

Iteration with



Open **06-Iteration.Rmd**

Partial output of fitting the linear model

```
lm(price ~ carat + cut + color + clarity, data = diamonds)
```

```
$rank
```

```
[1] 19
```

```
$assign
```

```
[1] 0 1 2 2 2 2 3 3 3 3 3 3 4 4 4 4 4 4 4
```

```
$contrasts
```

```
$contrasts$cut
```

```
[1] "contr.poly"
```

```
$contrasts$color
```

```
[1] "contr.poly"
```

```
$contrasts$clarity
```

```
[1] "contr.poly"
```

```
$call
```

```
lm(formula = price ~ carat + cut + color + clarity, data = diamonds)
```




```
$rank
```

```
[1] 19
```

```
$assign
```

```
[1] 0 1 2 2 2 2 3 3 3 3 3 3 4 4 4 4 4 4
```

```
$contrasts
```

```
$contrasts$cut
```

```
[1] "contr.poly"
```

```
$contrasts$color
```

```
[1] "contr.poly"
```

```
$contrasts$clarity
```

```
[1] "contr.poly"
```

```
$call
```

```
lm(formula = price ~ carat + cut + color + clarity, data = diamonds)
```



Lists



Quiz

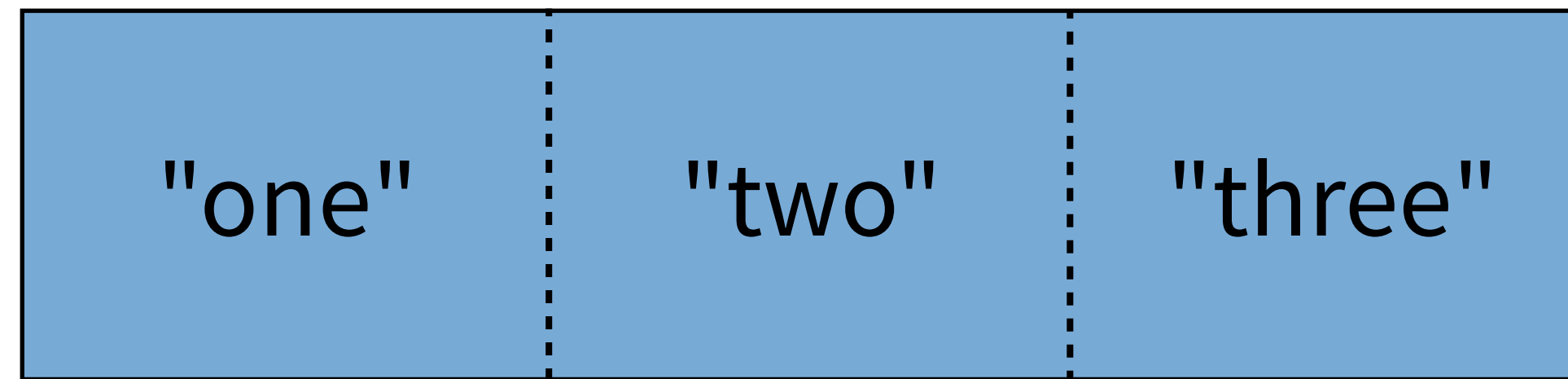
What is the difference between an atomic vector and a list?

Atomic Vector



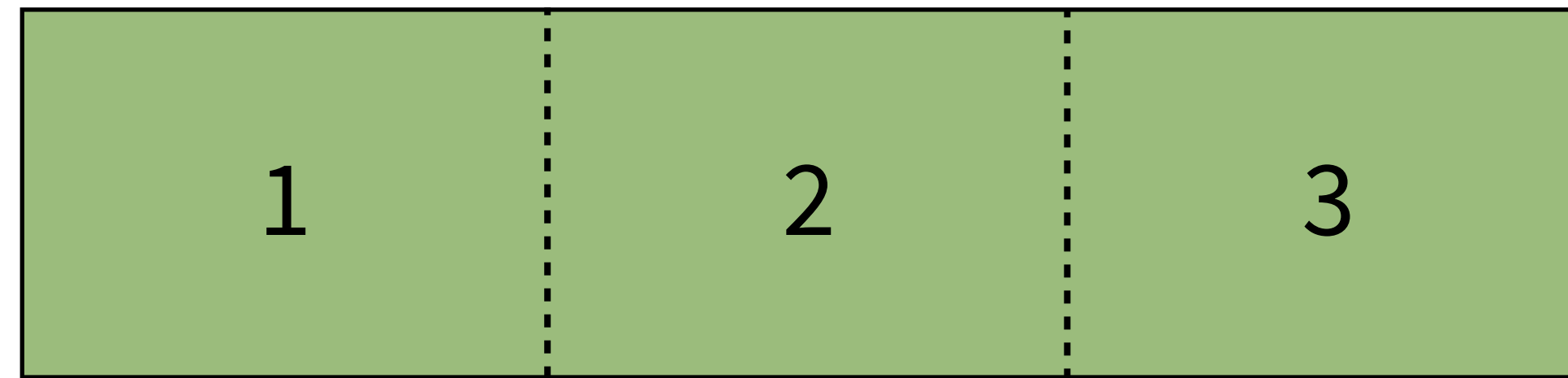
type

Atomic Vector



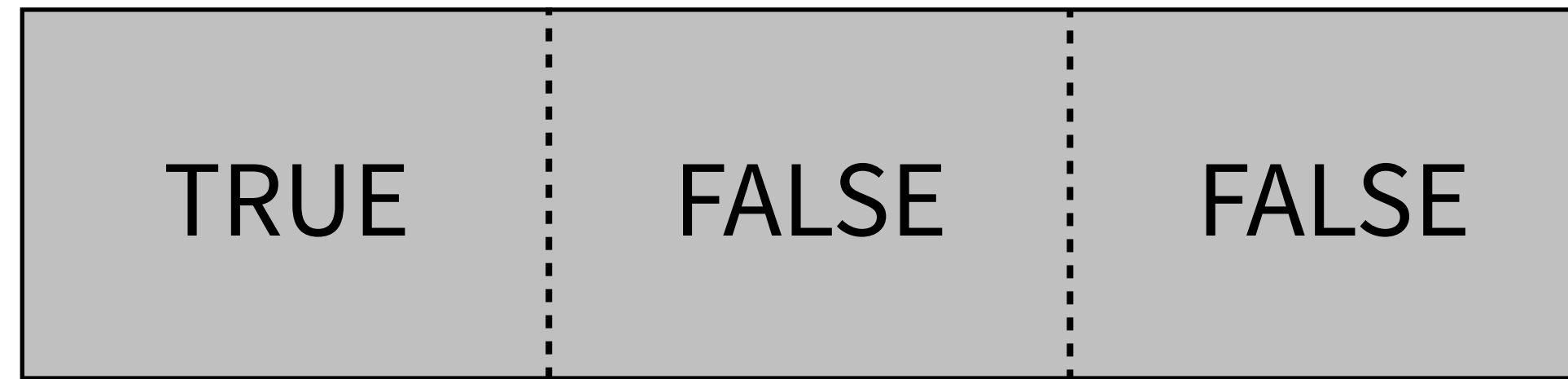
character

Atomic Vector



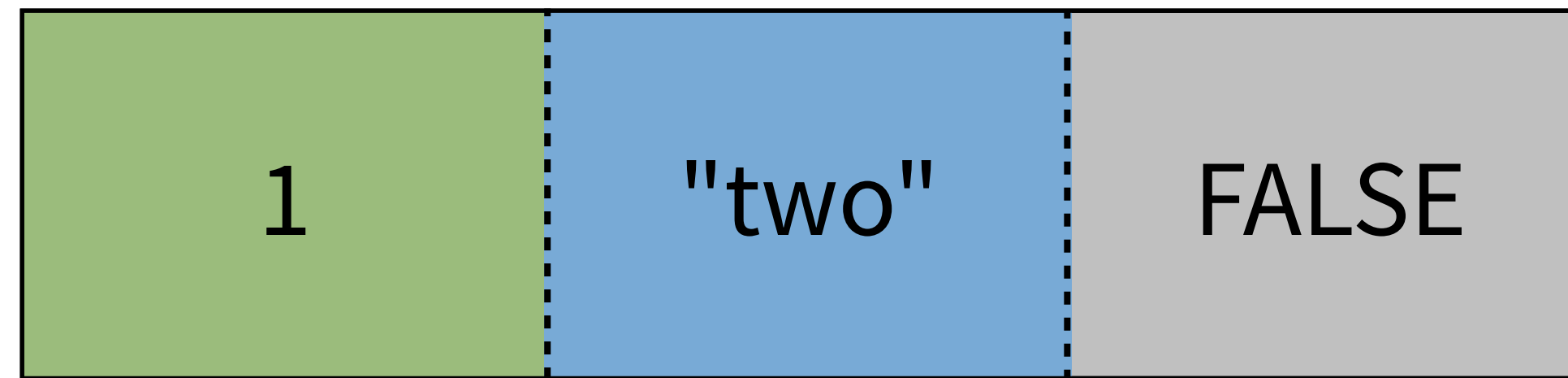
double

Atomic Vector



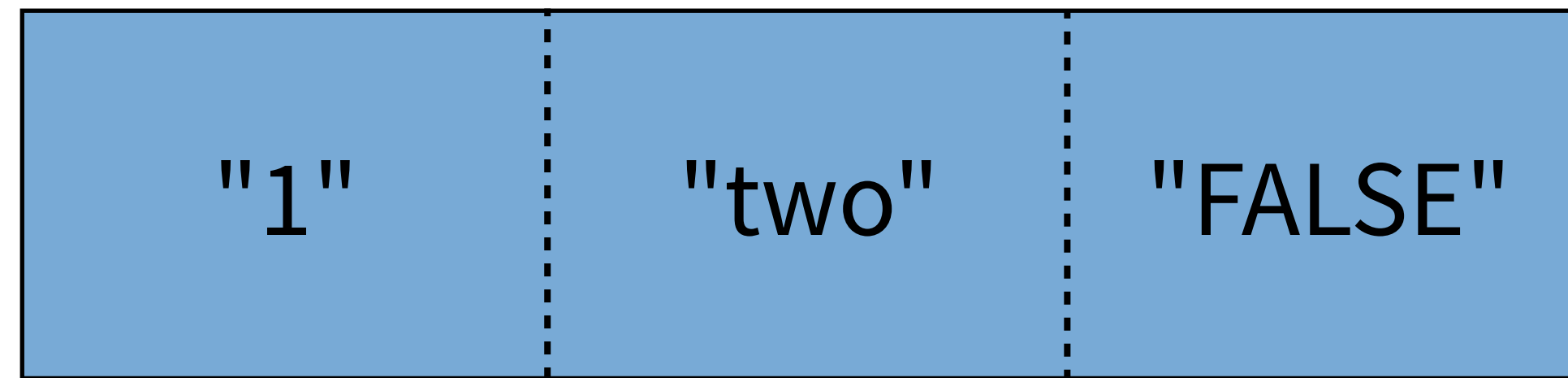
logical

Atomic Vector



?

