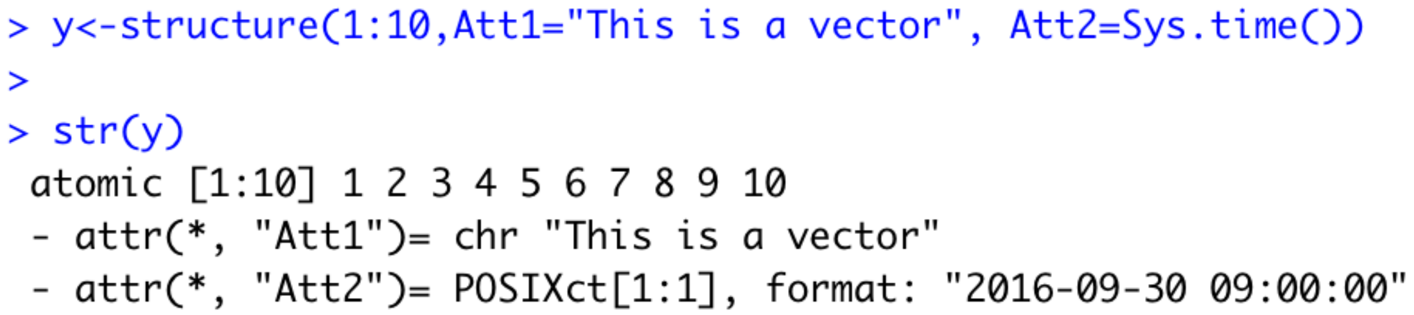
Example



```
> y<- 1:10
>
> attr(y,"Attribute1") <- "This is a vector"
> attr(y,"Time") <- Sys.time()
>
> str(y)
 atomic [1:10] 1 2 3 4 5 6 7 8 9 10
 - attr(*, "Attribute1")= chr "This is a vector"
 - attr(*, "Time")= POSIXct[1:1], format: "2016-09-30 08:56:19"
```

structure() function

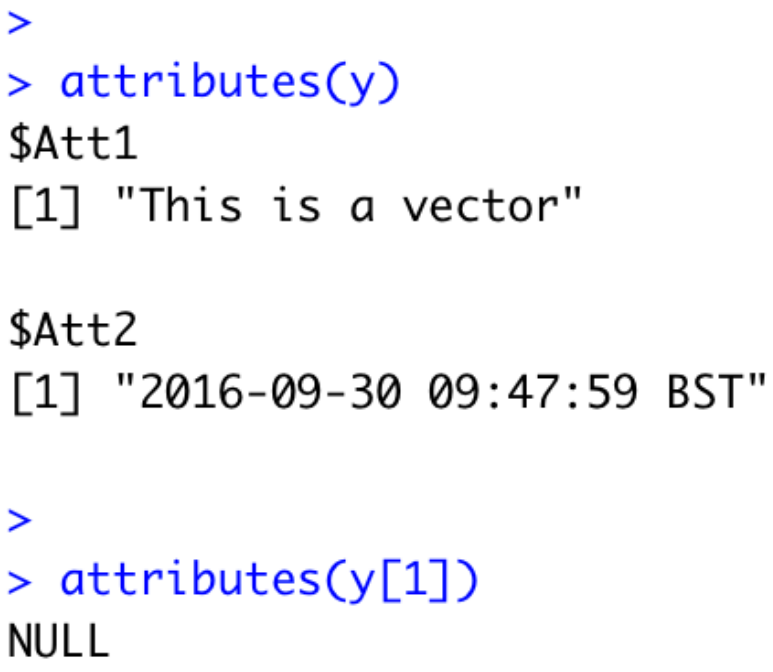
- The structure function returns a new object with modified attributes



```
> y<-structure(1:10,Att1="This is a vector", Att2=Sys.time())
>
> str(y)
 atomic [1:10] 1 2 3 4 5 6 7 8 9 10
 - attr(*, "Att1")= chr "This is a vector"
 - attr(*, "Att2")= POSIXct[1:1], format: "2016-09-30 09:00:00"
```

Properties of attributes

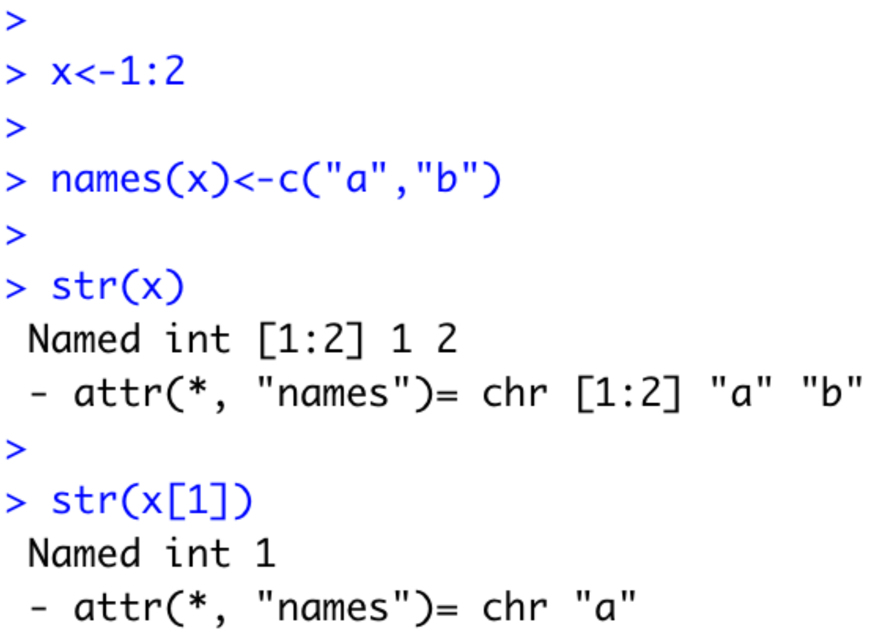
- By default, most attributes are lost when subsetting a vector



```
>
> attributes(y)
$Att1
[1] "This is a vector"

$Att2
[1] "2016-09-30 09:47:59 BST"

>
> attributes(y[1])
NULL
```

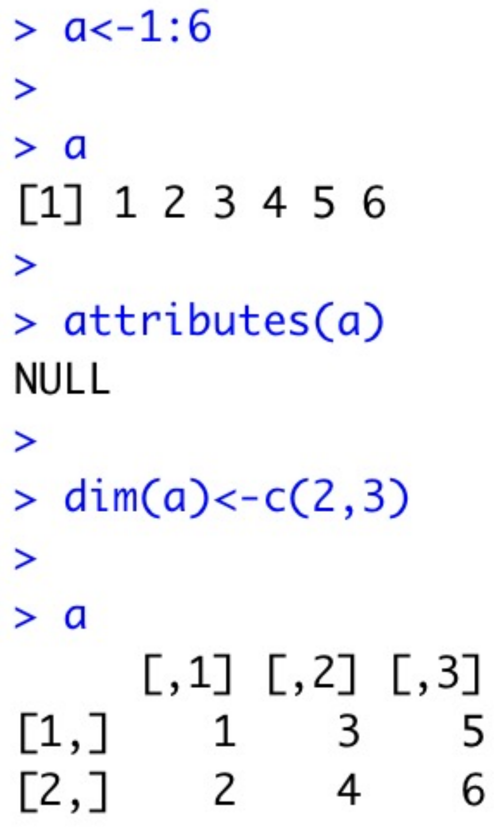
Attributes **not lost** during operations...

