

# Statistics 360: Advanced R for Data Science

## Lecture 1

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## Course Objectives

R objects: names and values

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# Course objectives

- ▶ Work through the book Advanced R by Hadley Wickham:  
<https://adv-r.hadley.nz/index.html>
- ▶ R objects: names and values
- ▶ Basic data structures and programming.
  - ▶ vectors, subsetting, control flow, functions, environments
  - ▶ No tidyverse this time
- ▶ Object-oriented programming in R
- ▶ Code performance: debugging, profiling, memory, calling Python, C or ++ from R
- ▶ Parallelizing R code (if time permits)

# Getting started with R, RStudio and git

- ▶ Follow the “getting started” instructions on the class canvas page to get set up with R, RStudio and git.
  - ▶ R and RStudio will be familiar, but you may not have used git before, so leave some time for that.
- ▶ Please try to get R and RStudio installed and create an RStudio project linked to the class GitHub repository as soon as possible.
- ▶ Those still having trouble after the weekend should ask our TA, Pulindu, for help during the first lab session on Jan. 21.

# Reading

- ▶ Welcome, Preface and Chapter 1 of the text.

R objects: names and values

# R objects

- ▶ In R, data structures and functions are all referred to as “objects”.
- ▶ Objects are created with the assignment operator `<-`; e.g.,  
`x <- c(1,2,3)`.
  - ▶ The objects a user creates from the R console are contained in the user's workspace, called the global environment.
  - ▶ Use `ls()` to see a list of all objects in the workspace.
  - ▶ Use `rm(x)` to remove object `x` from the workspace.



# Names and values

- ▶ Reference: text, chapter 2
- ▶ The description on the previous slide of `x <- c(1,2,3)` is an over-simplification.
- ▶ It is more accurate to say we've done two things: (i) created an object in computer memory that contains 1, 2, 3 and (ii) "bound" that object to the "name" `x`.

```
# install.packages("lobstr")  
library(lobstr)  
x <- c(1,2,3)  
ls()
```

```
## [1] "x"
```

```
obj_addr(x) # changes every time this code chunk is run
```

```
## [1] "0x55bf45371a58"
```

## Syntactic vs non-syntactic

- ▶ Valid, or “syntactic” names in R can consist of letters, digits, . and \_ but should start with a letter.
- ▶ Names that start with . are hidden from directory listing with `ls()`.
- ▶ Names that start with \_ or a digit are non-syntactic and will cause an error.
- ▶ If you need to create or access a non-syntactic name, use backward single-quotes (“backticks”).

```
x <- 1  
.x <- 1  
`_x` <- 1  
ls()
```

```
## [1] "_x" "x"
```

# Modifying, copying, binding

- Modifying a variable causes a copy to be made.

```
x <- c(1,2,3); y <- x  
c(obj_addr(x),obj_addr(y))
```

```
## [1] "0x55bf45fd92c8" "0x55bf45fd92c8"
```

```
x[[2]] <- 10 # Note: x[2] <- 10 has the same effect  
c(obj_addr(x),obj_addr(y))
```

```
## [1] "0x55bf44e39328" "0x55bf45fd92c8"
```

```
x
```

```
## [1] 1 10 3
```

```
y
```

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

# Tracing copying

- ▶ The `tracemem()` function marks an object so that a message is printed whenever a copy is made.

```
x <- c(1,2,3)
tracemem(x)
```

```
## [1] "<0x55bf4606f538>"
```

```
x[[2]] <- 10
```

```
## tracemem[0x55bf4606f538 -> 0x55bf45d959f8]: eval eval withVis
```

```
x <- 5 # removes the trace on the object
x[[1]] <- 1
```

## More on tracemem()

- ▶ As the output of `tracemem()` suggests, the trace is on the object, not the name:

```
x <- c(1,2,3)
tracemem(x)
```

```
## [1] "<0x55bf45fd8558>"
```

```
y <- x
c(obj_addr(x),obj_addr(y))
```

```
## [1] "0x55bf45fd8558" "0x55bf45fd8558"
```

```
y[[2]] <- 10
```

```
## tracemem[0x55bf45fd8558 -> 0x55bf45df4528]: eval eval withVis
c(obj_addr(x),obj_addr(y))
```

```
## [1] "0x55bf45fd8558" "0x55bf45df4528"
```

# Function calls

- R has a reputation for passing copies to functions, but in fact the copy-on-modify applies to functions too:

```
f <- function(arg) { return(arg) }  
x <- c(1,2,3)  
y <- f(x) # no copy made  
c(obj_addr(x),obj_addr(y))
```

```
## [1] "0x55bf45d95778" "0x55bf45d95778"
```

```
f <- function(arg) { arg <- 2*arg; return(arg) }  
y <- f(x) # copy made  
c(obj_addr(x),obj_addr(y))
```

```
## [1] "0x55bf45d95778" "0x55bf45ca5b08"
```

# Lists

- List elements point to objects too:

```
l1 <- list(1, 2, 3)
c(obj_addr(l1), obj_addr(l1[[1]]), obj_addr(l1[[2]]), obj_addr(l1[[3]]))

## [1] "0x55bf45f8ea08" "0x55bf45e2b138" "0x55bf45e2b100" "0x55bf45e2b0
# Note: ref() will print the above, formatted, but ...
```

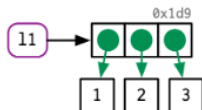


Figure 1: list

- (Note: `ref()` will print a nicely formatted version of the above, but it doesn't work with in my slides.)

