


loops and functions in

Berry Boessenkool, berry-b@gmx.de
Jannes Breier, jbreier@gfz-potsdam.de

<https://bit.ly/37AYX1D>

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github.com/brry/course

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R installation instructions: github.com/brry/course#install

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Outline

For loops

Functions

Debugging

```
print("Hello world!")
```

- Berry Boessenkool → Geoecology @ Potsdam University

```
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- Berry Boessenkool → Geoecology @ Potsdam University
- R Fan

```
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- Berry Boessenkool → Geoecology @ Potsdam University
- R Fanatic


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- Berry taught me R in 2013 😊

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-  Research Software Engineer at GFZ,  Sec.4.4: Hydrology
- If we're proceeding too fast, please interrupt!

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For loops

Execute a block of code several times, with different input values.

Syntax: `for(aRunningVariable in aSequence){ doSomething }`

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help("for") # needs quotation marks!
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print(1:2)
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```
print(1:5)
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```
print(1:9)
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This is easier and less prone to human errors with:

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```
help("for") # needs quotation marks!
```

```
print(1:2)
print(1:5)
print(1:9)
```

This is easier and less prone to human errors with:

```
for(i in c(2,5,9) ) { print(1:i) }
```

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

For loops: fill a vector

```
v <- vector(mode="numeric", length=20)
```

```
v
```

```
## [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

For loops: fill a vector

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```
v
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```
## [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```
for(i in 3:17) { v[i] <- (i+2)^2 }
```

For loops: fill a vector

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v
```

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```

```
for(i in 3:17) { v[i] <- (i+2)^2 }
```

```
v # this code was executed once for each i
```

```
## [1] 0 0 25 36 49 64 81 100 121
```

```
## [10] 144 169 196 225 256 289 324 361 0
```

```
## [19] 0 0
```

For loops: fill a vector

```
v <- vector(mode="numeric", length=20)
```

```
v
```

```
## [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

```
for(i in 3:17) { v[i] <- (i+2)^2 }
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```
## [1] 0 0 25 36 49 64 81 100 121
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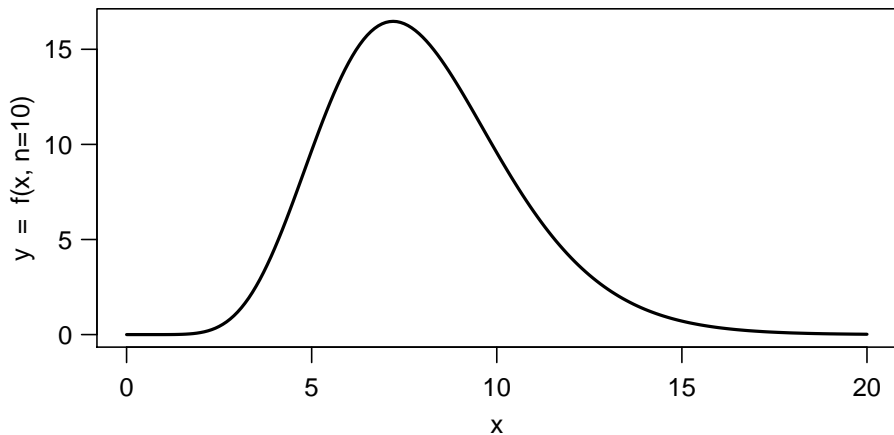
```
## [10] 144 169 196 225 256 289 324 361 0
```

```
## [19] 0 0
```

In R, `for` loops are slow. Always try to vectorize (the best option, not always possible) or use `lapply` (saves you the initiation of the empty vector, easier to parallelize).

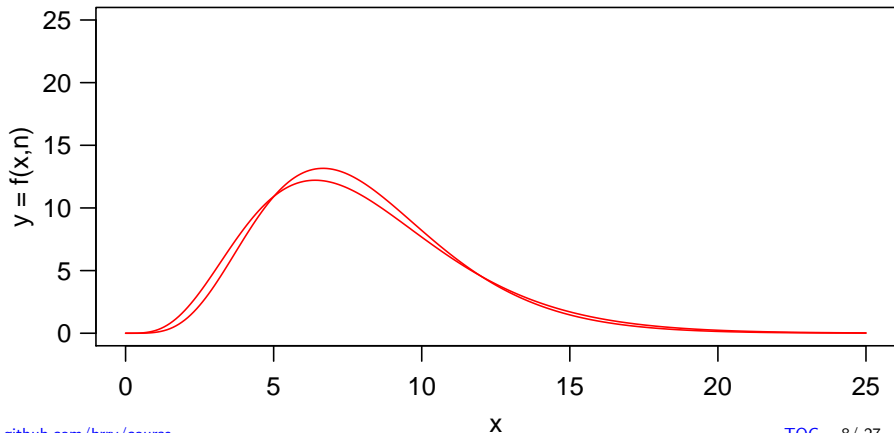
For loops: execute code multiple times I