Atomic Vector



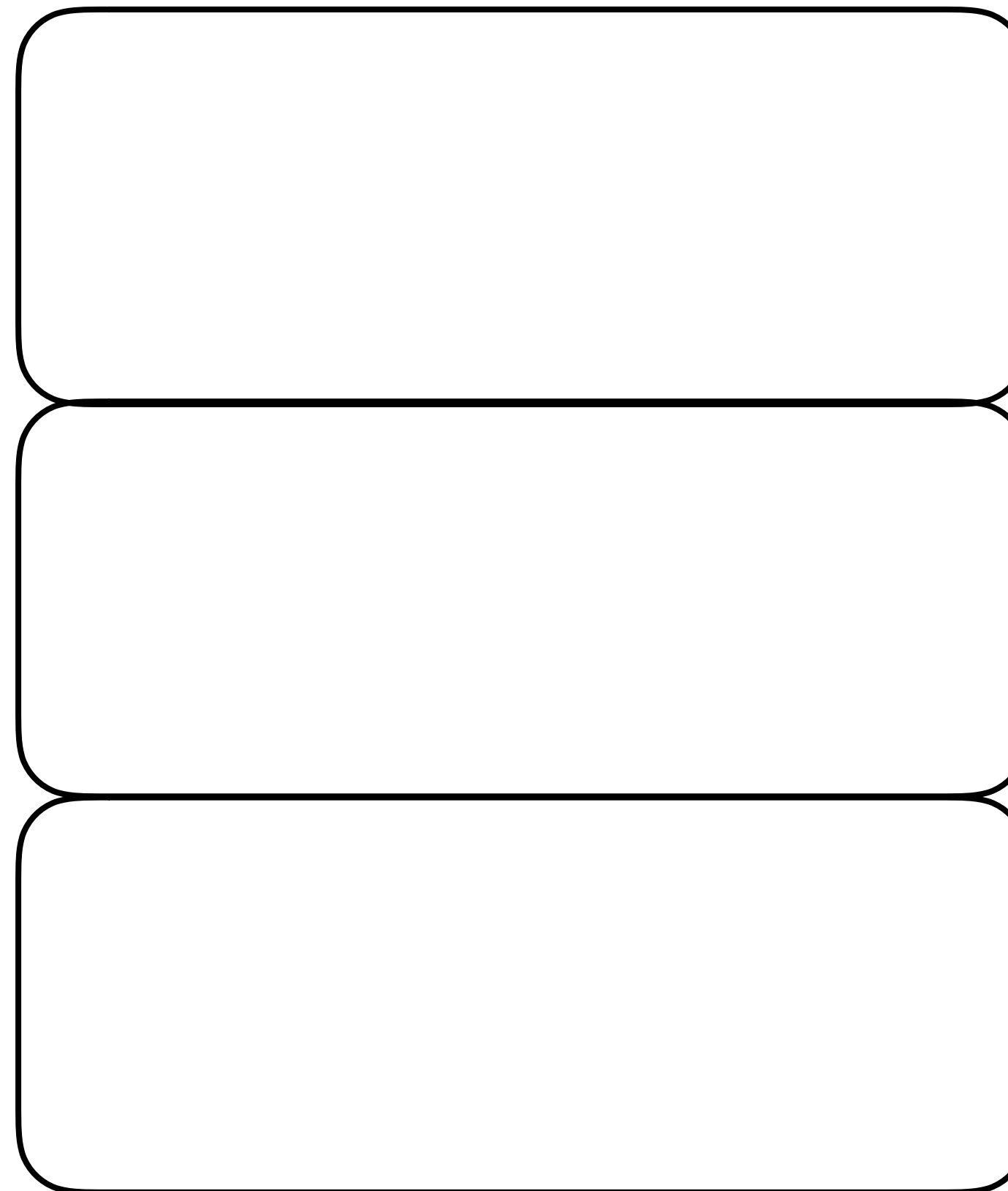
character

Atomic Vector

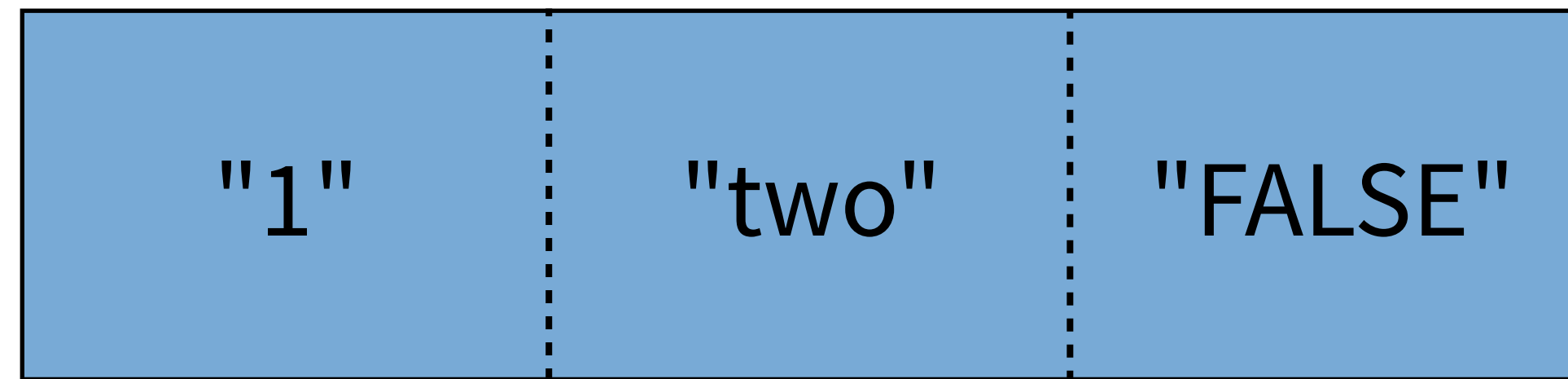


type

List

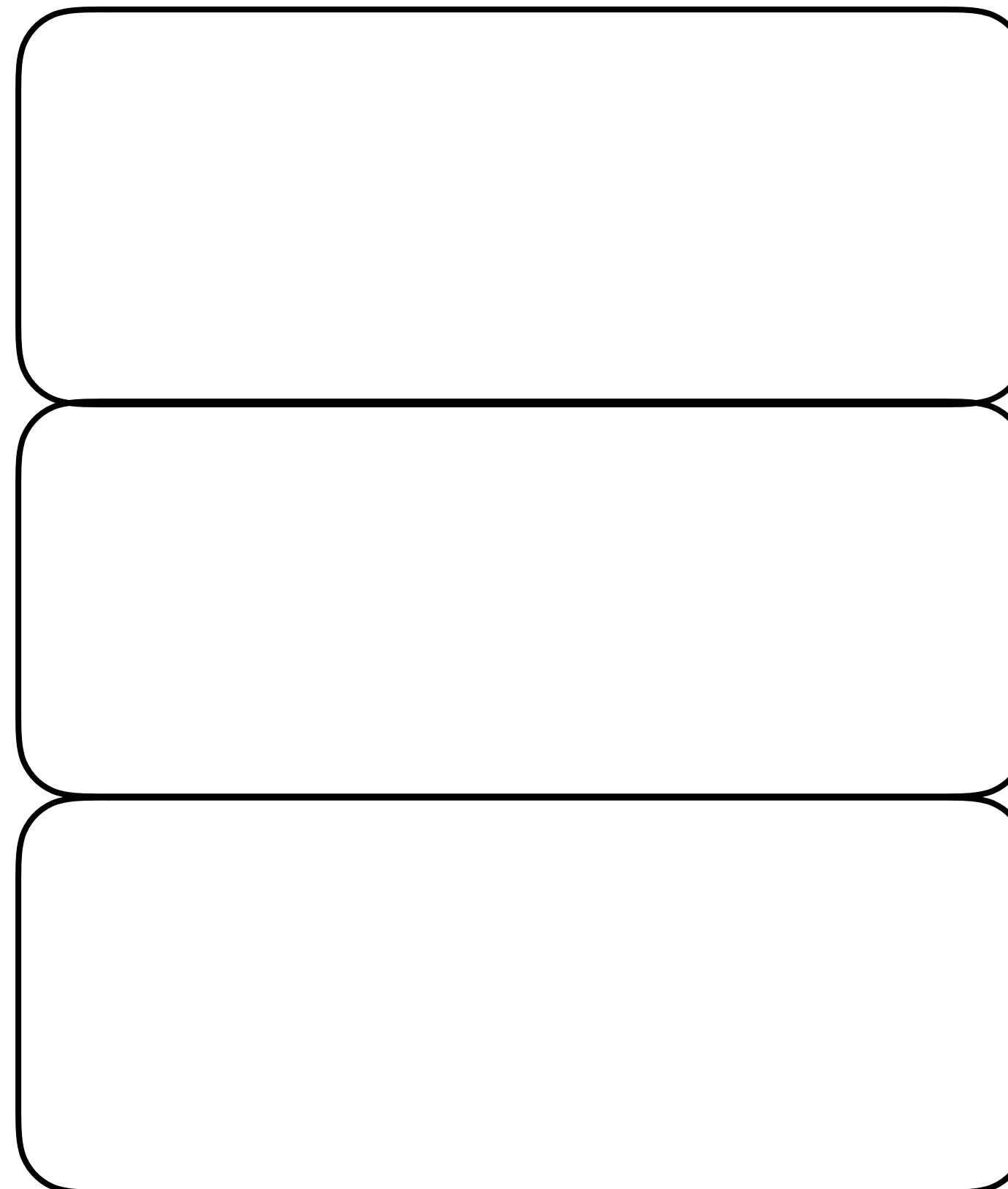


Atomic Vector

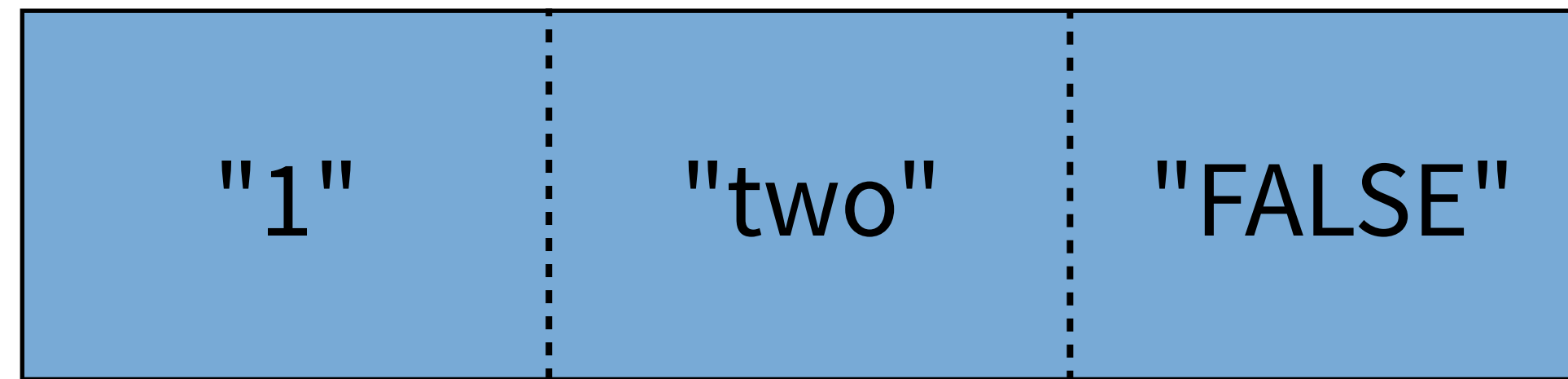


character