- **Names**, a character vector giving each element a name. ***names(x)***
- **Dimensions**, used to turn vectors into matrices and arrays. ***dim(x)***
- **Class**, used to implement the S3 object system. ***class(x)***

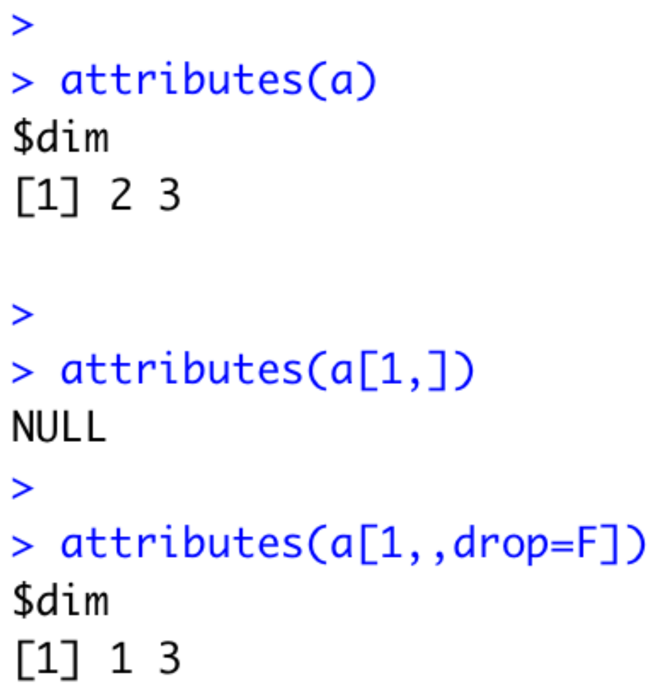


```
>
> x<-1:2
>
> names(x)<-c("a","b")
>
> str(x)
 Named int [1:2] 1 2
 - attr(*, "names")= chr [1:2] "a" "b"
>
> str(x[1])
 Named int 1
 - attr(*, "names")= chr "a"
```

dim() example

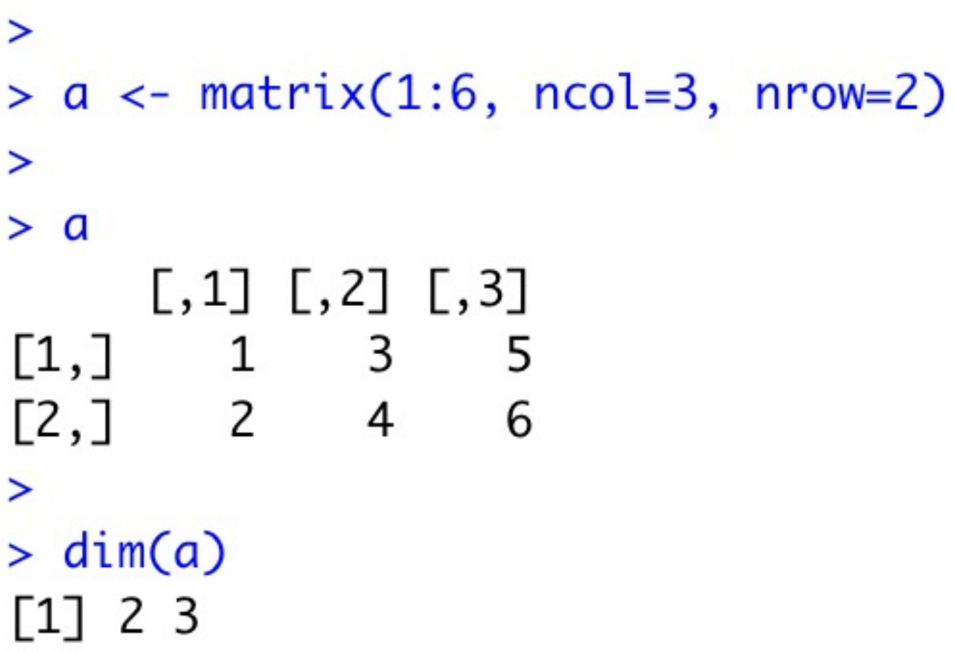


```
> a<-1:6
>
> a
[1] 1 2 3 4 5 6
>
> attributes(a)
NULL
>
> dim(a)<-c(2,3)
>
> a
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
```



```
>
> attributes(a)
$dim
[1] 2 3

>
> attributes(a[1,])
NULL
>
> attributes(a[1,,drop=F])
$dim
[1] 1 3
```

Declaring a matrix

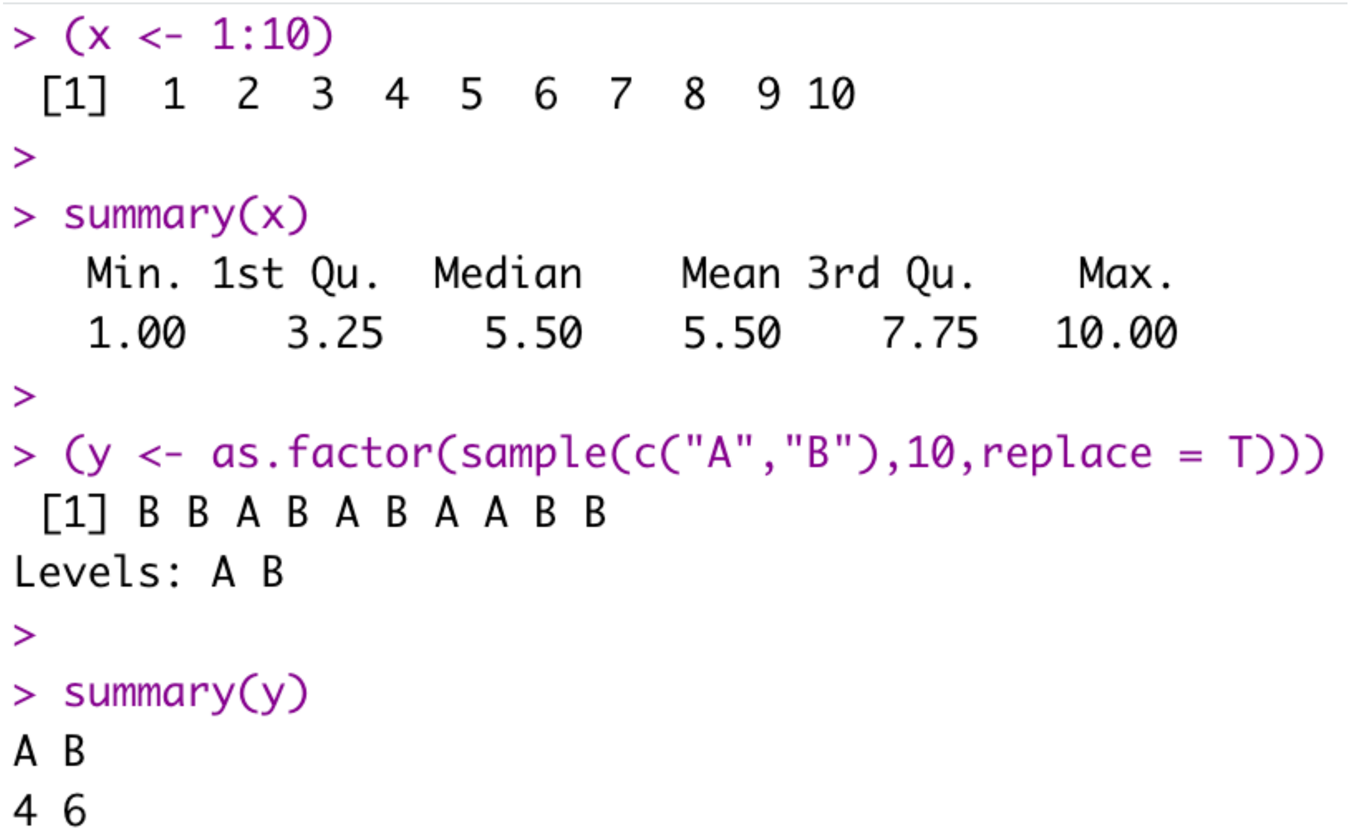


```
>
> a <- matrix(1:6, ncol=3, nrow=2)
>
> a
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
>
> dim(a)
[1] 2 3
```