$$y = f(x, n) = \frac{12.5 * n}{(n-1)!} * \left(\frac{nx}{8}\right)^{(n-1)} * e^{-\frac{nx}{8}}$$



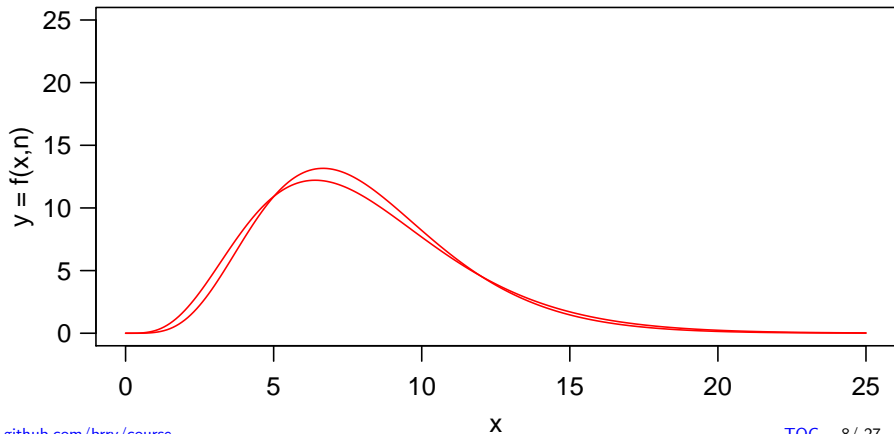
For loops: execute code multiple times II

```
x <- seq(0,25,0.1)
plot(x,x, type="n", ylab="y = f(x,n)")
lines(x, 12.5*5/factorial(5-1)*(x/8*5)^(5-1)*exp(-x/8*5), col=2)
lines(x, 12.5*6/factorial(6-1)*(x/8*6)^(6-1)*exp(-x/8*6), col=2)
```



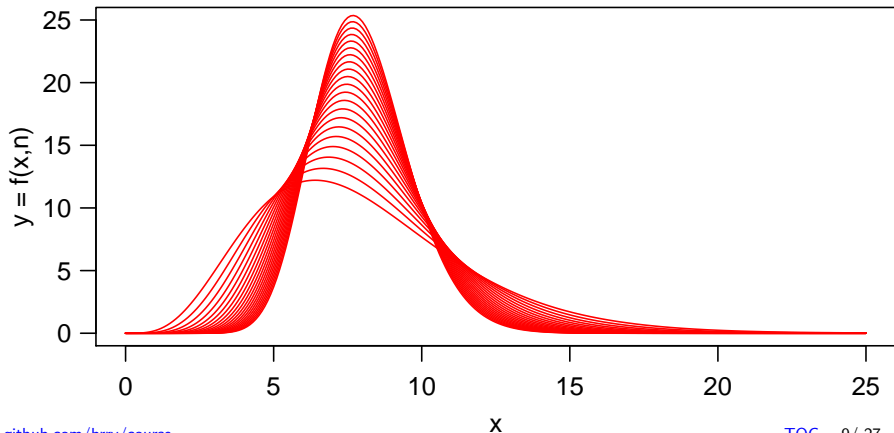
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lines(x, 12.5*5/factorial(5-1)*(x/8*5)^(5-1)*exp(-x/8*5), col=2)
lines(x, 12.5*6/factorial(6-1)*(x/8*6)^(6-1)*exp(-x/8*6), col=2)
```



For loops: execute code multiple times III

