9. Environments and Functions

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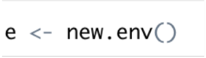
Overview

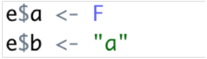
- Environments
- Function Environments
- Closures

Environment Basics

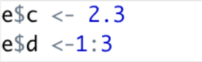
- The job of an environment is to associate a set of names to a set of values (a bag of names) (Wickham 2015)
- Each name points to an object stored elsewhere in memory



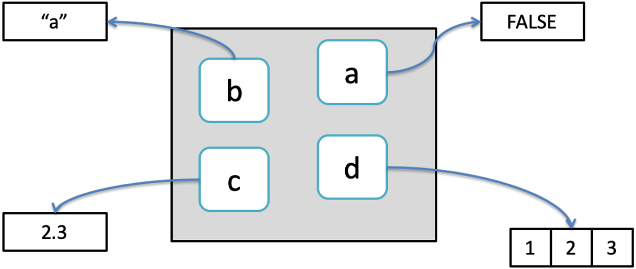
```
e <- new.env()
```

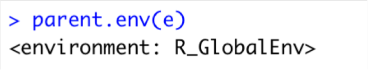


```
e$a <- F
e$b <- "a"
```



```
e$c <- 2.3
e$d <-1:3
```





```
> parent.env(e)
<environment: R_GlobalEnv>
```

Useful Definition

- Environments can be thought of as consisting of two things: a frame, which is a set of symbol-value pairs, and an enclosure, a pointer to an enclosing environment.
- When R looks up the value for a symbol the frame is examined and if a matching symbol is found its value will be returned.
- If not, the enclosing environment is then accessed and the process repeated.
- Environments form a tree structure in which the enclosures play the role of parents. The tree of environments is rooted in an empty environment, available through emptyenv(), which has no parent.

Properties of an environment

Generally, an environment is similar to a list, with four exceptions:

- Every object in an environment has a unique name
- The objects in an environment are not ordered
- An environment has a parent
- Environments have reference semantics: When you modify a binding in an environment, the environment is not copied; it's modified in place

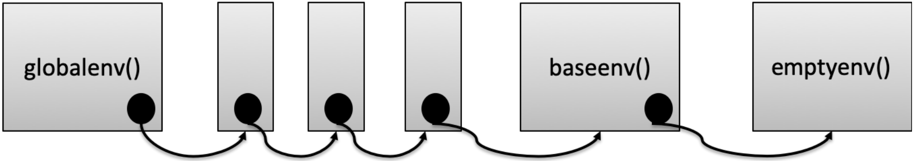
There are 4 Special Environments

- **globalenv()** is the interactive workspace. The parent of this is the last package attached with library() or require()
- **baseenv()** is the environment of the base package
- **emptyenv()** is the ultimate ancestor of all environments, and the only one without a parent
- **environment()** is the current environment

```
environment()
```

```
## <environment: R_GlobalEnv>
```

The Search Path



```
search()
```

```
## [1] ".GlobalEnv"        "package:stats"     "package:graphi
## [4] "package:grDevices" "package:utils"     "package:datase
## [7] "package:methods"   "Autoloads"         "package:base"
```

Searching Environments

```r
library(pryr)
```

```
## Registered S3 method overwritten by 'pryr':
##   method      from
##   print.bytes Rcpp
```

```r
where("mean")
```

```
## <environment: base>
```

```r
where("faithful")
```

```
## <environment: package:datasets>
## attr(,"name")
## [1] "package:datasets"
## attr(,"path")
## [1] "/Library/Frameworks/R.framework/Versions/3.6/Resources
```

Accessing data in other environments

- Code that exists at a certain level of the environment has at least read access to all the variables the level above it
- However, direct write access to variables at higher levels via the standard <- operator is not possible

```
y <- 100
f <- function()y<-200
f()
y
```

```
## [1] 100
```

Double arrow assignment operator

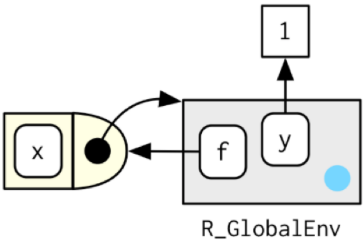
- The operator will search up the environment hierarchy, stopping at the first level the name is encountered
- If no name is found, the variable is assigned at the global level

```r
y <- 100
f <- function()y<<-200
f()
y
```

```
## [1] 200
```

Function Environments

- A function binds the current environment when it is created.
- In diagrams, functions are depicted as rectangles with a rounded end that binds an environment



```
y <- 1
f <- function(x)x+y
```

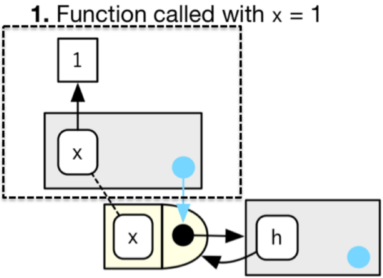
Execution Environments

- Each time a function is called, a new environment is created to host execution
- The parent of the execution environment is the enclosing environment of the function
- Once the function is completed, this execution environment is discarded

```r
h <- function(x){
  a <- 2
  x + a
}
y <- h(1)
```