List

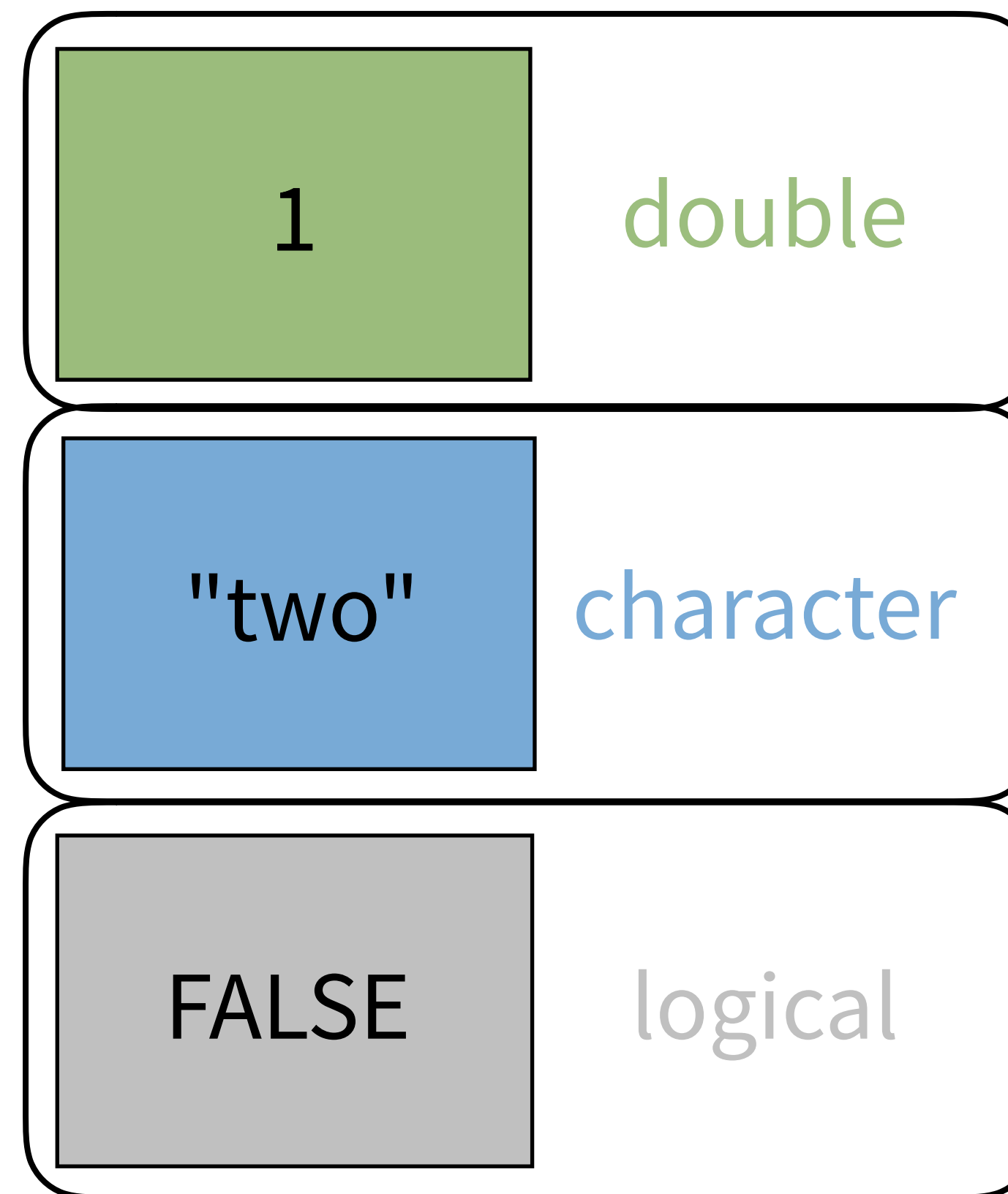


Atomic Vector

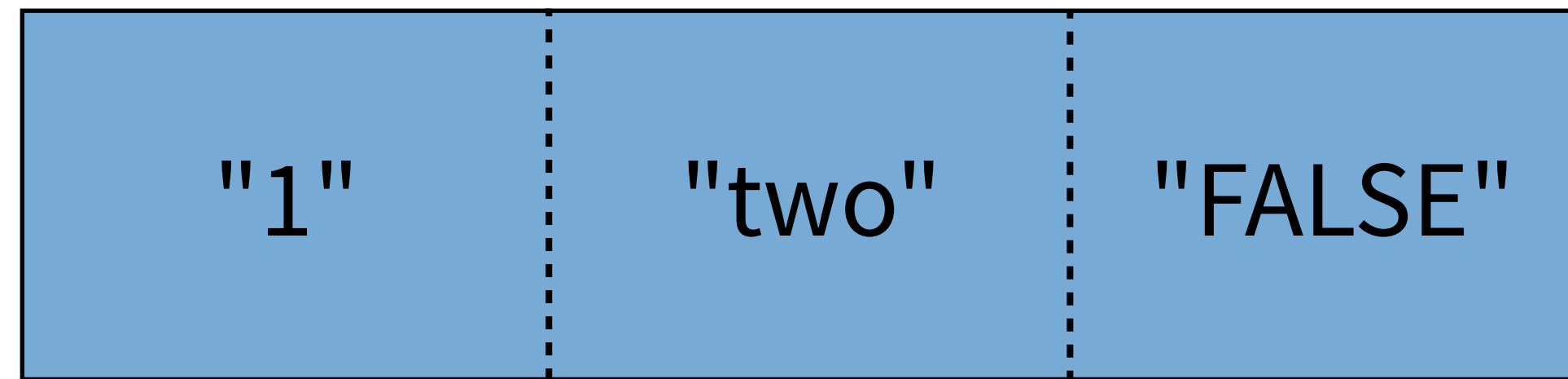


character

List

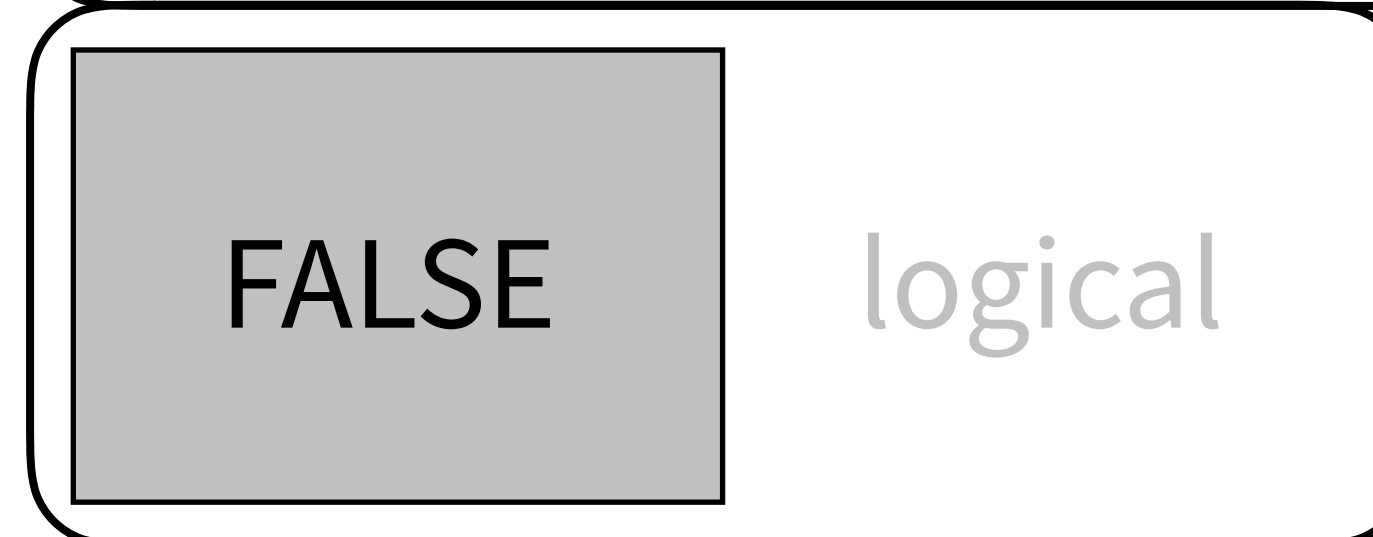
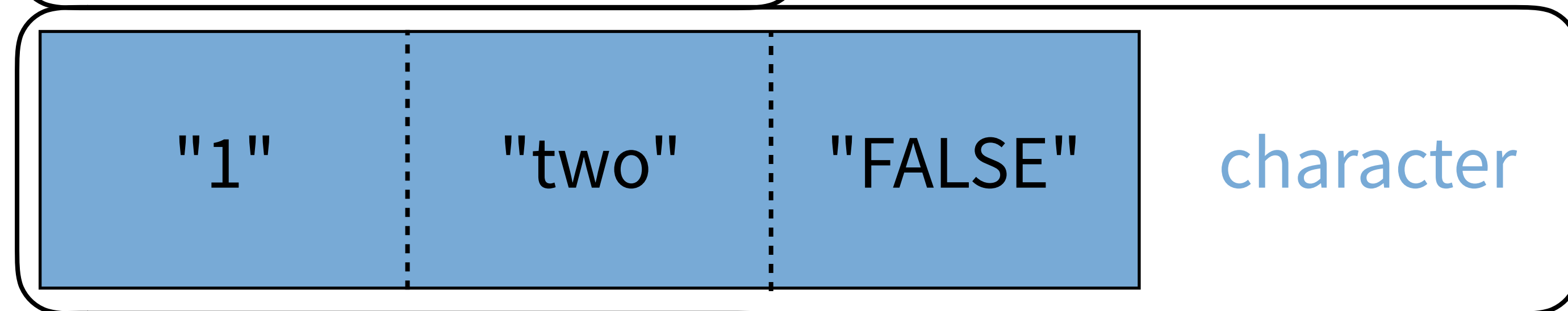
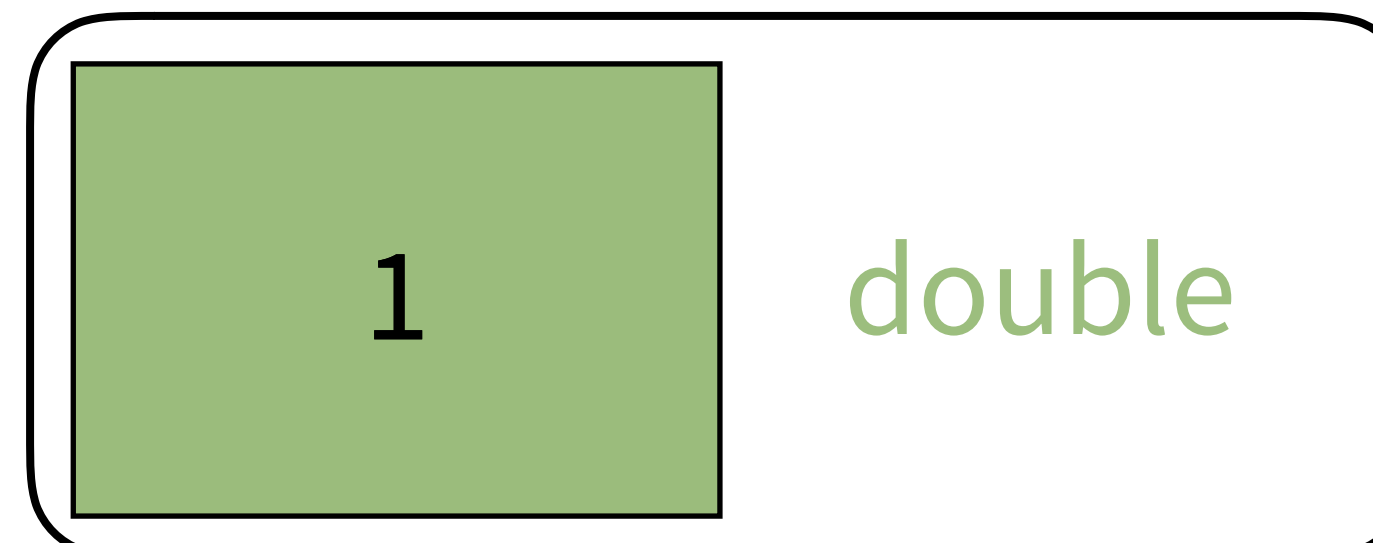


