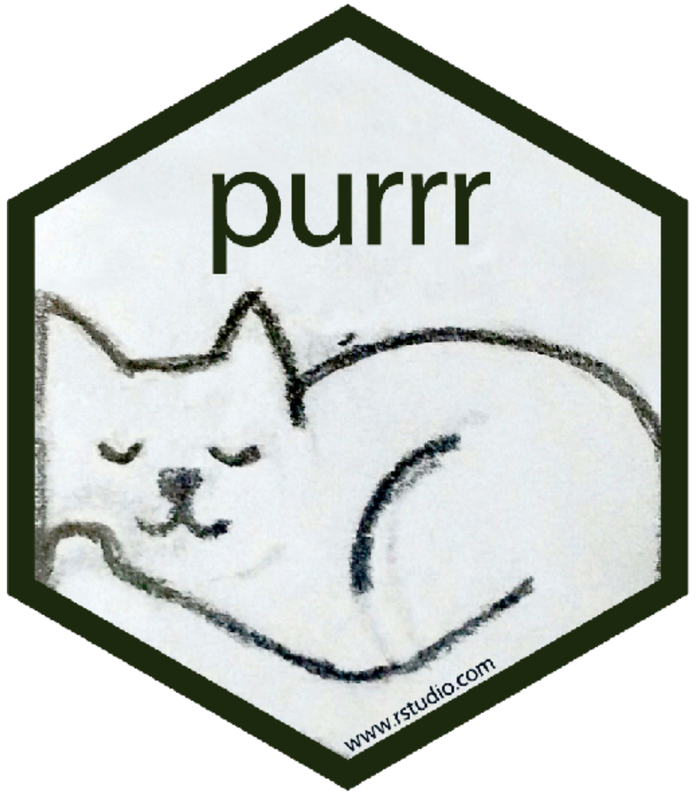
Iteration with



Open **06-Iteration.Rmd**

Your Turn 1

```
mod <- lm(price ~ carat + cut + color + clarity,
   data = diamonds)
View(mod)
```

What kind of object is `mod`? Why are models stored as this kind of object?