Step 1

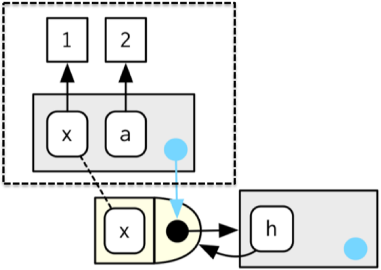
```
h <- function(x){
  a <- 2
  x + a
}
y <- h(1)
```



Step 2

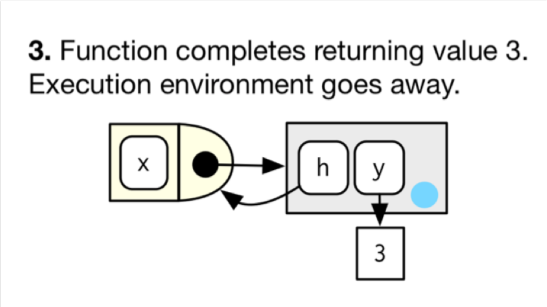
```
h <- function(x){
  a <- 2
  x + a
}
y <- h(1)
```

2. a bound to value 2



Step 3

```r
h <- function(x){
  a <- 2
  x + a
}
y <- h(1)
```



3. Function completes returning value 3. Execution environment goes away.

Function Factories

- A function factory is a function that makes functions
- The enclosing environment of the child function is the execution environment of the parent
- Therefore, the execution environment is no longer *ephemeral*

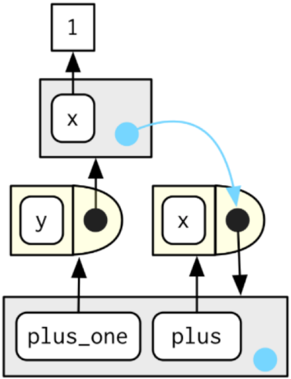
```
plus <- function(x){
  print(environment())
  function(y)x+y
}
plus_one <- plus(1)
```

```
## <environment: 0x7fb59848fb20>
```

```
rlang::fn_env(plus_one)
```

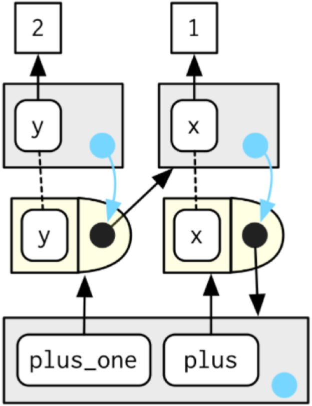
```
## <environment: 0x7fb59848fb20>
```

Visualising the "manufactured" function



```
plus <- function(x){
  function(y)x+y
}
plus_one <- plus(1)
```

Calling plus_one(2)



```
plus_one(2)
```

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

Exploring the enclosing environment of a manufactured function

```r
plus <- function(x){
  function(y)x+y
}
plus_one <- plus(1)

ls(env=rlang::fn_env(plus_one))
```

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

```r
rlang::fn_env(plus_one)$x
```

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

Doing some interesting things...

```r
my_power <- function(exp){
  function(x)x^exp
}
f1 <- my_power(2)
f1(2)
```

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

```r
rlang::fn_env(f1)$exp <- 3
f1(2)
```

```
## [1] 8
```

Closures

- "An object is data with functions. A closure is a function with data." John D. Cook.
- Anonymous functions can be used to create closures, functions written by functions
- Closures can also be created by returning a list of functions from a function
- Closures get their name because the enclose the environment of the parent function and can then access all its variables
- Along with the double assignment arrow operator, it can provide mutable state

Mutable State Example

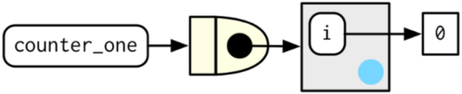
```
new_counter <- function(){
  i <- 0
  function(){
    i <<- i+1
    i
  }
}
counter_one <- new_counter()
counter_one()
```

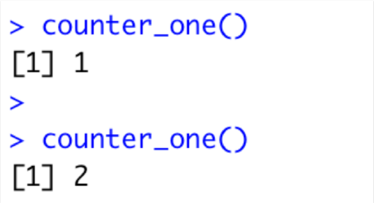
```
## [1] 1
```

```
counter_one()
```

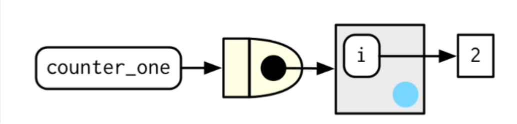
```
## [1] 2
```

Visualising the process





```
> counter_one()
[1] 1
>
> counter_one()
[1] 2
```



Multiple functions as part of a closure using list()

```r
counter <- function(init){
  i <- init
  list(increment=function(v=1)i<<-i+v,
       decrement=function(v=1)i<<-i-v,
       show=function()i)
}
c1 <- counter(10)
c1$increment()
c1$show()
```

```
## [1] 11
```

```r
c1$decrement(11)
c1$show()
```

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

Summary

- Role of environments in R
- For a function
  - The enclosing environment
  - The execution environment
- Function factories and mutable state