Challenge 9.1

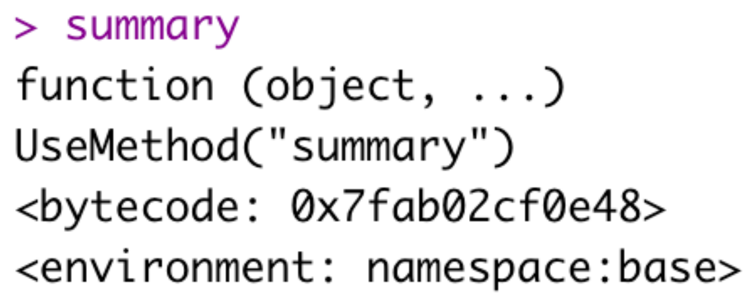
- For the vector **1:100**, convert this to a **10 x 10 matrix** using the attr() function
- Perform a similar conversion using the dim function

(2) S3 System – Example

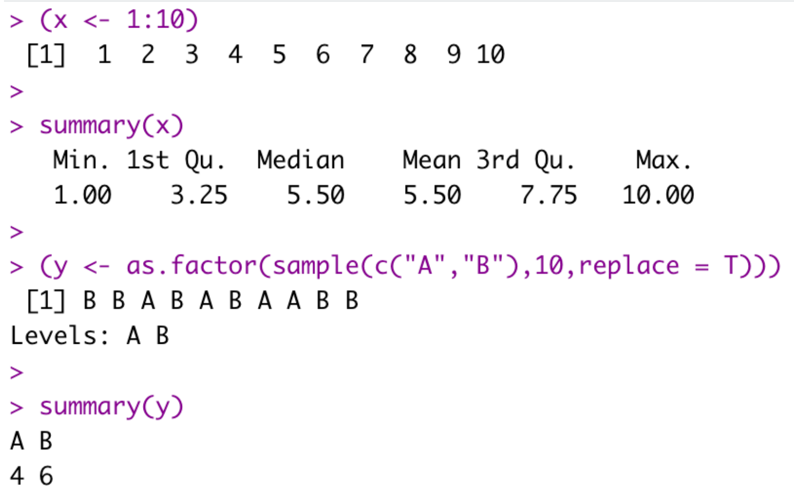


```
> (x <- 1:10)
 [1]  1  2  3  4  5  6  7  8  9 10
>
> summary(x)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   1.00    3.25    5.50    5.50    7.75   10.00 
>
> (y <- as.factor(sample(c("A","B"),10,replace = T)))
 [1] B B A B A B A A B B
Levels: A B
>
> summary(y)
A B 
4 6 
```

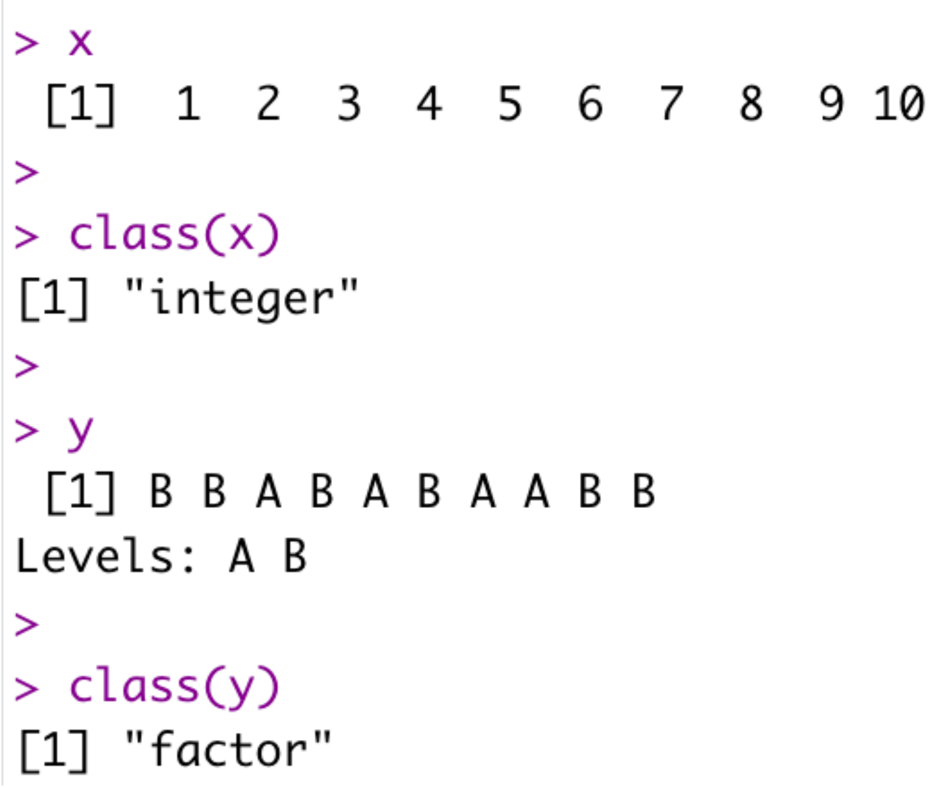
summary()



```
> summary
function (object, ...)
UseMethod("summary")
<bytecode: 0x7fab02cf0e48>
<environment: namespace:base>
```



```
> (x <- 1:10)
 [1]  1  2  3  4  5  6  7  8  9 10
>
> summary(x)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   1.00    3.25    5.50    5.50    7.75   10.00 
>
> (y <- as.factor(sample(c("A","B"),10,replace = T)))
 [1] B B A B A B A A B B
Levels: A B
>
> summary(y)
A B 
4 6 
```



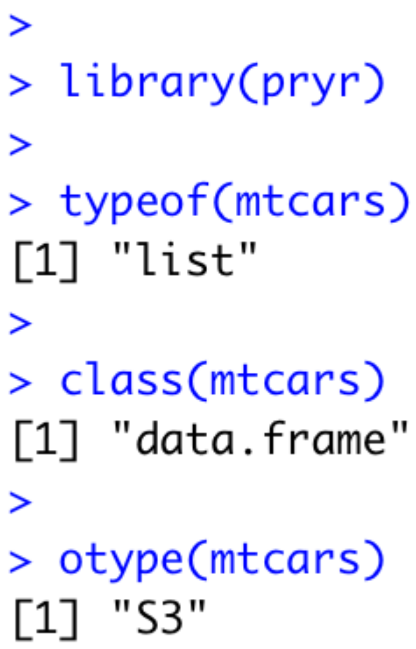
```
> x
 [1]  1  2  3  4  5  6  7  8  9 10
>
> class(x)
[1] "integer"
>
> y
 [1] B B A B A B A A B B
Levels: A B
>
> class(y)
[1] "factor"
```

S3 System

- Most OO languages
  - implement message-passing OO
  - Object determines which function to call
  - **canvas.drawRect(“blue”)**
- S3
  - Implements generic-function OO
  - A special type of function called a **generic function** decides which method to call (i.e. method dispatch)
  - **drawRect(canvas, “blue”)**
  - S3 is a very casual system, it has no formal definition of classes

S3 Information

- The only OO system used in the base and stats packages, and the most commonly used in CRAN packages
- “S3 is informal and ad-hoc, but has a certain elegance in its minimalism” (Wickham 2015)