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 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)
```

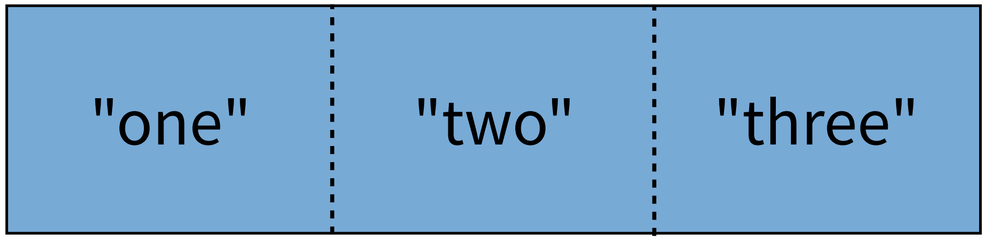

Lists

Quiz

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

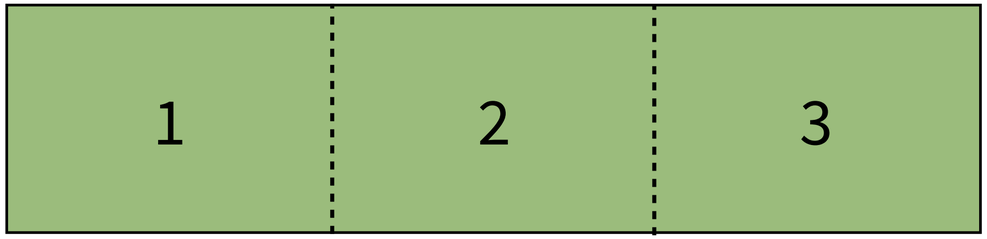
Atomic Vector  type

Atomic Vector



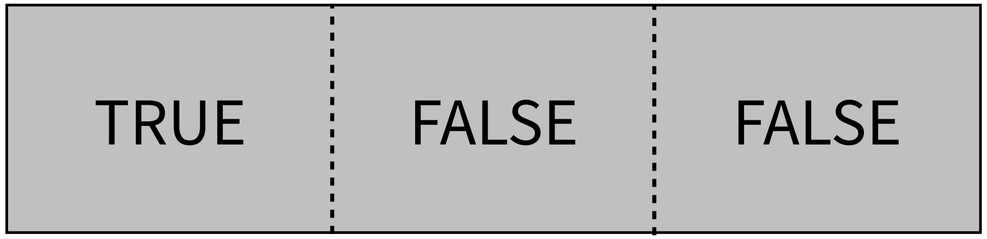
character

Atomic Vector



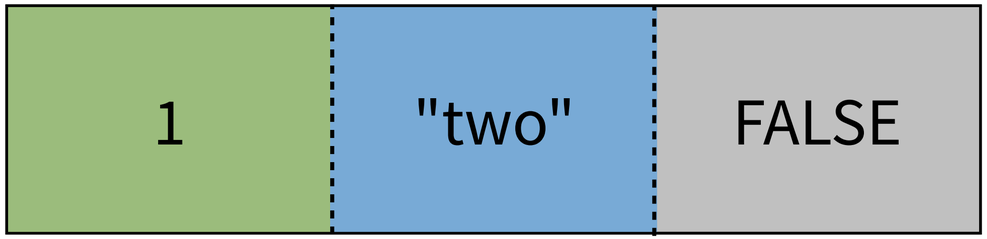
double

Atomic Vector



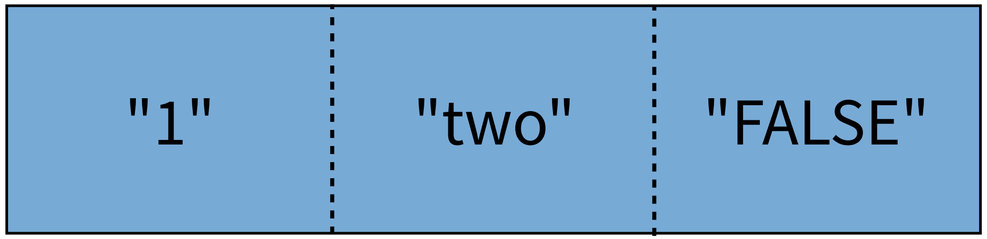
logical