```
x <- seq(0,25,0.1)
plot(x,x, type="n", ylab="y = f(x,n)")
for (n in 5:25)
  lines(x, 12.5*n/factorial(n-1)*(x/8*n)^(n-1)*exp(-x/8*n), col=2)
```



For loops exercise

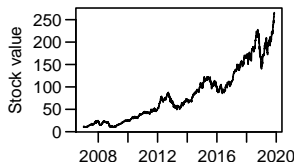
Exercise 1: for loop

- 1 Read `stocks.txt` (rightclick **Raw**, save as), so that there are no factors in the data.frame. Use the command `read.table` and set the arguments `file`, `header` and `stringsAsFactors`
- 2 Change the first column type from `char` to `date` with `as.Date(yourDF$Date)`
- 3 What do you get with `plot(yourDF[,c(1,2)])`? Make it a line graph by setting the argument `type`.
- 4 With a `for` loop, plot each stock time series, i.e. plot the i th column over the first column.
- 5 BONUS 1: Use good annotations (`main`, `ylab`, `xlab`)
- 6 BONUS 2: Turn y axis labels upright (`las`)
- 7 BONUS 3: With `par(mfrow=...)`, set up a two by three panel plot

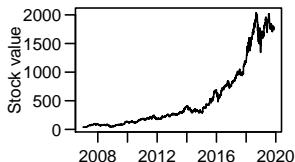
For loops exercise solution

```
stocks <- read.table("data/stocks.txt", header=T, stringsAsFactors=FALSE)
stocks$Date <- as.Date(stocks$Date)
for(i in 2:7) plot(stocks[, c(1,i)], type="l", main=colnames(stocks)[i],
  ylab="Stock value", las=1)
```

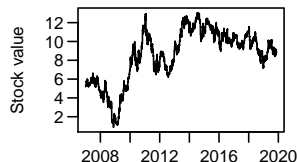
APPLE



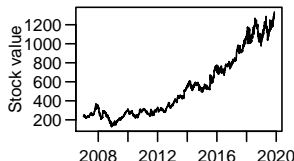
AMAZON



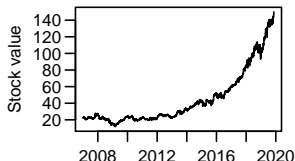
FORD



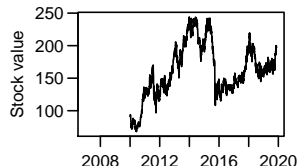
GOOGLE



MICROSOFT



VOLKSWAGEN



for -> lapply

lapply: apply a function to elements of a list (or vector)

list: R object containing other objects

for -> lapply

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```
files <- dir("../rawdata", pattern="*.csv", full=TRUE)
```

for -> lapply

lapply: apply a function to elements of a list (or vector)

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files <- dir("../rawdata", pattern="*.csv", full=TRUE)
```

bad and slow way:

```
ldfs <- list() # initiate empty list
```

```
for(i in 1:length(files))
```

```
  ldfs[[i]] <- read.csv(files[i], as.is=TRUE)
```


for -> lapply

lapply: apply a function to elements of a list (or vector)

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files <- dir("../rawdata", pattern="*.csv", full=TRUE)
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```
  ldfs[[i]] <- read.csv(files[i], as.is=TRUE)
```

much better way: apply function to each file

```
ldfs <- lapply(X=files, FUN=read.csv, as.is=TRUE)
```

for -> lapply

lapply: apply a function to elements of a list (or vector)

list: R object containing other objects

```
files <- dir("../rawdata", pattern="*.csv", full=TRUE)
```

bad and slow way:

```
ldfs <- list() # initiate empty list
```

```
for(i in 1:length(files))
```

```
  ldfs[[i]] <- read.csv(files[i], as.is=TRUE)
```

much better way: apply function to each file

```
ldfs <- lapply(X=files, FUN=read.csv, as.is=TRUE)
```

progress bar with remaining time (+ parallelized!)

```
library("pbapply")
```

```
ldfs <- pblapply(X=files, FUN=read.csv, as.is=TRUE)
```

```
ldfs <- pblapply(X=files, FUN=read.csv, as.is=TRUE, cl=8)
```

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Functions I

<http://r4ds.had.co.nz/functions.html>

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?"function"

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Syntax:

```
Functionobjectname <- function(argument1, argument2, ...)
  {"DoSomething"}
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? "function"

Syntax:

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Functionobjectname <- function(argument1, argument2, ...)
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```
myfunct <- function(grappig)
  {plot(grappig, type="l"); return(grappig*7) }
```