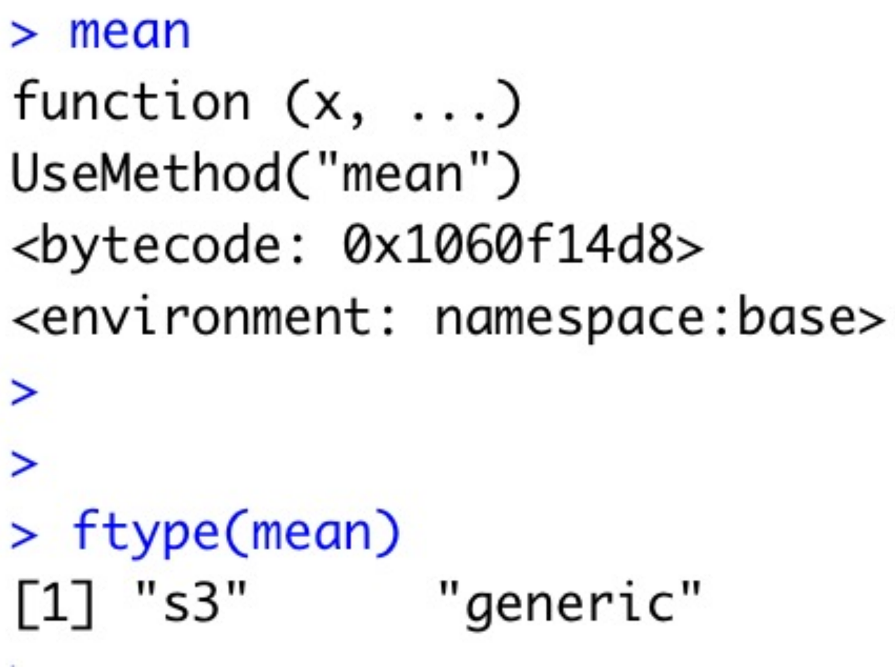


```
> 
> library(pryr)
> 
> typeof(mtcars)
[1] "list"
> 
> class(mtcars)
[1] "data.frame"
> 
> otype(mtcars)
[1] "S3"
```

Methods in S3

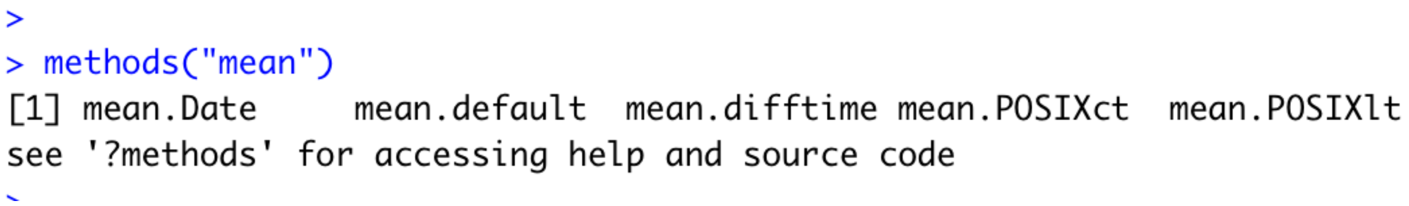
- In S3, methods belong to functions, called **generic functions**
- S3 methods to not belong to objects or classes
- To determine if a function is an S3 generic, inspect the source code for a call to **UseMethod()**
- UseMethod() – Figures out the correct method to call, the process of **method dispatch**
- Method names tend to be **generic.class()**

mean() function example



```
> mean
function (x, ...)
UseMethod("mean")
<bytecode: 0x1060f14d8>
<environment: namespace:base>
>
>
> ftype(mean)
[1] "s3"      "generic"
```

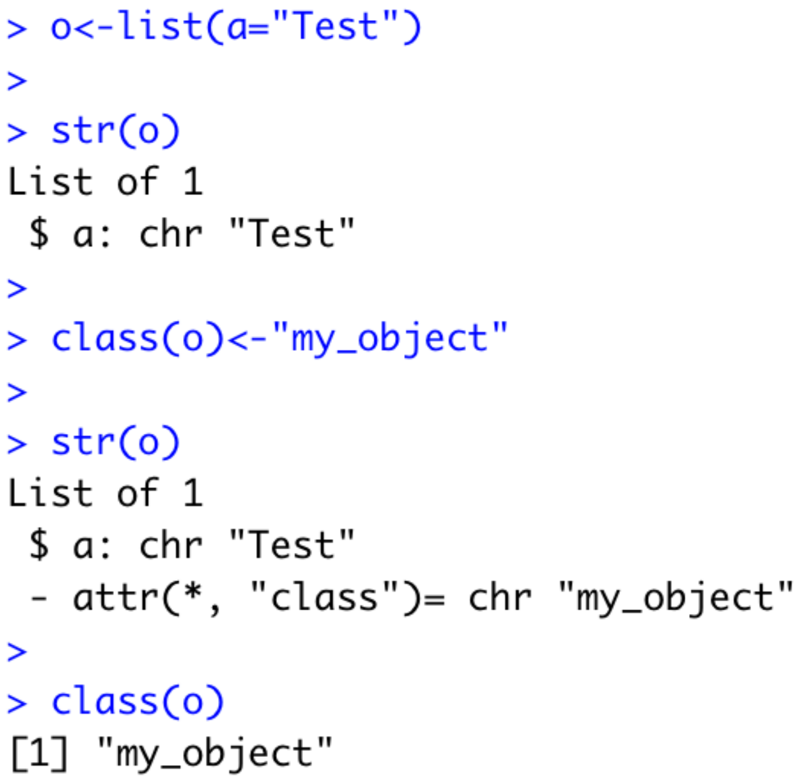
See all methods belonging to a generic



```
>
> methods("mean")
[1] mean.Date     mean.default  mean.difftime mean.POSIXct  mean.POSIXlt
see '?methods' for accessing help and source code
```

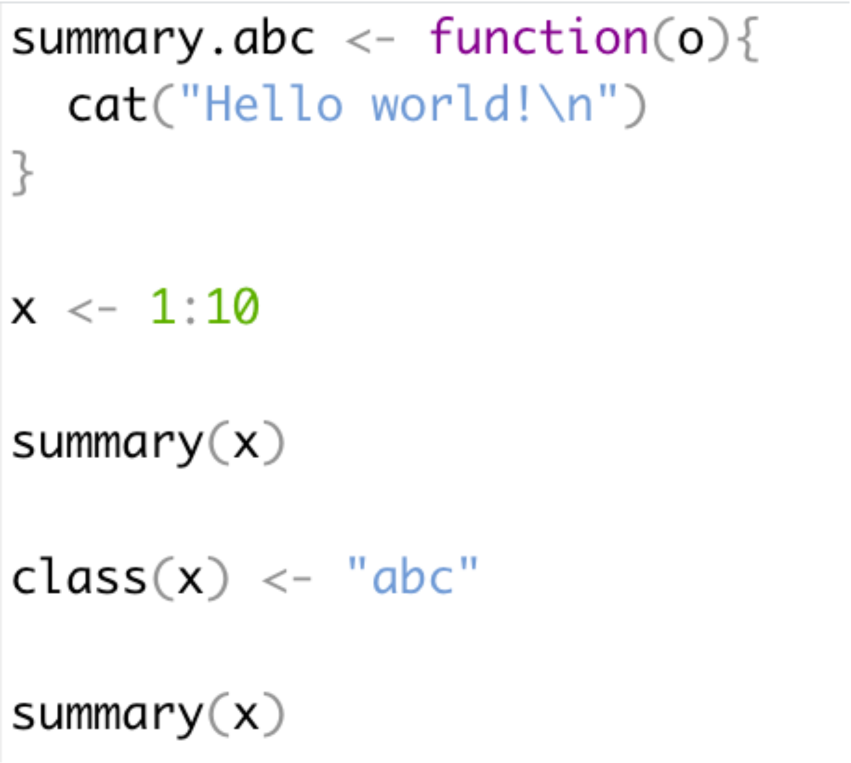
Defining classes and creating objects

- S3 objects usually built on top of lists, or atomic vectors with attributes
- Functions can also be S3 objects
- **class(x)** shows the class of an object