Atomic Vector



?

Atomic Vector

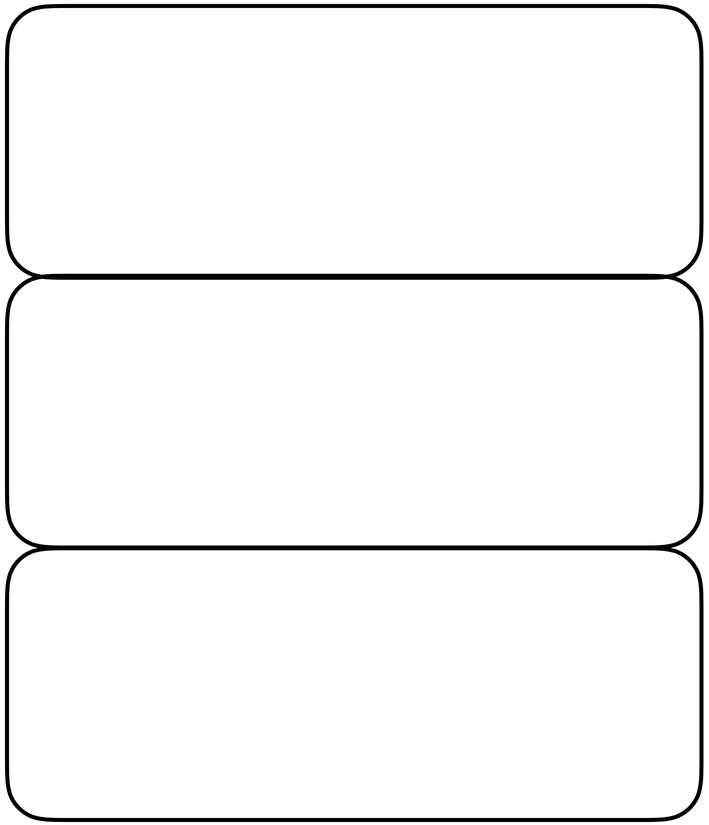


character

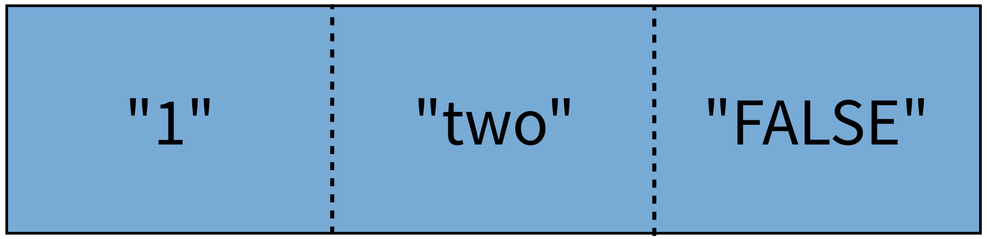
Atomic Vector

type

List

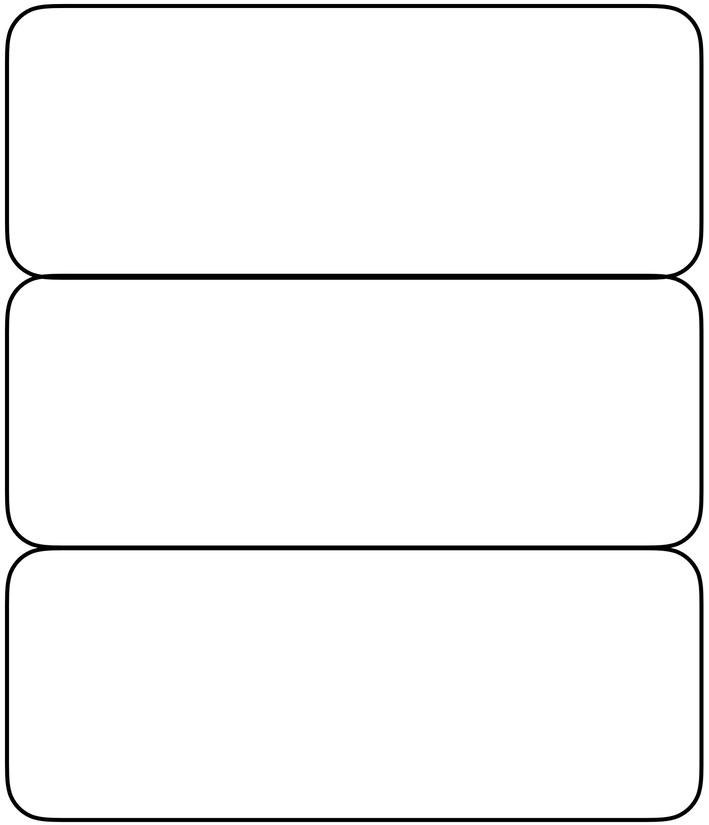


Atomic Vector

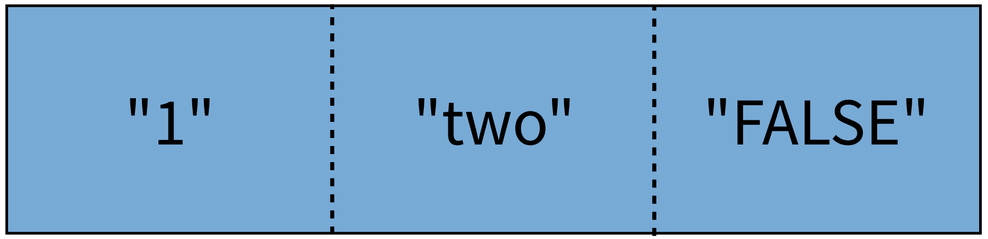


