



WRITING EFFICIENT R CODE

General principle: Memory allocation

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If we programmed in C...

WE'RE IN CHARGE OF MEMORY ALLOCATION

```
// C code: request memory for a number  
x = (double *) malloc(sizeof(double));  
  
// Free the memory  
free(x);
```

- In R, memory allocation happens automatically
- R allocates memory in RAM to store variables
- Minimize variable assignment for speed

Example: Sequence of integers

$1, 2, \dots, n$

THE OBVIOUS AND BEST WAY

```
## Method 1  
x <- 1:n
```

NOT SO BAD

```
## Method 2  
x <- vector("numeric", n) # length n  
for(i in 1:n)  
  x[i] <- i
```

DON'T EVER DO THIS!

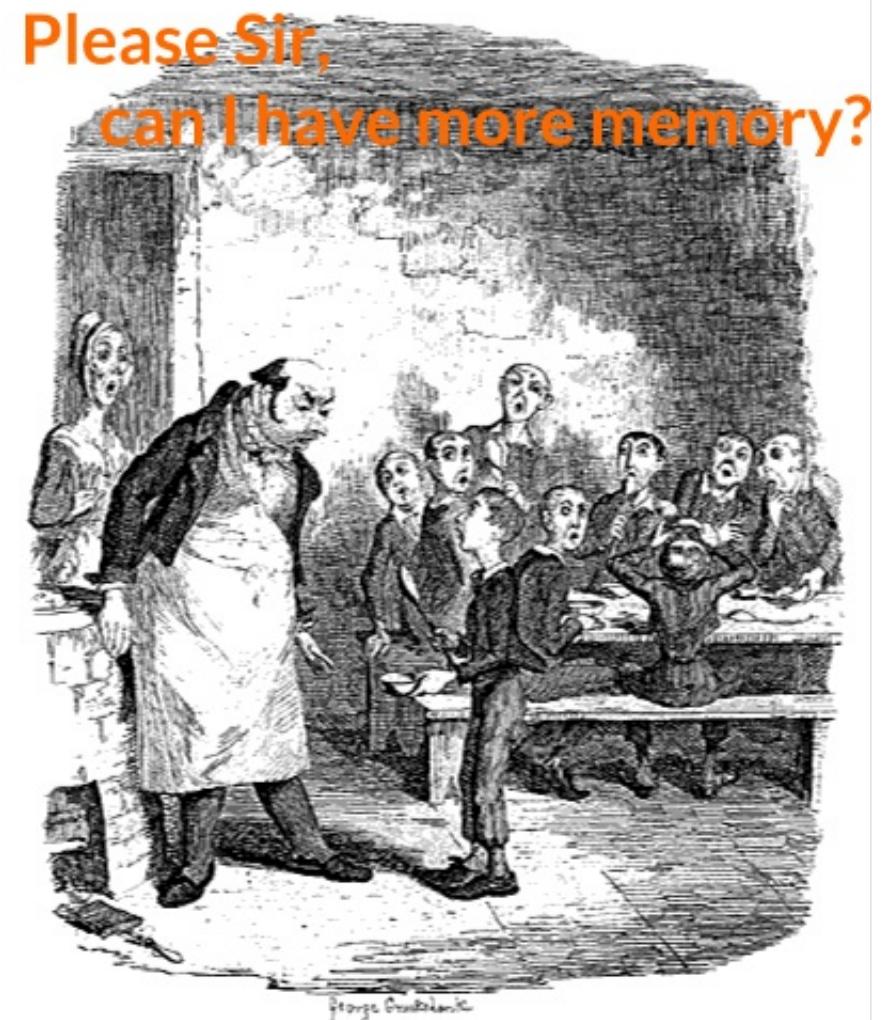
```
## Method 3  
x <- NULL # Length zero  
for(i in 1:n)  
  x <- c(x, i)
```

Benchmarking

- Method 1: `1:n`
- Method 2: Preallocate
- Method 3: Growing

TIME IN SECONDS

n	1	2	3
10^5	0.00	0.02	0.2
10^6	0.00	0.2	30
10^7	0.00	2	3800



Welcome to R club!

The first rule of R club: never, ever grow a vector



WRITING EFFICIENT R CODE

Let's practice!



WRITING EFFICIENT R CODE

The importance of vectorizing your code

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General rule

- Calling an R function eventually leads to C or FORTRAN code
- This code is *very* heavily optimised

Goal

- Access the underlying C or FORTRAN code as quickly as possible; the fewer functions call the better.

Vectorised functions

- Many R functions are vectorised
- Single number but return a vector

```
rnorm(4)
# -0.7247  0.2502  0.3510  0.6919
```

- Vector as input

```
mean(c(36, 48))
# 42
```

Generating random numbers

```
library(microbenchmark)
n <- 1e6
x <- vector("numeric", n)
microbenchmark(
  x <- rnorm(n),
  {
    for(i in seq_along(x))
      x[i] <- rnorm(1)
  },
  times = 10
)
# Unit: milliseconds
# expr      lq  mean    uq  cld
# rnorm(n)  60   70   80   a
# Looping  2600 2700 2800   b
## Output trimmed for presentation
```

Compare

```
x <- vector("numeric", n)
for(i in seq_along(x))
  x[i] <- rnorm(1)
```

to

```
x <- rnorm(n)
```

Why is the loop slow?