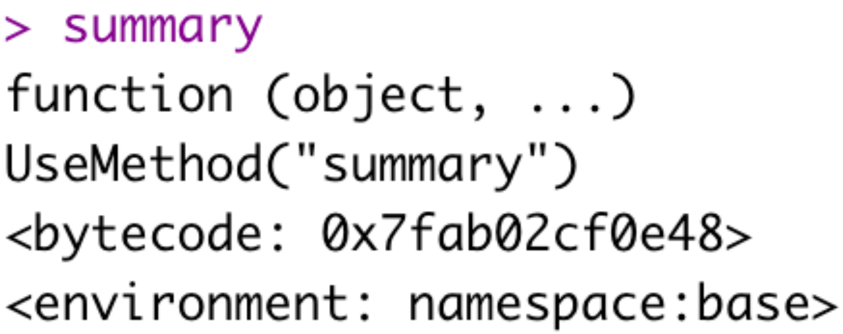


```
> o<-list(a="Test")
>
> str(o)
List of 1
 $ a: chr "Test"
>
> class(o)<-"my_object"
>
> str(o)
List of 1
 $ a: chr "Test"
 - attr(*, "class")= chr "my_object"
>
> class(o)
[1] "my_object"
```

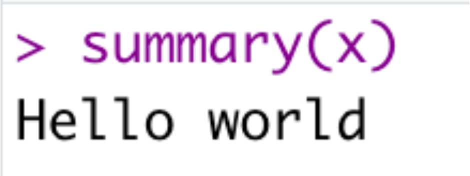
Using the existing generic function system



```r
summary.abc <- function(o){
  cat("Hello world!\n")
}

x <- 1:10

summary(x)

class(x) <- "abc"

summary(x)
```



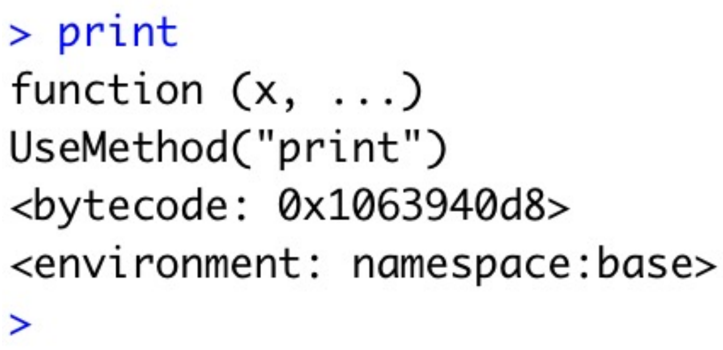
```
> summary
function (object, ...)
UseMethod("summary")
<bytecode: 0x7fab02cf0e48>
<environment: namespace:base>
```



```
> summary(x)
Hello world
```

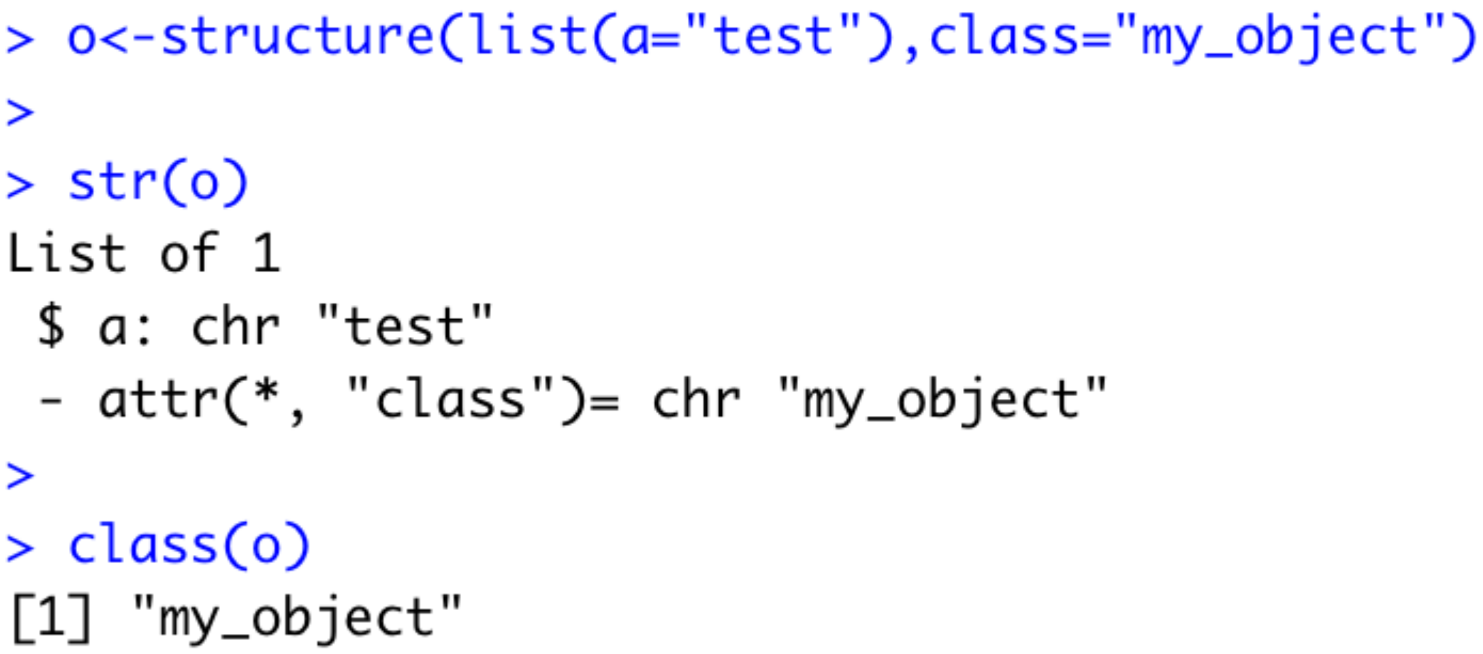
Challenge 9.2

- Find a way to “override” the print function for a vector object so that it prints a summary of the vector when it is called (using the summary() function).



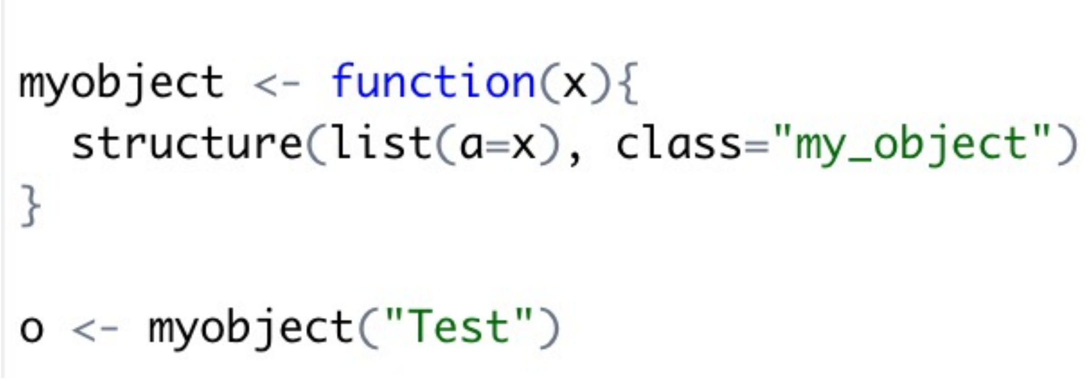
```
> print
function (x, ...)
UseMethod("print")
<bytecode: 0x1063940d8>
<environment: namespace:base>
>
```

Using structure() function

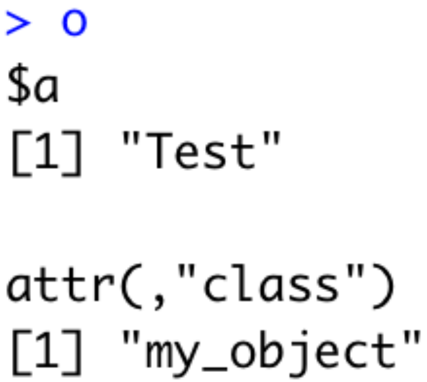


```
> o<-structure(list(a="test"),class="my_object")
>
> str(o)
List of 1
 $ a: chr "test"
 - attr(*, "class")= chr "my_object"
>
> class(o)
[1] "my_object"
```