Functions I

<http://r4ds.had.co.nz/functions.html>

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Syntax:

```
Functionobjectname <- function(argument1, argument2, ...)
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```

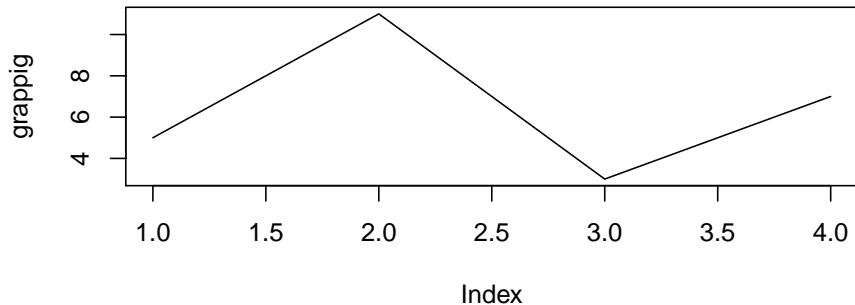
```
myfunct <- function(grappig)
  {plot(grappig, type="l"); return(grappig*7) }
```

After `return()`ing, the execution of the function is terminated, so it should only be positioned at the end. It can also be left away, the last instruction ("expression") will then be returned.

Functions II

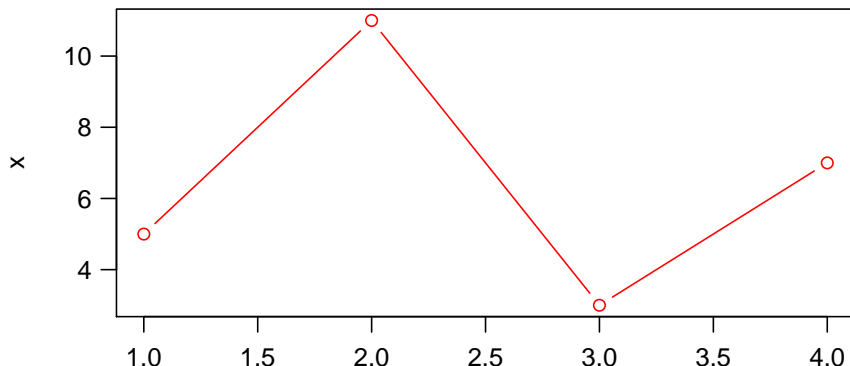
```
myfunct( c(5,11,3,7) )
```

```
## [1] 35 77 21 49
```



Functions with more arguments + default values

```
myfunct <- function(x, type="b", ...) plot(x, type=type, ...)
# type="b" is now the default, thus used unless specified
# The ellipsis (...) passes arguments to other functions
myfunct( c(5,11,3,7) , col="red", las=1)
```



Conditional execution

Syntax: `if(this_is_true) {do_something}`

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`if(this_is_true) {do_something} else {do_other_thing}`

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```
7-3 > 2
```

```
class(7-3 > 2 )
```

```
if(7-3 > 2) 18
```

```
if(7-3 > 5) 18
```

```
if(7-3 > 5) 18 else 17
```

Conditional execution

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`7-3 > 2`

TRUE

`class(7-3 > 2)`

`if(7-3 > 2) 18`

`if(7-3 > 5) 18`

`if(7-3 > 5) 18 else 17`

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logical = truth value, boolean

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Condition is TRUE, so 18 is returned

`if(7-3 > 5) 18`

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`if(7-3 > 5) 18`

Condition is FALSE, so nothing happens

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Condition is TRUE, so 18 is returned

`if(7-3 > 5) 18`

Condition is FALSE, so nothing happens

`if(7-3 > 5) 18 else 17`

Condition FALSE, so 17 is returned.

```
if(length(input)>1)
```

```
  stop("length must be 1, not ", length(input))
```

Conditional execution

Syntax: `if(this_is_true) {do_something}`

`if(this_is_true) {do_something} else {do_other_thing}`

If condition == TRUE, then expression1 is evaluated,
if condition == FALSE, then expression2 is evaluated.