LOOPING

```
n <- 1e6  
x <- vector("numeric", n)  
for(i in seq_along(x))  
  x[i] <- rnorm(1)
```

ALLOCATION

```
x <- vector("numeric", n)
```

- *Loop*: One-off cost
- *Vectorized*: Comparable

GENERATION

- *Loop*: one million calls to `rnorm()`
- *Vectorized*: a single call to `rnorm()`

ASSIGNMENT

- *Loop*: One million calls to the assignment method
- *Vectorized*: a single assignment

R club

This is the second rule of R club: use a vectorised solution wherever possible.



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Let's practice!



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Data frames and matrices

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The data frame

- Key data structure in R
- Copied in other languages
 - Python: pandas data frame
 - If you can't beat them, join them!

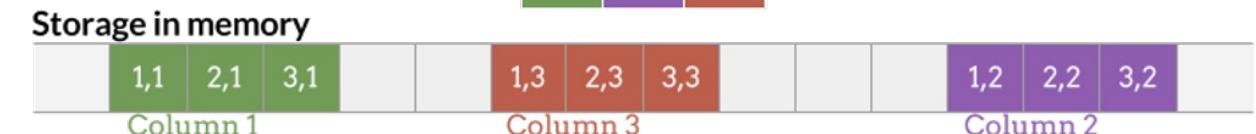
Data frames

- Tabular structure: rows and columns

- `read.csv()` and friends returns a data frame

STORAGE

Data frame		
1,1	1,2	1,3
2,1	2,2	2,3
3,1	3,2	3,3



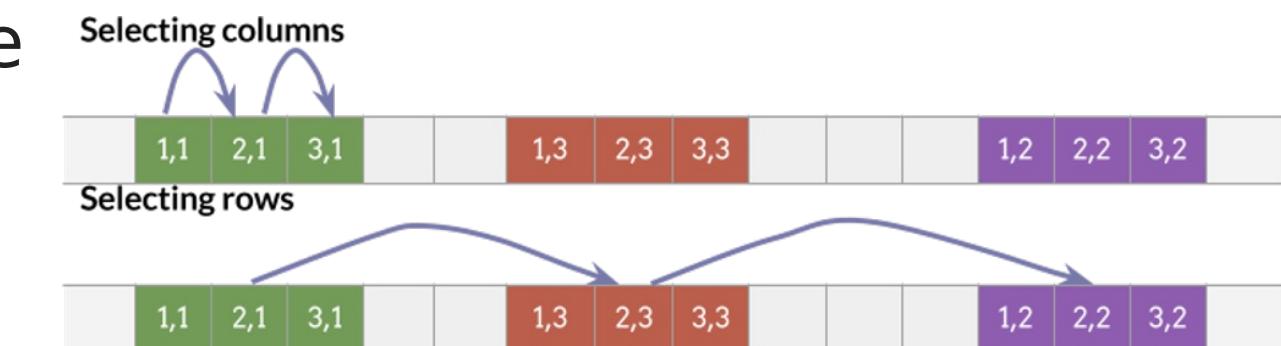
- Columns

- Data must be the same type

- Rows

- Different type

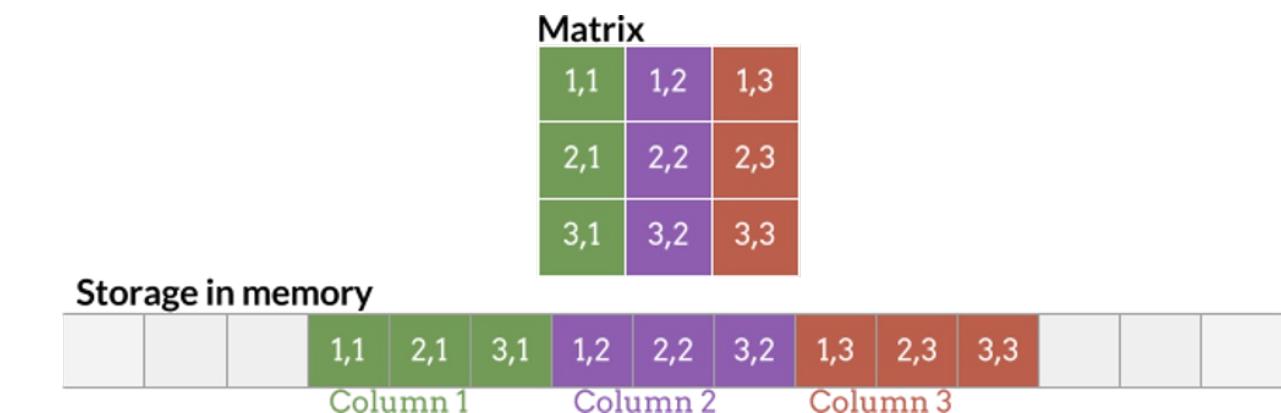
SELECTION



Matrices

- It's a rectangular data structure
- You can perform usual subsetting and extracting operations
- BUT - every element must be the same data type

STORAGE



SELECTION



R club

The third rule of R club. Use a matrix whenever appropriate.



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Let's practice!