Atomic Vector

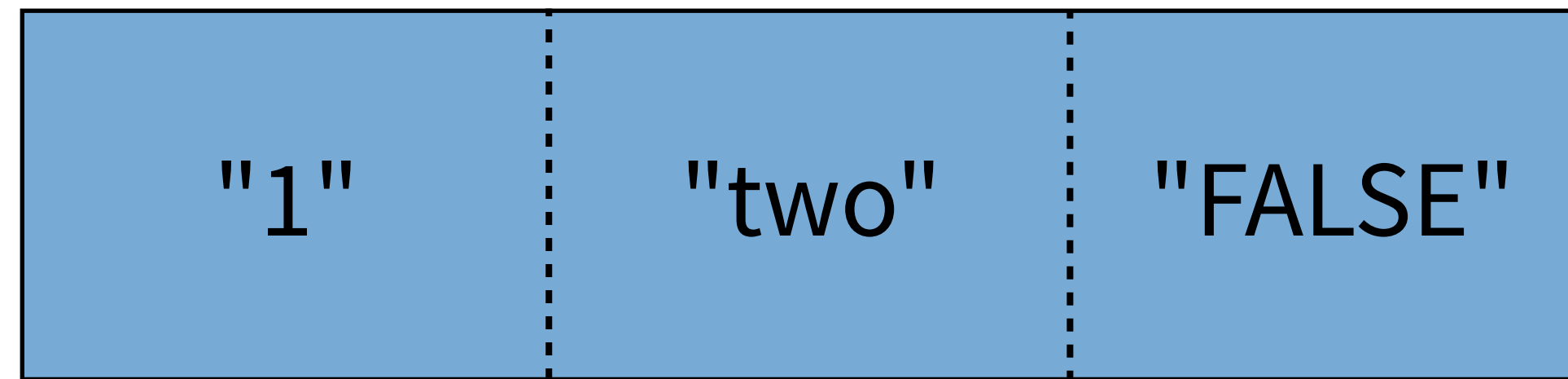


character

List

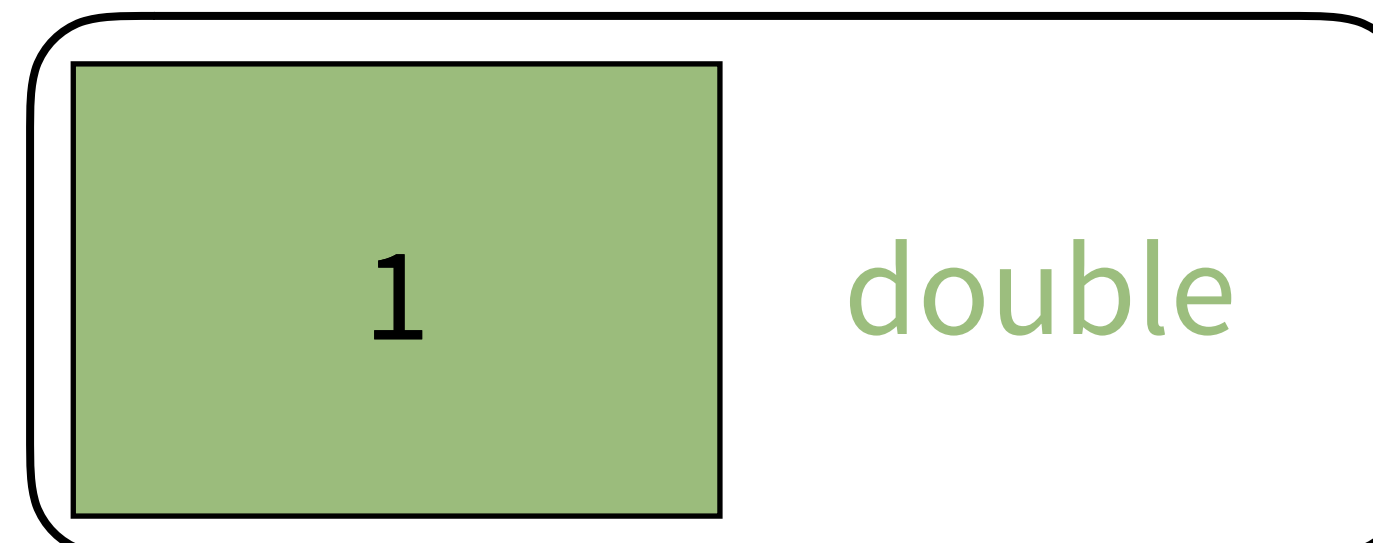


Atomic Vector

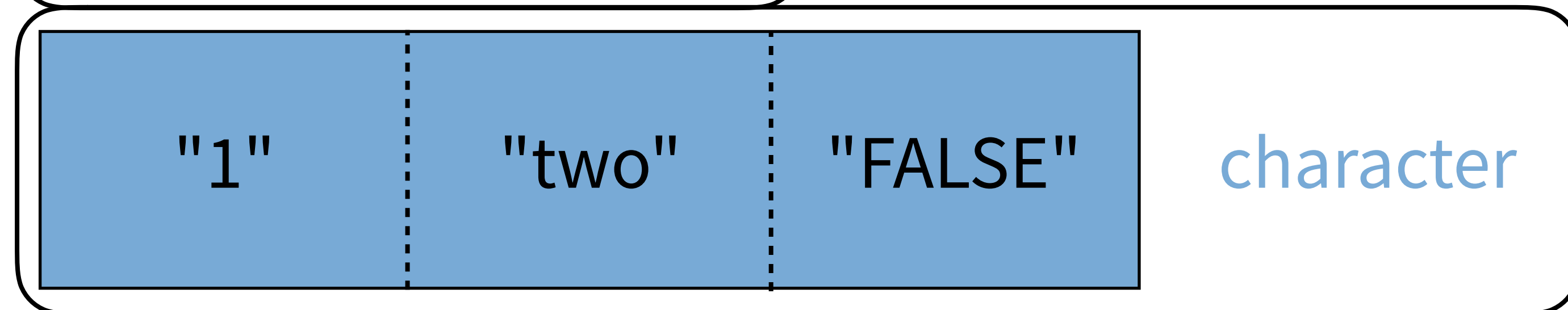


character

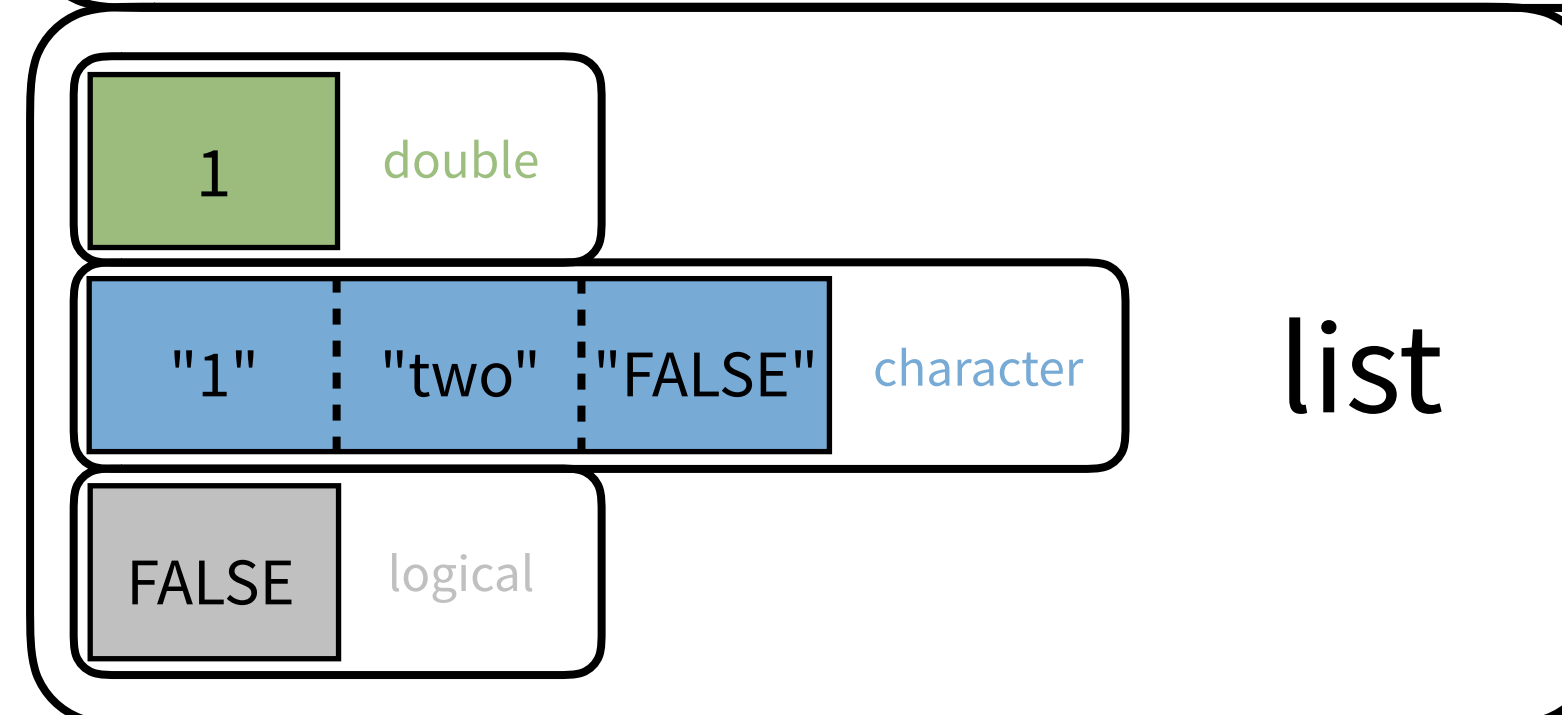
List



double



character



list

Your Turn 1

Here is a list:

```
a_list <- list(num = c(8, 9),  
              log = TRUE,  
              cha = c("a", "b", "c"))
```

Here are two subsetting commands. Do they return the same values? Run the code chunks to confirm

```
a_list["num"]
```

```
a_list$num
```

```
a_list["num"]
```