Most S3 classes provide a constructor function



```
myobject <- function(x){
  structure(list(a=x), class="my_object")
}

o <- myobject("Test")
```

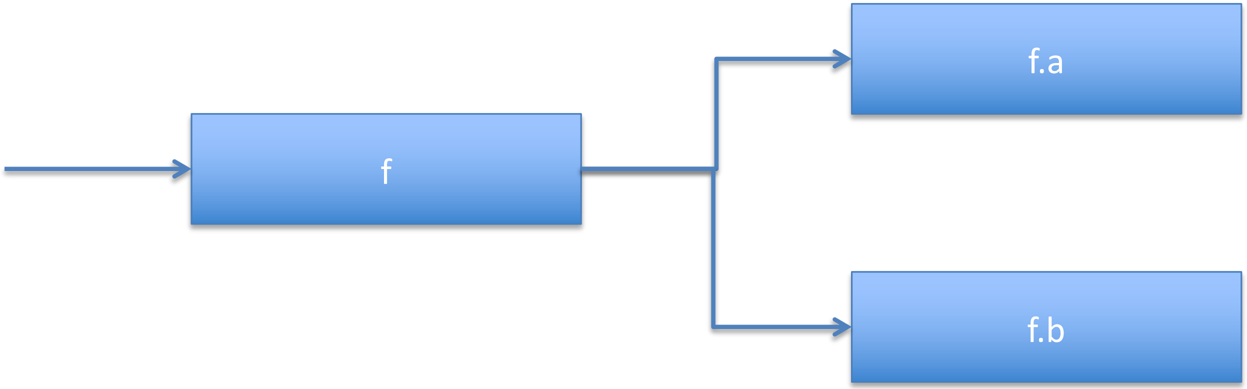


```
> o
$a
[1] "Test"

attr(,"class")
[1] "my_object"
```

Creating new methods and generics

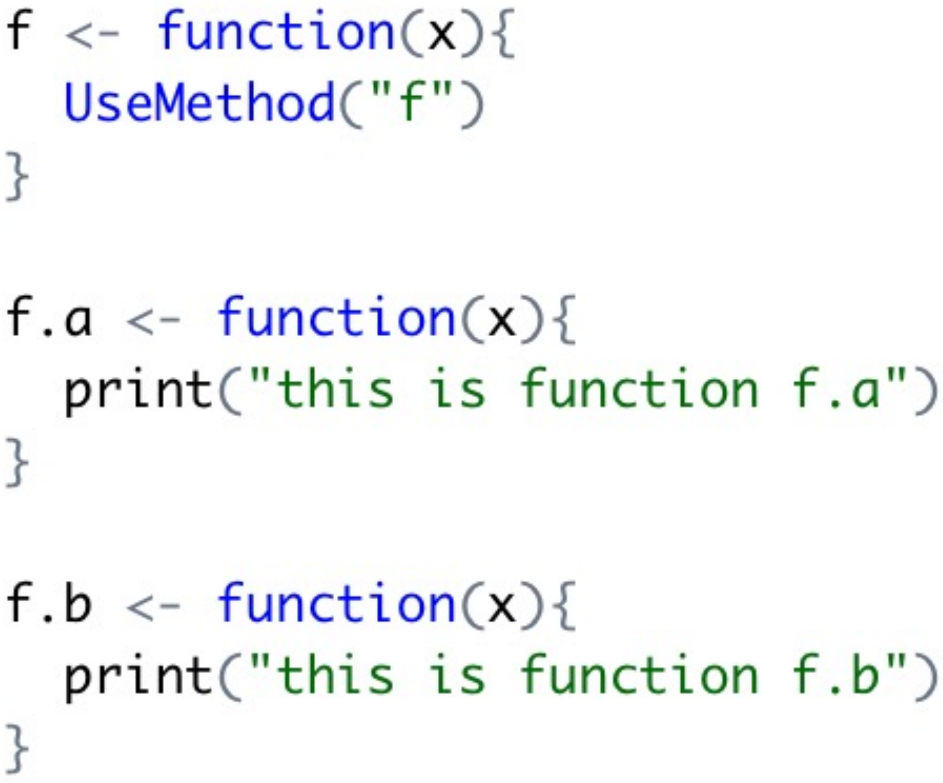
- To add a new generic, create a function that calls **UseMethod()**
- UseMethod takes two arguments
  - The name of the generic function
  - The argument to use for method dispatch
- If the 2nd argument is omitted, it will dispatch on the first argument to the function
- Methods are then added, using a regular function with the name *generic.class*

Overall idea…



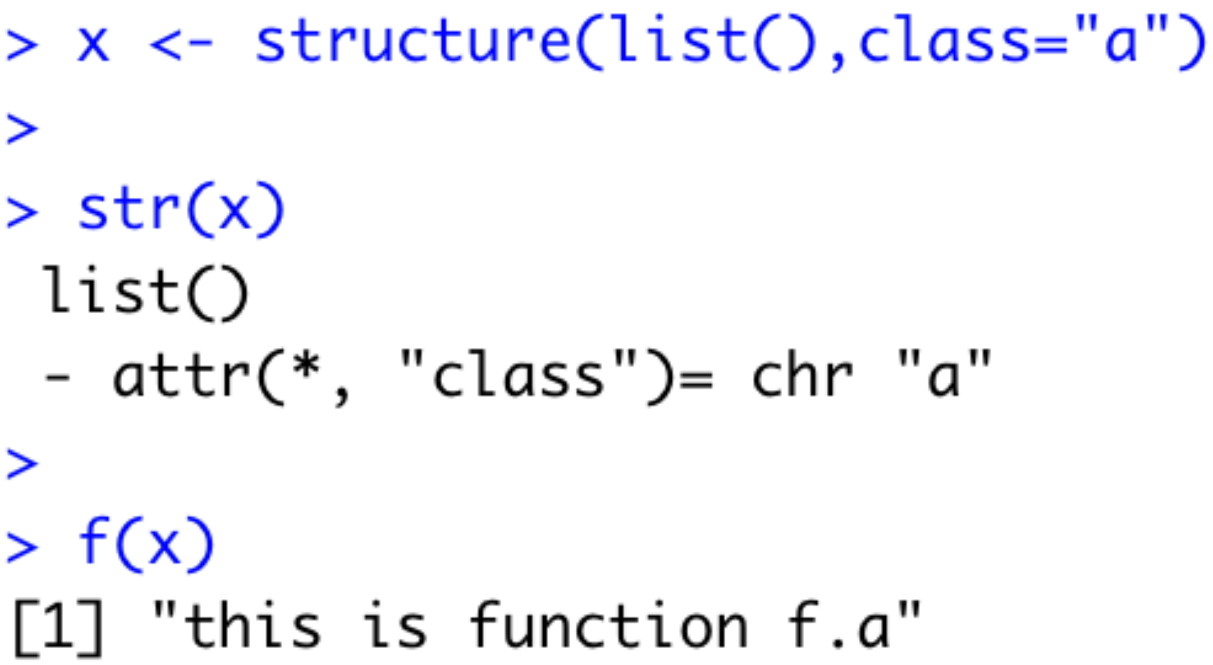
Format for specific functions are *[generic function].[class name]*