<code>7-3 > 2</code>	TRUE
<code>class(7-3 > 2)</code>	logical = truth value, boolean
<code>if(7-3 > 2) 18</code>	Condition is TRUE, so 18 is returned
<code>if(7-3 > 5) 18</code>	Condition is FALSE, so nothing happens
<code>if(7-3 > 5) 18 else 17</code>	Condition FALSE, so 17 is returned.

```
if(length(input)>1)
  stop("length must be 1, not ", length(input))
```

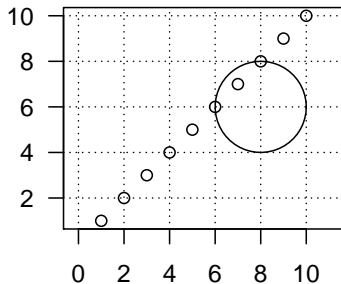
`stop`: Interrupts function execution and gives error

`warning`: continues but gives warning

`message`: to inform instead of worry the user

Exercise: add circles with given radius

```
plot(1:10, asp=1) # aspect ratio y/x of graph range
grid(col=1)
# the next part should go into a function:
x <- 8 ; y <- 6 ; r <- 2
p <- seq(0, 2*pi, len=50)
cx <- x+r*cos(p) ; cy <- y+r*sin(p)
polygon(cx, cy)
```



Time to practice programming

Exercise 2: Writing functions

Write a function that

- 1 - draws a circle with a certain radius at user-specified locations of an existing plot (see last slide).
- 2 - uses ellipsis (...) to allow the user to customize the appearance
- 3 - checks all the arguments and gives useful warnings if the wrong type of input is provided
- 4 - has useful explanations for each argument (documentation)
- 5 - has readable indentation, spacing and comments explaining the code
- 6 Now let your neighbor use it without explaining how it is to be used (this should be inferred from the code and comments!)
- 7 Use your neighbor's function with a vector to draw several circles at once. (unintended use?) What happens?
- 8 BONUS: Learn writing packages at [packdev.R](https://packdev.r-lib.org/) (rightclick **Raw**, save as)

```
# Small helper function drawing circles into existing graphics
circle <- function(
  x, # x-coordinate of points, numeric value of length 1
  y, # ditto for y
  r, # radius of the circle, in the graphic's units
  locnum=100, # number of points on circle (more means smoother but slower)
  ...) # Further Arguments passed to polygon, like col, border, lwd
{
  #
```



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  locnum=100, # number of points on circle (more means smoother but slower)
  ...) # Further Arguments passed to polygon, like col, border, lwd
{

# input checking - only one circle can be drawn:
if(length(x) >1 | length(y) >1 | length(r) >1 | length(locnum) >1)
{
  warning("Only the first element of the vectors is used.")
  x <- x[1]; y <- y[1]; r <- r[1]; locnum <- locnum[1]
}

#

```

```

# Small helper function drawing circles into existing graphics
circle <- function(
  x, # x-coordinate of points, numeric value of length 1
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{
  warning("Only the first element of the vectors is used.")
  x <- x[1]; y <- y[1]; r <- r[1]; locnum <- locnum[1]
}

if(!is.numeric(x)) stop("x must be numeric, not ", class(x))
if(!is.numeric(y)) stop("y must be numeric, not ", class(y))
if(!is.numeric(r)) stop("r must be numeric, not ", class(r))

#

```

```

# Small helper function drawing circles into existing graphics
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  if(length(x) >1 | length(y) >1 | length(r) >1 | length(locnum) >1)
  {
    warning("Only the first element of the vectors is used.")
    x <- x[1]; y <- y[1]; r <- r[1]; locnum <- locnum[1]
  }

  if(!is.numeric(x)) stop("x must be numeric, not ", class(x))
  if(!is.numeric(y)) stop("y must be numeric, not ", class(y))
  if(!is.numeric(r)) stop("r must be numeric, not ", class(r))