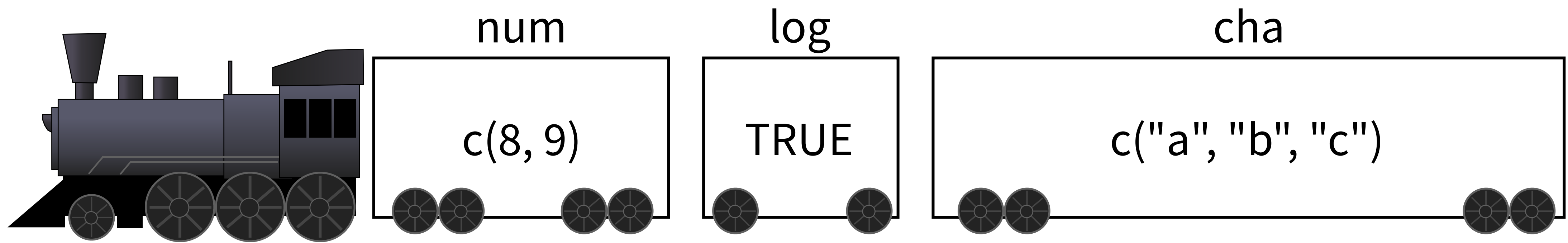
```
$num  
[1] 8 9
```

A list
(with one element named
num that contains an
atomic vector)

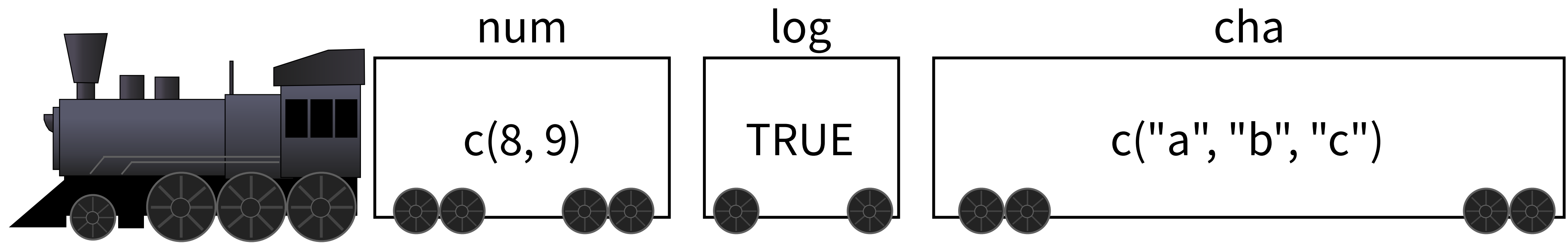
```
a_list$num
```

```
[1] 8 9
```

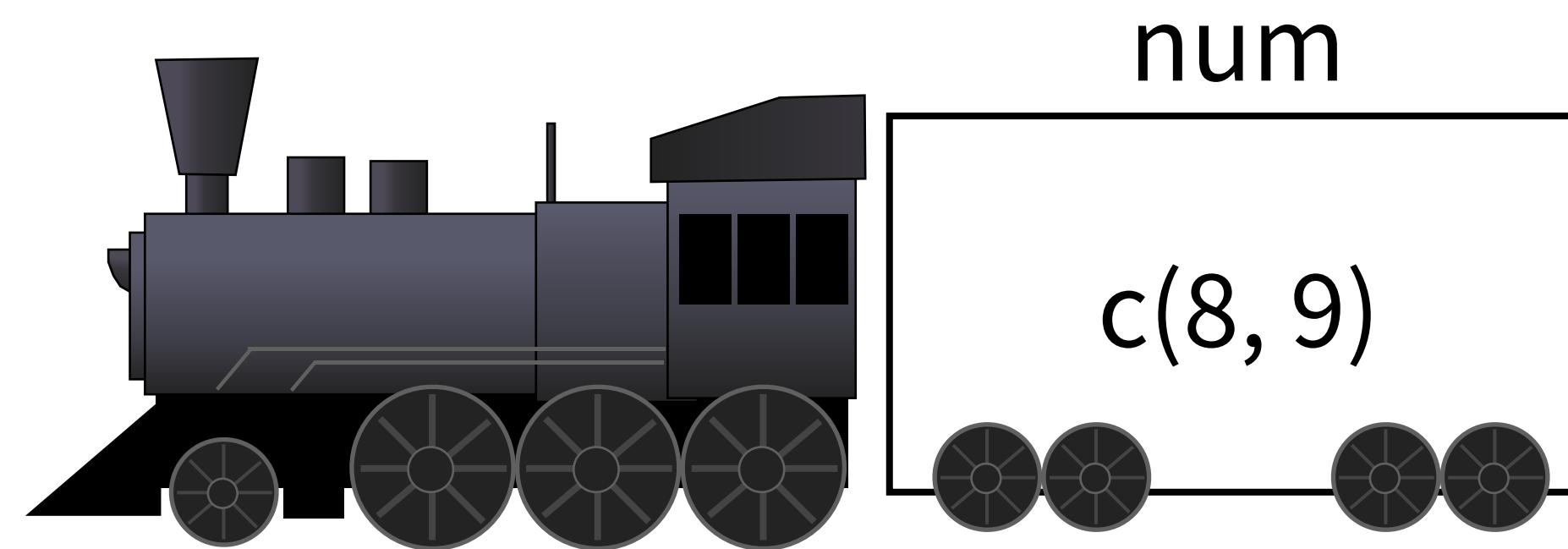
An atomic vector

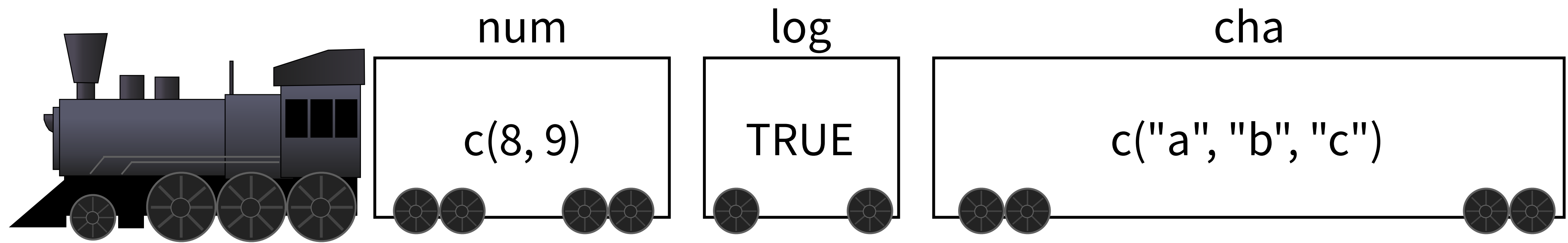


```
lst <- list(num = c(8,9), log = TRUE, cha = c("a", "b", "c"))
```

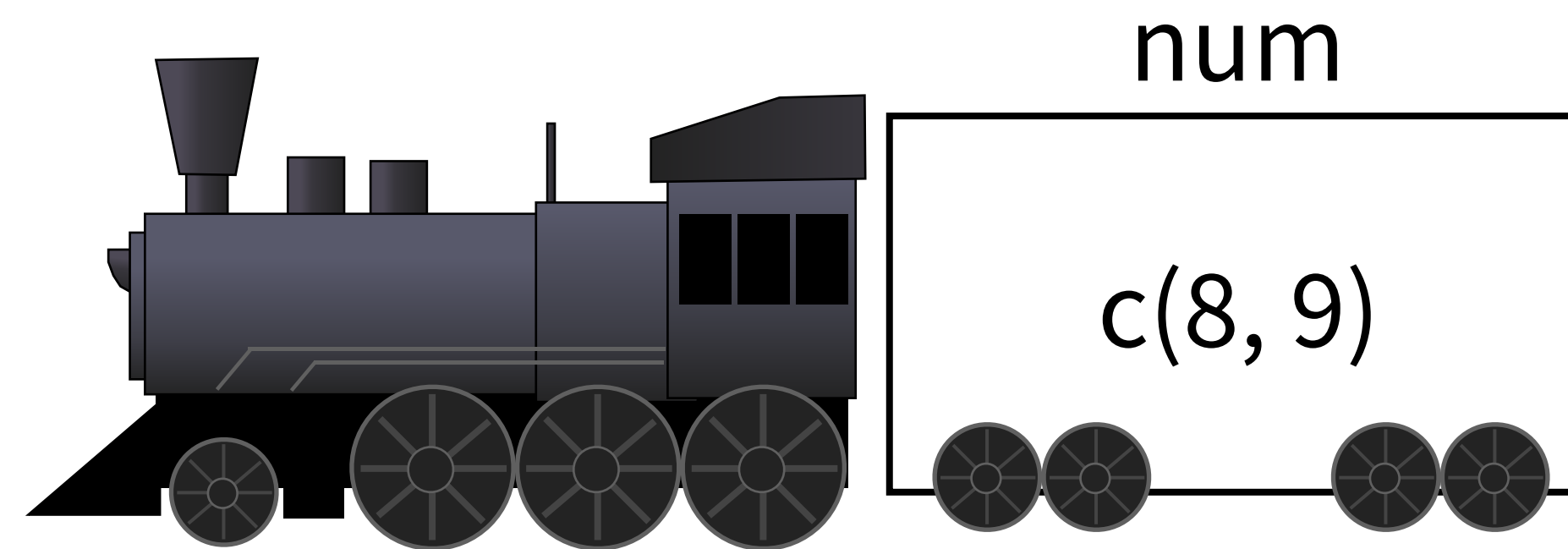



```
lst["num"]
```



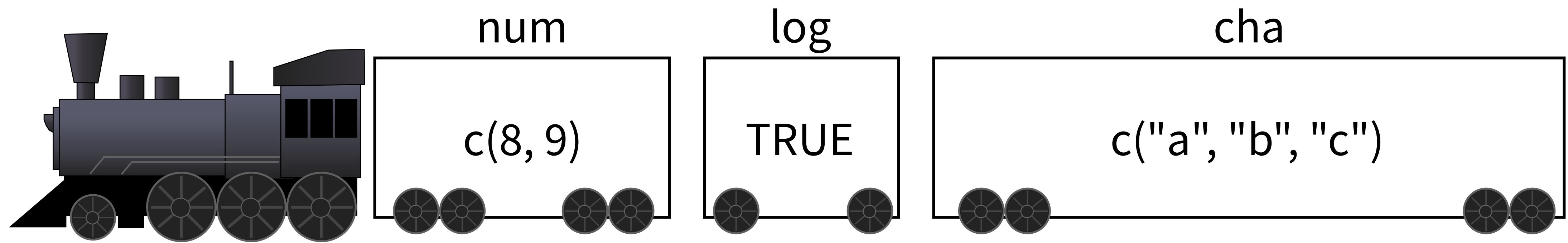


```
lst["num"]
```



c(8, 9)