Example…



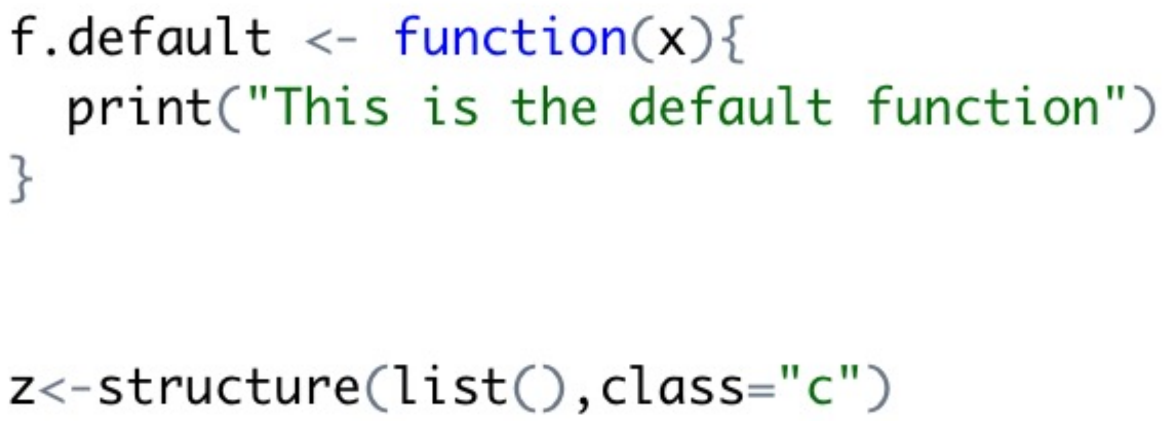
```
f <- function(x){
  UseMethod("f")
}

f.a <- function(x){
  print("this is function f.a")
}

f.b <- function(x){
  print("this is function f.b")
}
```

Calling the generic…

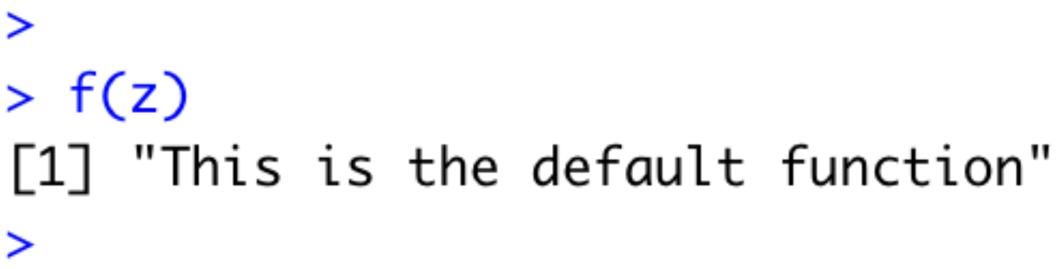


```
> x <- structure(list(),class="a")
>
> str(x)
 list()
 - attr(*, "class")= chr "a"
>
> f(x)
[1] "this is function f.a"
```

Default functions…



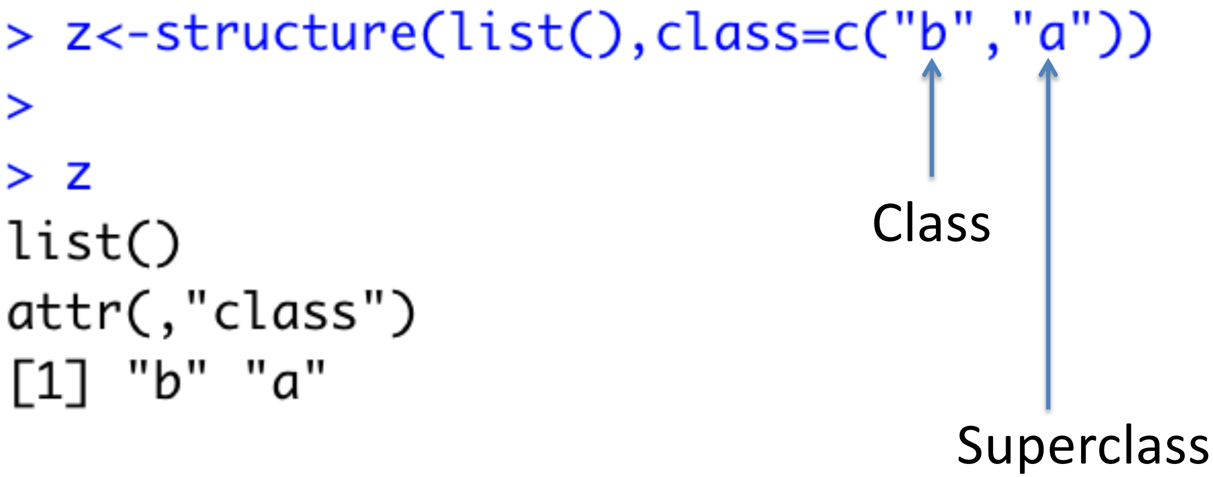
```r
f.default <- function(x){
  print("This is the default function")
}


z<-structure(list(),class="c")
```



```
>
> f(z)
[1] "This is the default function"
>
```

(3) Inheritance

- The idea of inheritance is to form new classes of specialised versions of existing ones.

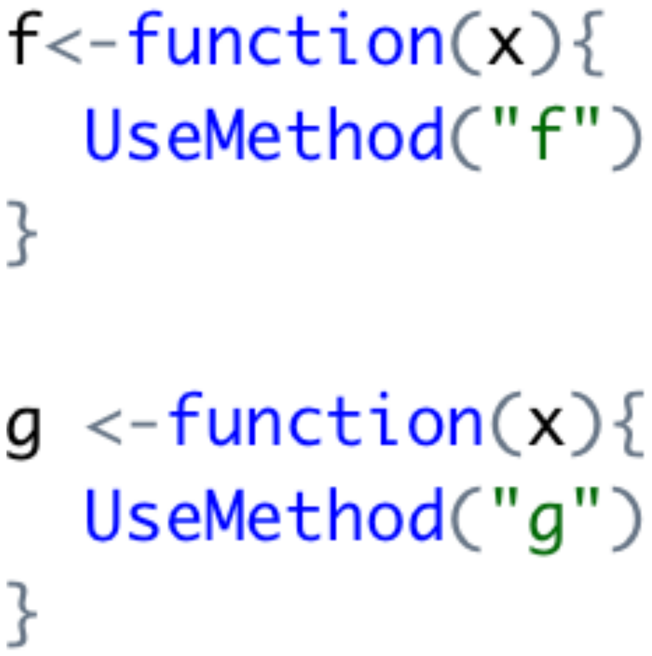


```
> z<-structure(list(),class=c("b","a"))
>
> z
list()
attr(,"class")
[1] "b" "a"
```