## Copy-on-modify in lists

- ▶ As you would expect, we only copy the list **elements** that are modified, rather than the entire list.

- ▶ `tracemem()` flags **any** change to the list

```
l1 <- list(c(1,2), c(3,4), c(5,6,7))
c(obj_addr(l1),obj_addr(l1[[1]]),obj_addr(l1[[2]]),obj_addr(l1[[3]]))

## [1] "0x55bf4522e028" "0x55bf43193168" "0x55bf431931e8" "0x55bf4522e028"
tracemem(l1)

## [1] "<0x55bf4522e028>"
l1[[1]] <- 55

## tracemem[0x55bf4522e028 -> 0x55bf4573a0b8]: eval eval withVisible wi
c(obj_addr(l1),obj_addr(l1[[1]]),obj_addr(l1[[2]]),obj_addr(l1[[3]]))

## [1] "0x55bf4573a0b8" "0x55bf44a27a88" "0x55bf431931e8" "0x55bf4522e028"
```



## Copies of lists are “shallow”

```
l2 <- l1  
l2[[3]] <- 111
```

```
## tracemem[0x55bf4573a0b8 -> 0x55bf45316738]: eval eval withVisible wi  
c(obj_addr(l1),obj_addr(l1[[1]]),obj_addr(l1[[2]]),obj_addr(l1[[3]]))
```

```
## [1] "0x55bf4573a0b8" "0x55bf44a27a88" "0x55bf431931e8" "0x55bf4522e0  
c(obj_addr(l2),obj_addr(l2[[1]]),obj_addr(l2[[2]]),obj_addr(l2[[3]]))
```

```
## [1] "0x55bf45316738" "0x55bf44a27a88" "0x55bf431931e8" "0x55bf4621aa
```

## Data frames are lists ...

```
dd <- data.frame(x=1:3,y=4:6)
c(obj_addr(dd[[1]]),obj_addr(dd[[2]]))
```

```
## [1] "0x55bf433f6c28" "0x55bf433f6d08"
```

```
dd[,2] <- 7:9
c(obj_addr(dd[[1]]),obj_addr(dd[[2]]))
```

```
## [1] "0x55bf433f6c28" "0x55bf43b07a90"
```

```
dd[1,] <- c(11,22)
c(obj_addr(dd[[1]]),obj_addr(dd[[2]]))
```

```
## [1] "0x55bf4606f628" "0x55bf4606f5d8"
```

```
dd[1,2] <- 111
c(obj_addr(dd[[1]]),obj_addr(dd[[2]]))
```

```
## [1] "0x55bf4606f628" "0x55bf45d95548"
```

# Beware of data frame overhead

- ▶ Data frames are convenient, but the convenience comes at a cost.

- ▶ Can illustrate by tracing copying when we modify columns.

```
dd <- data.frame(x=rnorm(100)) # try yourself with rnorm(1e7)
tracemem(dd)
```

```
## [1] "<0x55bf4624c3f8>"
```

```
dmed <- lapply(dd,median)
```

```
## tracemem[0x55bf4624c3f8 -> 0x55bf44b51388]: as.list.data.frame as.li
```

```
dd[[1]] <- dd[[1]] - dmed[[1]] # same as dd[,1] - dmed[[1]]
```

```
## tracemem[0x55bf4624c3f8 -> 0x55bf45f99f10]: eval eval withVisible wi
```

```
## tracemem[0x55bf45f99f10 -> 0x55bf45f98b60]: [[<-data.frame [[<- eva
```

- Fewer copies if we do the same with a list.

```
l1 <- list(x=rnorm(100))  
tracemem(l1)
```

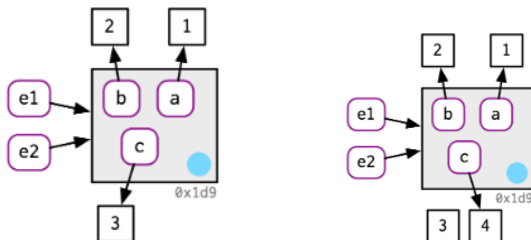
```
## [1] "<0x55bf452a7a28>"
```

```
lmed <- lapply(l1,median)  
l1[[1]] <- l1[[1]] - dmed[[1]]
```

```
## tracemem[0x55bf452a7a28 -> 0x55bf45da6a48]: eval eval withVisible wi
```

# Modify-in-place

- The text claims two exceptions to the copy-on-modify, but in my experiments environments are the only one:



```
e1 <- rlang::env(a = 1, b = 2, c = 3)
e2 <- e1
e1$c <- 4
e2$c
```

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