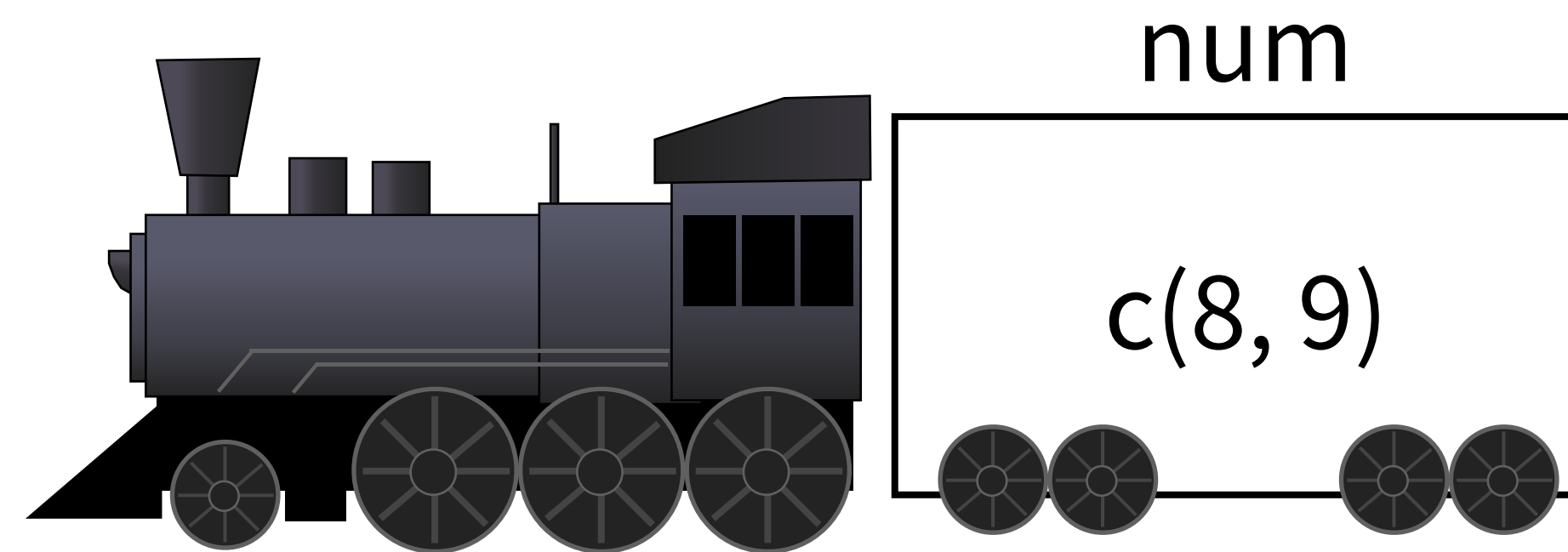
```
lst[["num"]]
```



```
lst["num"]
```

```
lst[["num"]]
```

```
lst$num
```



c(8, 9)

c(8, 9)

Your Turn 2

What will each of these return? Run the code chunks to confirm.

```
vec <- c(-2, -1, 0, 1, 2)
```

```
abs(vec)
```

```
# 2 1 0 1 2
```

```
lst <- list(-2, -1, 0, 1, 2)
```

```
abs(lst)
```

```
# Error in abs(lst) :
```

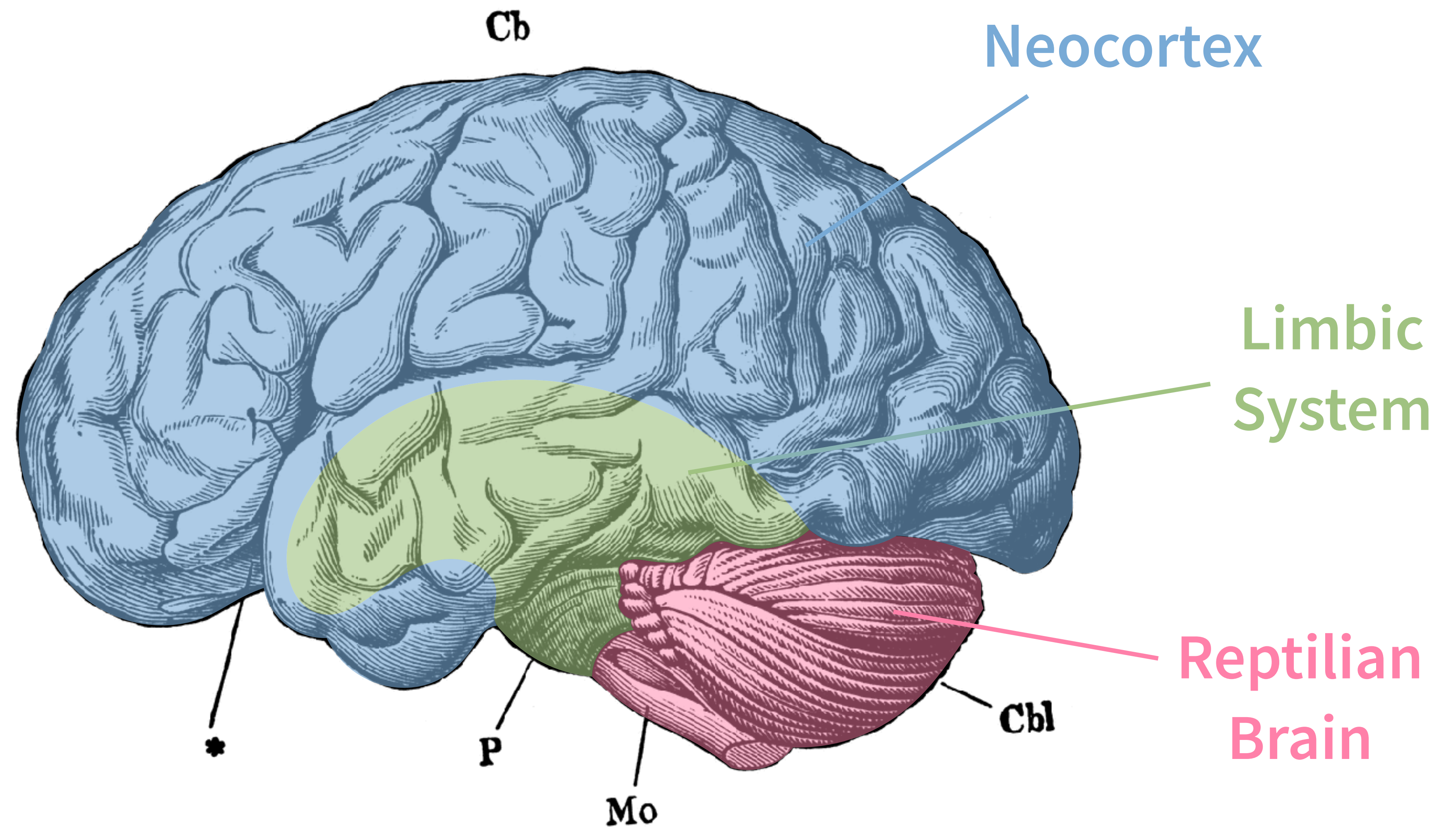
```
# non-numeric argument to mathematical function
```

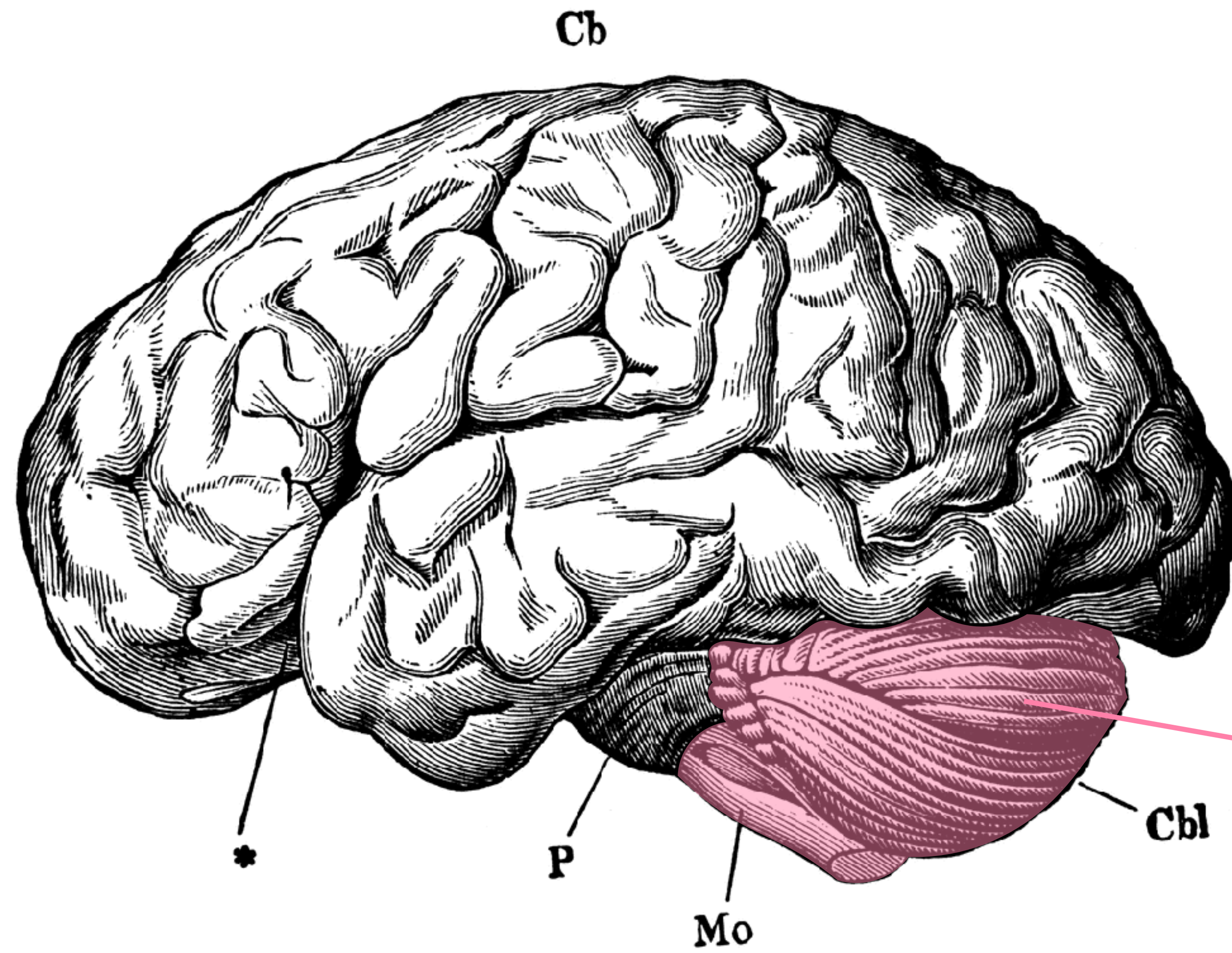

Take aways

Lists are a useful way to organize data.