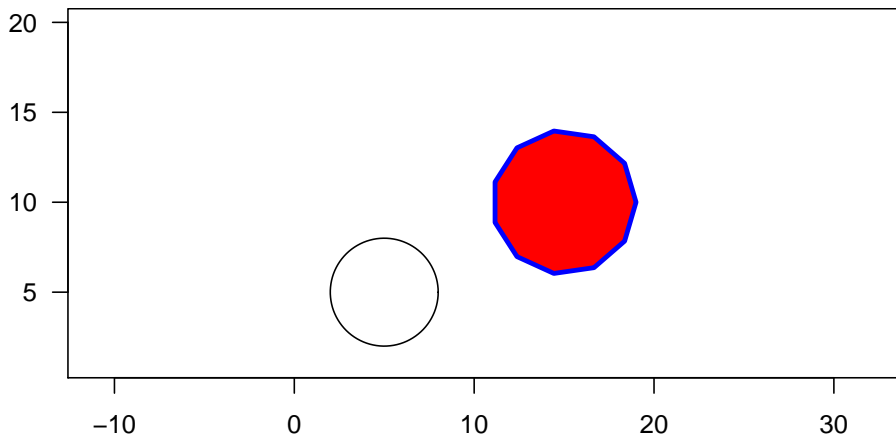
  # prepare circle line coordinates:
  cx <- x+r*cos( seq(0,2*pi,len=locnum) )
  cy <- y+r*sin( seq(0,2*pi,len=locnum) )
  polygon(cx, cy, ...) # actually draw it
}

# Note: if circles look like ellipsis, use plot(... asp=1)

```

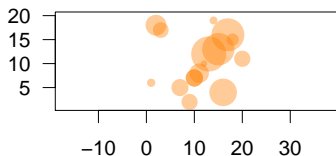
Solution for exercise 2 II: functions

```
plot(1:20, type="n", asp=1, cex=2)  
circle(5,5, r=3)  
circle(15,10, r=4, locnum=12, col=2, border=4, lwd=3)
```



Solution for exercise 2 III: functions

```
# can not be vectorized:  
x <- sample(1:20, 15) ; y <- sample(1:20, 15) ; r <- runif(20)*4  
circle(x,y,r, col=rgb(1,0.5,0,alpha=0.4), border=NA)  
  
## Warning in circle(x, y, r, col = rgb(1, 0.5, 0, alpha = 0.4), border = NA):  
Only the first element of the vectors is used.  
  
for(i in 1:15) circle(x[i],y[i],r[i], col=rgb(1,0.5,0,alpha=0.4), border=NA)
```



Outline

For loops

Functions

Debugging

Debugging

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- You want to step into the function you are developing at a specific point. You add `browser()` at that point of the code.

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R. Peng (2002): Interactive Debugging Tools in R

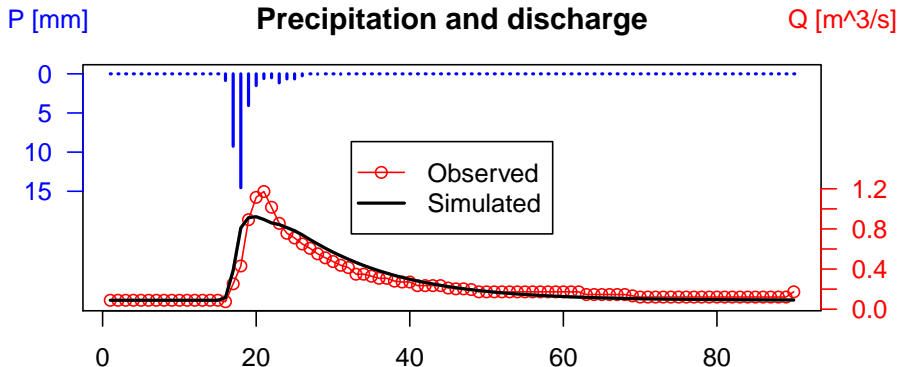
D. Murdoch (2010): Debugging in R

H. Wickham (2015): Advanced R: debugging

Example: Pete Werner Blog Post (2013)

Exercise 3: Debugging

- 1 Load your package and the datasets. Correct the functions until `lsc(calib$P, calib$Q, area=1.6)` returns the result below.
- 2 BONUS: commit each change to git.



Solution for exercise 3: Debugging

- `stupid error you can easily remove` - traceback - find location of error - `lsc#73` - just comment it out
- `harder to find but still stupid` - traceback - `nse#11` - ditto
- `Error in plot: need finite 'ylim' value` - `browser/options(error=recover)` - `lsc#105` - NAs in `Q` - `range(Q, na.rm=TRUE)` - also in other applicable locations
- `There were 50 or more warnings` - come from `rmse` being called in optimization - add argument `quietNA` (or similar) to `lsc` that is passed to `rmse` in `lsc#79`