Class

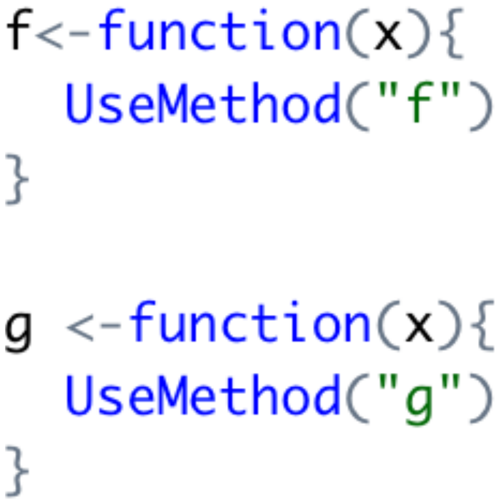
Superclass

S3 Inheritance:
(1) Define two generic functions

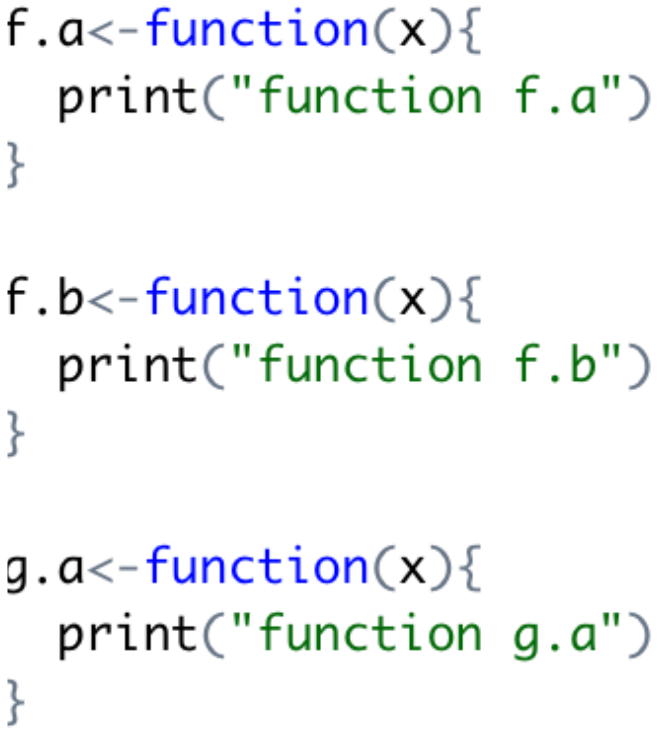


```
f<-function(x){
  UseMethod("f")
}

g <-function(x){
  UseMethod("g")
}
```

S3 Inheritance:
(2) Create methods for class a and b

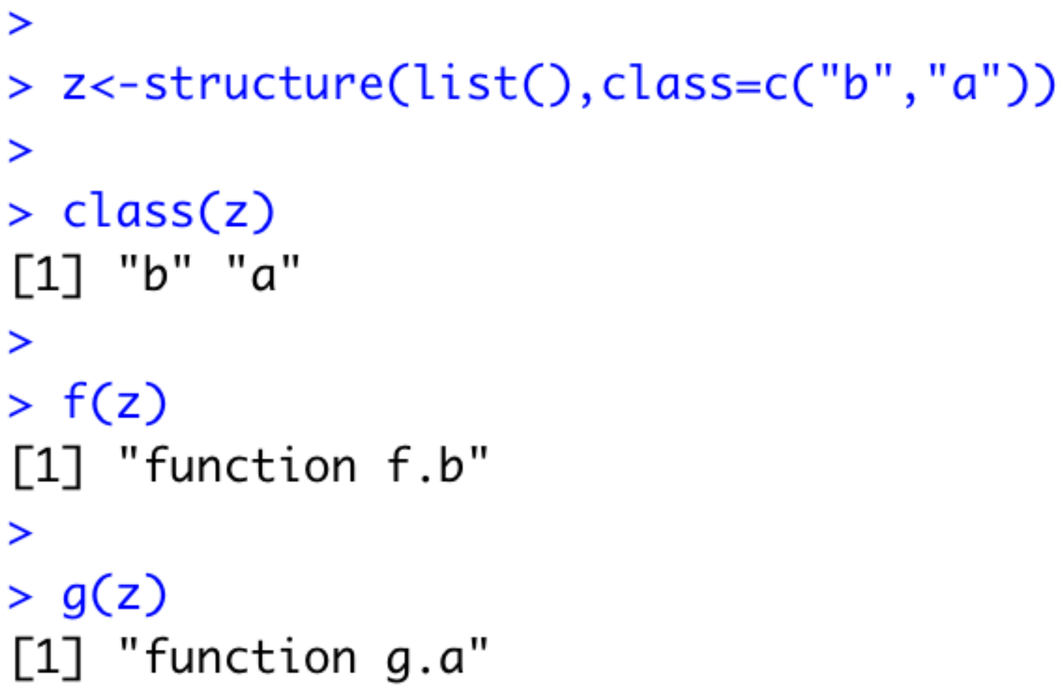


```r
f<-function(x){
  UseMethod("f")
}

g <-function(x){
  UseMethod("g")
}
```

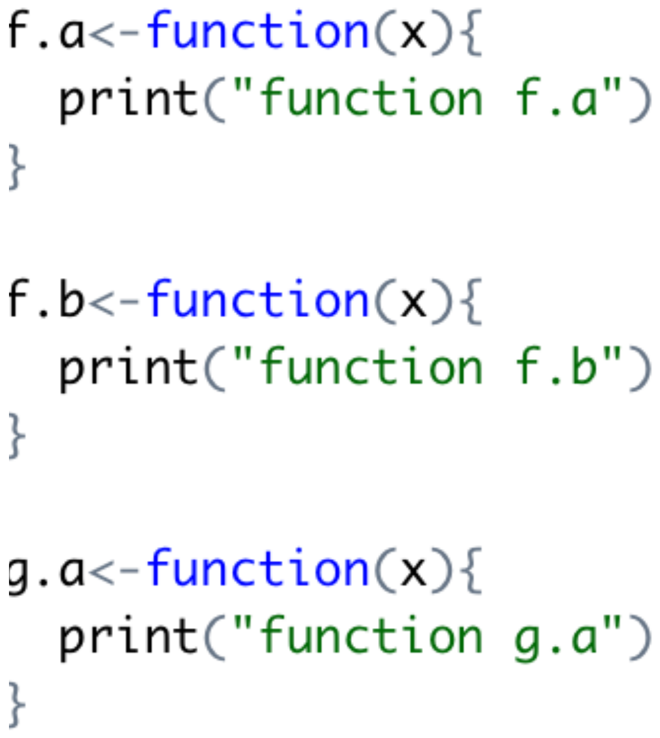


```r
f.a<-function(x){
  print("function f.a")
}

f.b<-function(x){
  print("function f.b")
}

g.a<-function(x){
  print("function g.a")
}
```

S3 Inheritance:
(3) Create object of b, inherit from a



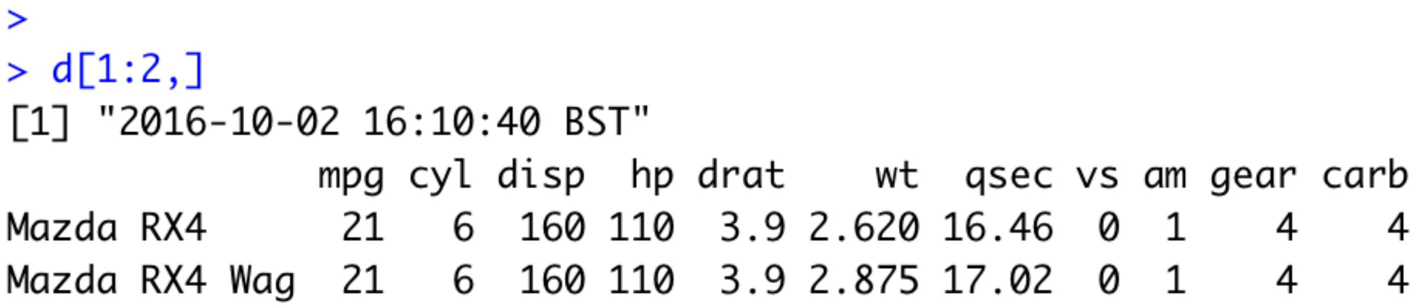
```
>
> z<-structure(list(),class=c("b","a"))
>
> class(z)
[1] "b" "a"
>
> f(z)
[1] "function f.b"
>
> g(z)
[1] "function g.a"
```



```
f.a<-function(x){
  print("function f.a")
}

f.b<-function(x){
  print("function f.b")
}

g.a<-function(x){
  print("function g.a")
}
```

Challenge 9.3

- Write a new class called “df1” which inherits from “data.frame”
- Create a print function for “df1” which displays the current time, before calling the standard print methods for a data.frame class
- Test the results as follows with the mtcars data frame



```
>
> d[1:2,]
[1] "2016-10-02 16:10:40 BST"
              mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4      21   6  160 110  3.9 2.620 16.46  0  1    4    4
Mazda RX4 Wag  21   6  160 110  3.9 2.875 17.02  0  1    4    4
```