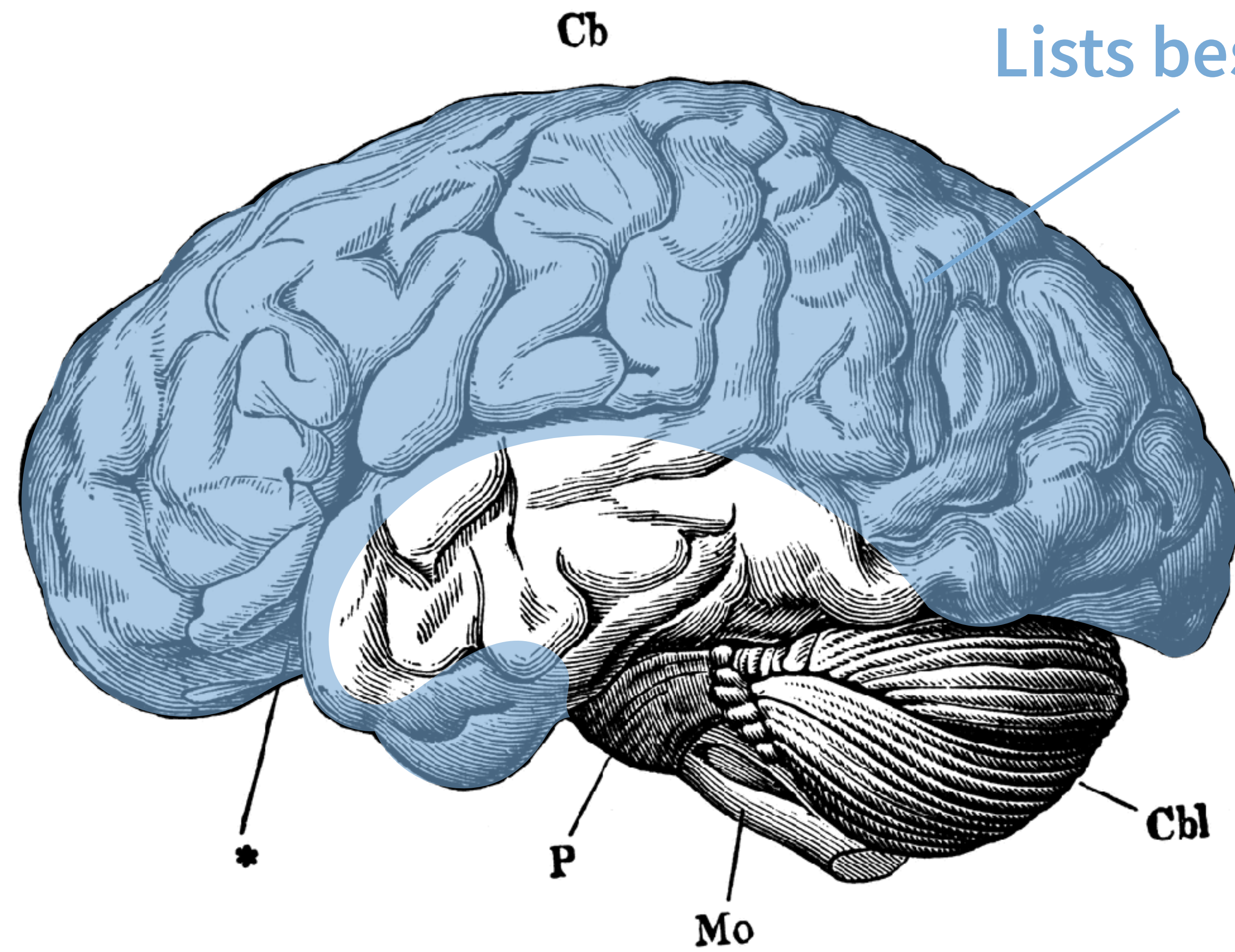
But you need to arrange manually for functions to iterate over the elements of a list.



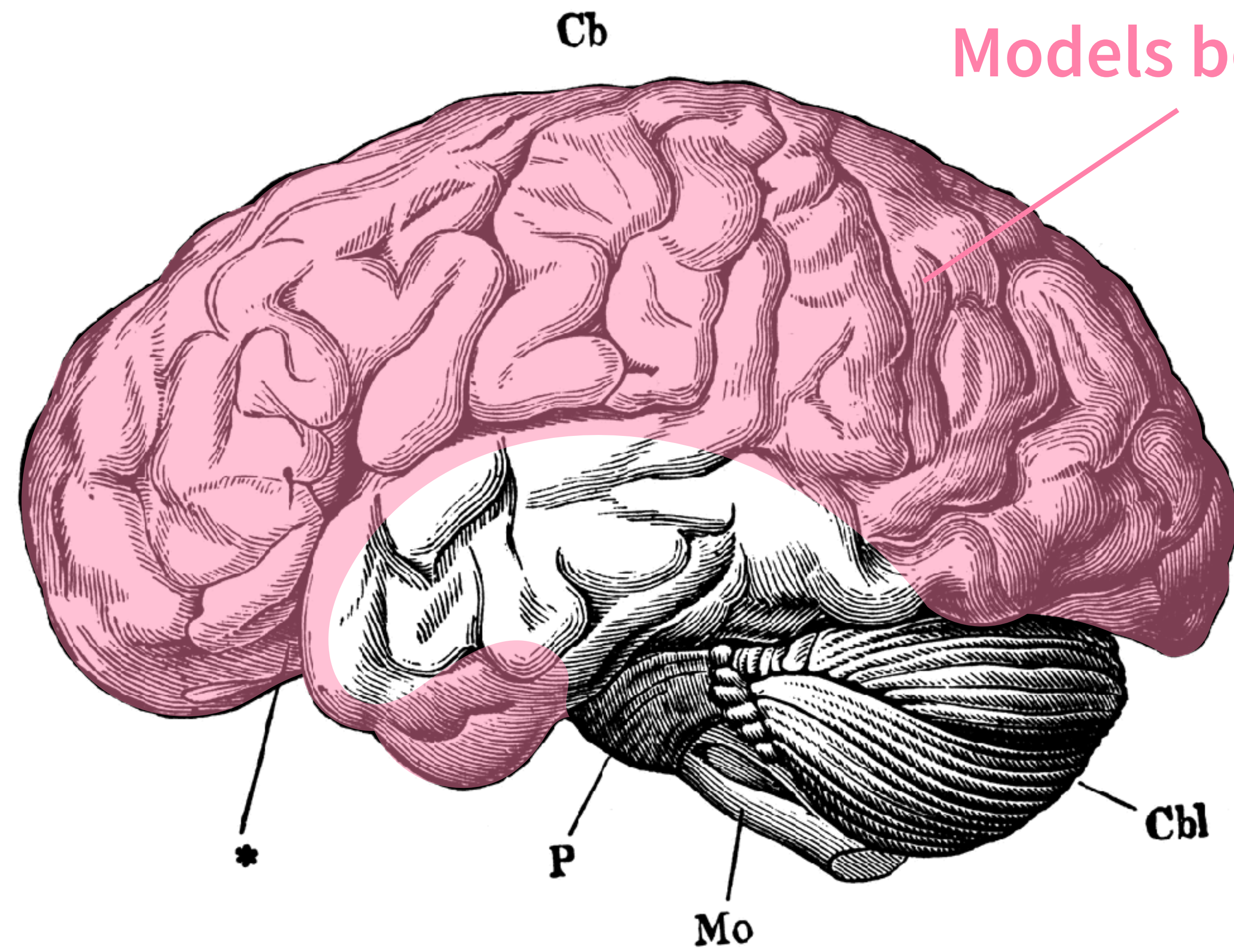




Models
and lists



Lists best practices



Iteration



Toy data

Suppose we have the exam scores of five students...

```
06-Iteration.Rmd x
1 ---
2 title: "Iteration"
3 output: html_notebook
4 ---
5
6 ```{r setup}
7 library(tidyverse)
8
9 # Toy data
10 set.seed(1000)
11 exams <- list(
12   student1 = round(runif(10, 50, 100)),
13   student2 = round(runif(10, 50, 100)),
14   student3 = round(runif(10, 50, 100)),
15   student4 = round(runif(10, 50, 100)),
16   student5 = round(runif(10, 50, 100))
17 )
18
19 extra_credit <- list(0)
20 ...
21
22 ## Your Turn 1
23
24 Here is a list:
25
26 ```{r}
27 a_list <- list(num = c(1, 2, 3),
28               log = TRUE,
29               cha = c("a", "b", "c"))
30 ...
31
32 Here are two subsetting
33 the code chunk above, and then run the code chunks below to confirm
```

Ensures that you and I
generate the same
"random" values

```
set.seed(1000)
exams <- list(
  student1 = round(runif(10, 50, 100)),
  student2 = round(runif(10, 50, 100)),
  student3 = round(runif(10, 50, 100)),
  student4 = round(runif(10, 50, 100)),
  student5 = round(runif(10, 50, 100))
)
```



Suppose we have the exam scores of five students...

```
exams
```

```
$student1
```

```
[1] 66 88 56 85 76 53 87 79 61 63
```

```
$student2
```

```
[1] 67 88 66 93 88 54 75 82 54 79
```

```
$student3
```

```
[1] 58 90 64 54 77 84 73 91 55 56
```

```
$student4
```

```
[1] 78 52 78 98 75 85 51 89 79 66
```

```
$student5
```

```
[1] 100 77 55 82 90 86 85 78 63 75
```

How can we compute the
mean grade for each
student?



How could we compute the average grade?

```
mean(exams)
```

argument is not numeric or logical: returning NA[1] NA



How could we compute the average grade?

```
list(student1 = mean(exams$student1),  
      student2 = mean(exams$student2),  
      student3 = mean(exams$student3),  
      student4 = mean(exams$student4),  
      student5 = mean(exams$student5))
```



```
$student1  
[1] 71.4
```

```
$student3  
[1] 70.2
```

```
$student5  
[1] 79.1
```

```
$student2  
[1] 74.6
```

```
$student4  
[1] 75.1
```

Is there a better way?



purrr



purrr



Functions for working with lists.

```
# install.packages("tidyverse")  
library(tidyverse)
```



Your Turn 3

Run the code in the chunk. What does it do?

```
map(exams, mean)
```

01:00

```
exams %>% map(mean)
```

```
$student1
```

```
[1] 71.4
```

```
$student2
```

```
[1] 74.6
```

```
$student3
```

```
[1] 70.2
```

```
$student4
```

```
[1] 75.1
```

```
$student5
```

```
[1] 79.1
```



map()

Applies a function to every element of a list.
Returns the results as a list.

```
map(.x, .f, ...)
```

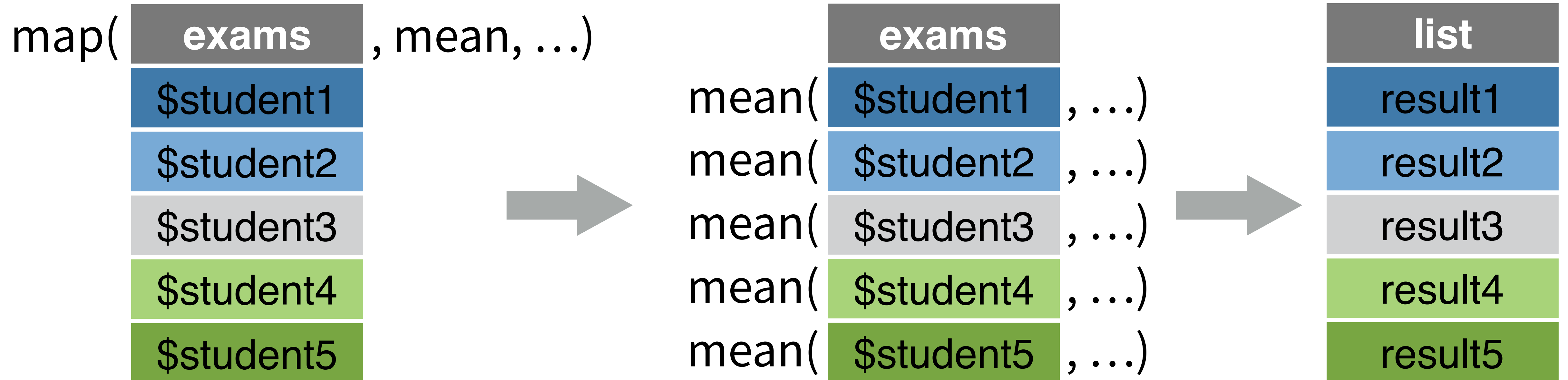
A list

**A function to apply to
each element of the list**
(element become first
argument)

**Other
arguments to
pass to the
function**



map()



Your Turn 4

Calculate the variance (**var()**) of each student's exam grades.

02:00

```
exams %>% map(var)
```

```
$student1  
[1] 174.0444
```

```
$student2  
[1] 194.7111
```

```
$student3  
[1] 216.8444
```

```
$student4  
[1] 227.2111
```

```
$student5  
[1] 167.6556
```



map functions

function	returns results as
map()	list
map_chr()	character vector
map_dbl()	double vector (numeric)
map_int()	integer vector
map_lgl()	logical vector
map_df()	data frame



map_dbl()

If we want the output as a vector:

```
exams %>%  
  map_dbl(mean)
```

```
## student1 student2 student3 student4 student5  
## 71.34850 74.60950 70.21575 75.30758 79.06386
```



extra arguments

What if the grade was the 90th percentile score?

```
exams %>%  
  map_dbl(quantile, prob = 0.9)
```

```
## student1 student2 student3 student4 student5  
## 87.03640 88.71630 90.34335 90.09150 90.88785
```

extra argument for
quantile



map_lgl()

How about a participation grade?

```
exams %>%  
  map(length) %>%  
  map_lgl(all.equal, 10)
```

```
## student1 student2 student3 student4 student5  
##      TRUE      TRUE      TRUE      TRUE      TRUE
```



Your Turn 5

Calculate the max grade (**max()**) for each student. Return the result as a vector.

02:00

```
exams %>%  
  map_dbl(max)
```

##	student1	student2	student3	student4	student5
##	88	93	91	98	100



Quiz

What if what we want to do is not a function?

For example, what if the final grade is the mean exam score **after we drop the lowest score**?

A: Write a function.

Functions



Functions (very basics)

1. Write code that solves the problem for a real object

```
vec <- exams$student1
```



To write a function (very basics)

1. Write code that solves the problem for a real object

```
vec <- exams$student1  
(sum(vec) - min(vec)) / (length(vec) - 1)  
# 73.34424
```



Note: this code does the same thing no matter what vec is.
But it is a bother to redefine vec each time we use the code.

```
vec <- exams$student1  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
vec <- exams$student2  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
vec <- exams$student3  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
vec <- exams$student4  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
vec <- exams$student5  
  (sum(vec) - min(vec)) / (length(vec) - 1)
```



To write a function (very basics)

1. Write code that solves the problem for a real object
2. Wrap the code in **function(){} to save it**

```
vec <- exams[[1]]  
grade <- function() {  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
}
```



To write a function (very basics)

1. Write code that solves the problem for a real object
2. Wrap the code in `function(){} to save it`
3. Add the name of the real object as the function argument

```
vec <- exams[[1]]  
grade <- function(vec) {  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
}
```



To write a function (very basics)

1. Write code that solves the problem for a real object
2. Wrap the code in `function(){} to save it`
3. Add the name of the real object as the function argument
4. To run the function, call the object followed by parentheses.
Supply new values to use for each of the arguments.

```
vec <- exams[[1]]  
grade <- function(vec) {  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
}  
grade(exams[[2]]) # 76.93898
```




```
grade <- function(vec) {  
  (sum(vec) - min(vec)) / (length(vec) - 1)  
}
```

```
exams %>%
```

```
  map_dbl(grade)
```

```
## student1  student2  student3  student4  student5  
## 73.34424   76.93898   72.06320   78.00649   81.68257
```



```
grade <- function(x) {  
  (sum(x) - min(x)) / (length(x) - 1)  
}
```

```
exams %>%
```

```
  map_dbl(grade)
```

```
## student1  student2  student3  student4  student5  
## 73.34424   76.93898   72.06320   78.00649   81.68257
```



```
grade <- function(x) (sum(x) - min(x)) / (length(x) - 1)
```

```
exams %>%
```

```
  map_dbl(grade)
```

```
## student1  student2  student3  student4  student5
```

```
## 73.34424  76.93898  72.06320  78.00649  81.68257
```



```
grade <- function(x) (sum(x) - min(x)) / (length(x) - 1)

exams %>%
  map_dbl(function(x) (sum(x) - min(x)) / (length(x) - 1))
## student1 student2 student3 student4 student5
## 73.34424 76.93898 72.06320 78.00649 81.68257
```



Your Turn 6

Write a function that counts the best exam twice and then takes the average. Use it to grade all of the students.

1. Write code that solves the problem for a real object
2. Wrap the code in `function(){} to save it`
3. Add the name of the real object as the function argument

05:00


```
exams %>%  
  map_dbl(function(x) (sum(x) + max(x)) / (length(x) + 1))  
## student1    student2    student3    student4    student5  
## 72.85703    76.30779    72.12398    77.39862    80.94991
```



Quiz

What does this return?

```
add_1 <- function(x) x + 1
```

```
add_1(1)
```

Quiz

What does this return?

```
add_1 <- function(x) x + 1
```

```
add_1(1)
```

2

Quiz

What does this return?

```
add_2 <- function(x, y) x + y
```

```
add_2(2, 3)
```

Quiz

What does this return?

```
add_2 <- function(x, y) x + y
```

```
add_2(2, 3)
```

5

If functions can take two arguments, how can you pass two lists as the arguments?

map2()

Applies a function to every element of two lists.
Returns the results as a list.

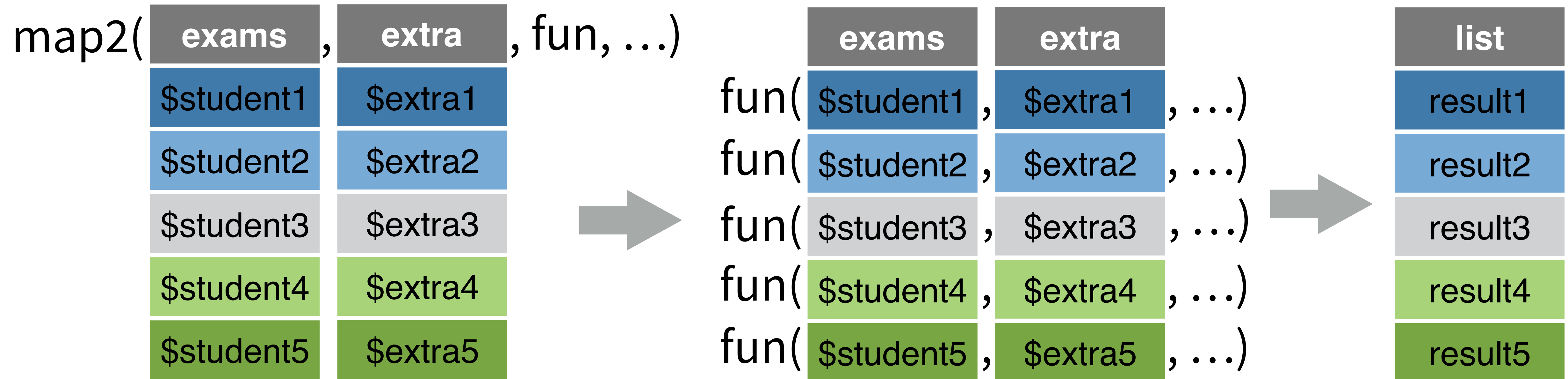
```
map2(.x, .y, .f, ...)
```

**A list of elements
to pass to the first
argument of .f**

**A list of elements to
pass to the second
argument of .f**



map2()



map functions

single list	two lists	returns results as
map()	map2()	list
map_chr()	map2_chr()	character vector
map_dbl()	map2_dbl()	double vector
map_int()	map2_int()	integer vector
map_lgl()	map2_lgl()	logical vector
map_df()	map2_df()	data frame



Toy data

Suppose we have extra credit for the five students...

```
06-Iteration.Rmd x
1 ---
2 title: "Iteration"
3 output: html_notebook
4 ---
5
6 ```{r setup}
7 library(tidyverse)
8
9 # Toy data
10 set.seed(1000)
11 exams <- list(
12   student1 = round(runif(10, 50, 100)),
13   student2 = round(runif(10, 50, 100)),
14   student3 = round(runif(10, 50, 100)),
15   student4 = round(runif(10, 50, 100)),
16   student5 = round(runif(10, 50, 100))
17 )
18
19 extra_credit <- list(0, 0, 10, 10, 15)
20 ```
21
22 ## Your Turn 1
23
24 Here is a list:
25
26 ```{r}
27 a_list <- list(num = c(8, 9),
28               log = TRUE,
29               cha = c("a", "b", "c"))
30 ```
31
32 Here are two subsetting commands. Do they return the same values? Run
33 the code chunk above, and then run the code chunks below to confirm
```

```
extra_credit <- list(0, 0, 10, 10, 15)
```



Your Turn 7

Compute a final grade for each student, where the final grade is the average test score plus any extra credit assigned to the student. Return the results as a double (i.e. numeric) vector.

05:00

The grades with extra credit...

```
exams %>%
```

```
  map2_dbl(extra_credit, function(x, y) mean(x) + y)
```

```
## student1 student2 student3 student4 student5  
##      71.4      74.6      80.2      85.1      94.1
```

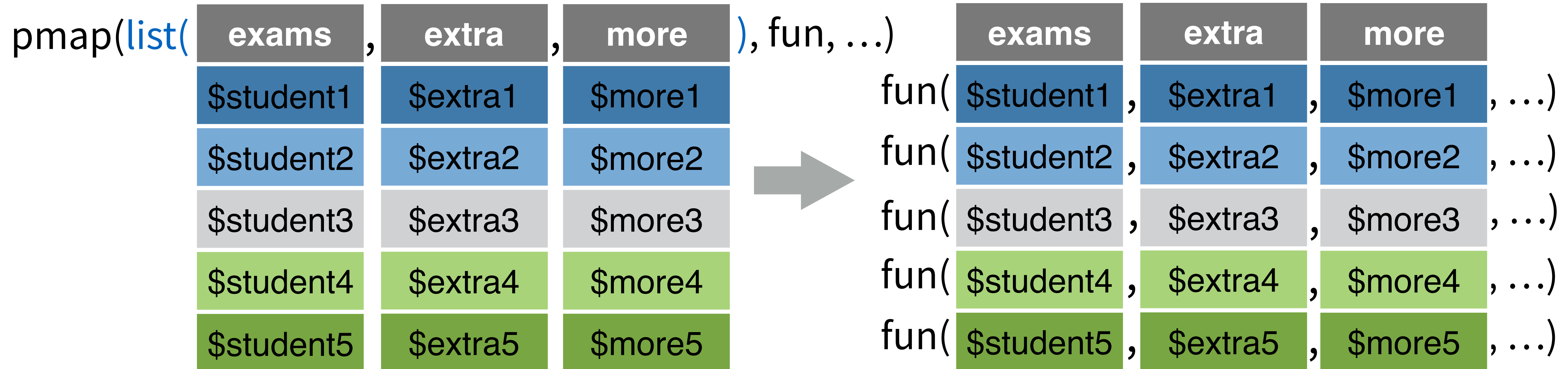


Other mapping functions



pmap()

Map over three or more lists. Put the lists into a list of list whose names match argument names in the function.



walk(), walk_2(), and pwalk()

Versions of map(), map2(), and pmap() that do not return results. These are for triggering side effects (like writing files or saving graphs).



map and walk functions

single list	two lists	n lists	returns results as
map()	map2()	pmap()	list
map_chr()	map2_chr()	pmap_chr()	character vector
map_dbl()	map2_dbl()	pmap_dbl()	double vector
map_int()	map2_int()	pmap_int()	integer vector
map_lgl()	map2_lgl()	pmap_lgl()	logical vector
map_df()	map2_df()	pmap_df()	data frame
walk()	walk2()	pwalk()	side effect



Iteration with