character

List

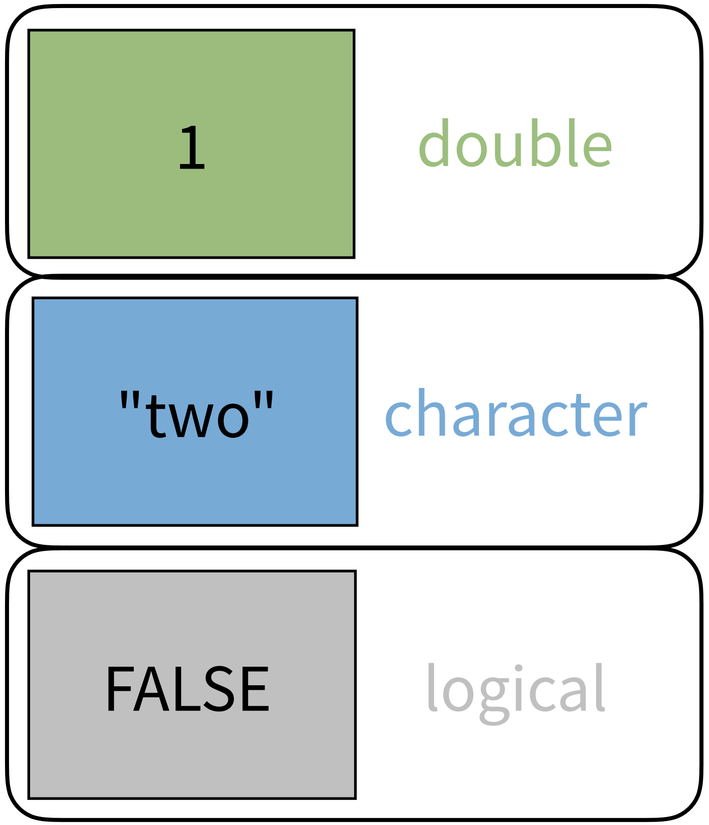


Atomic Vector

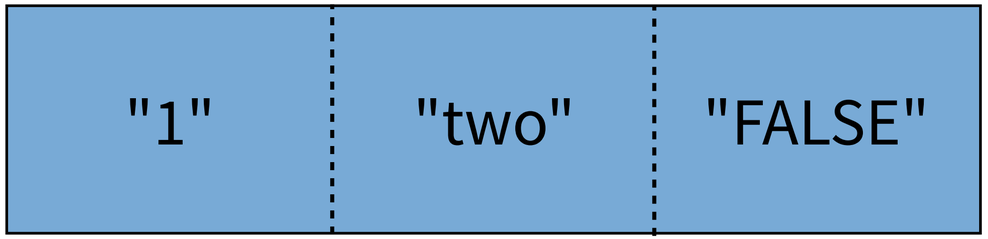


character

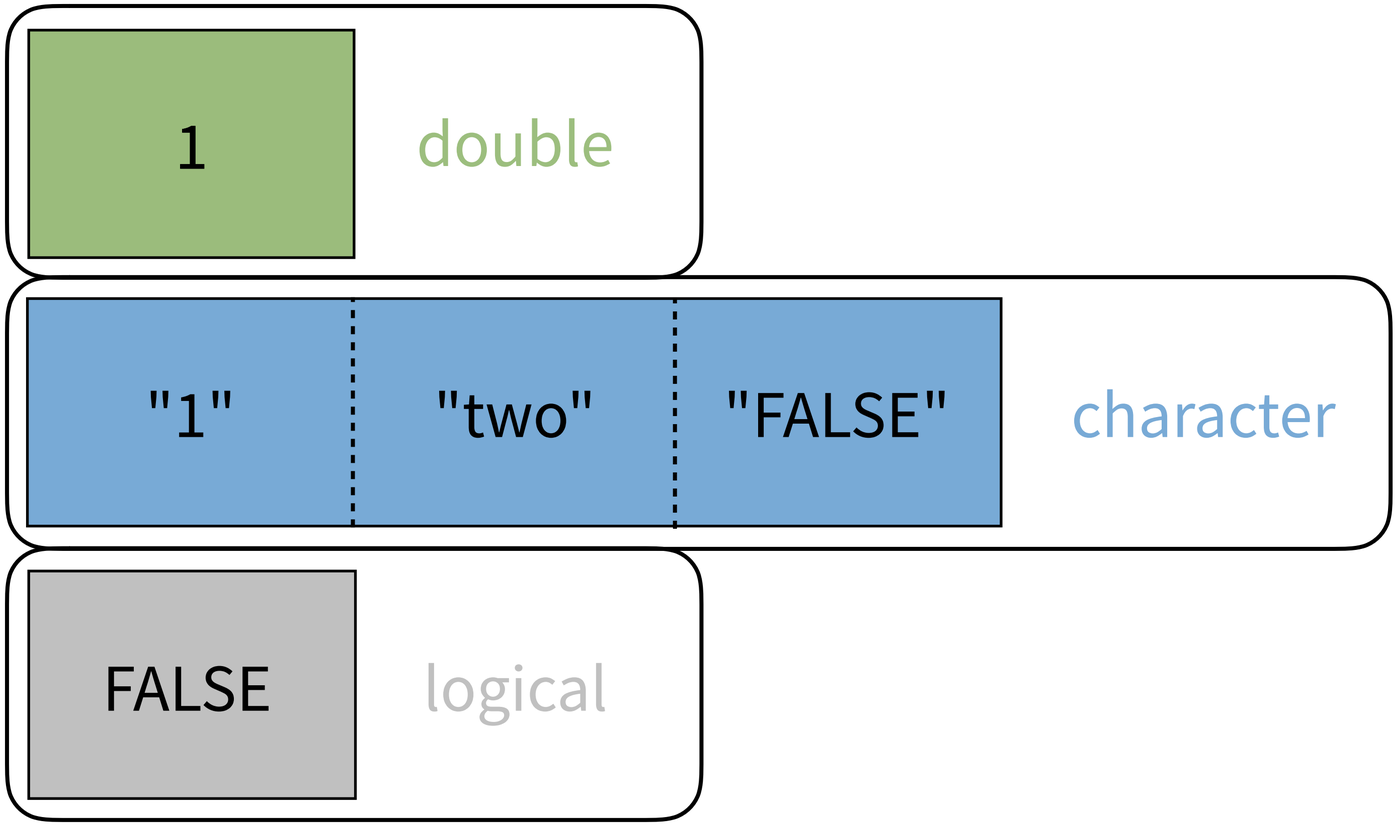
List



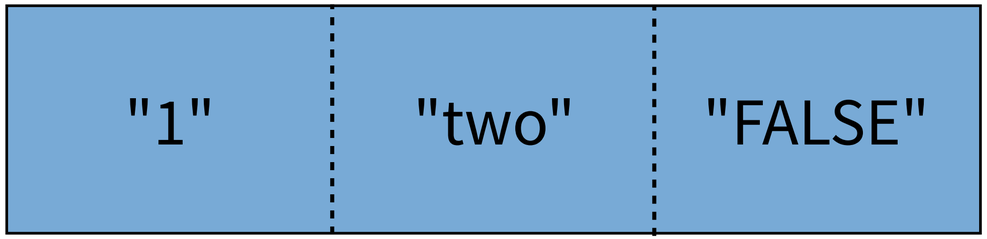
Atomic Vector



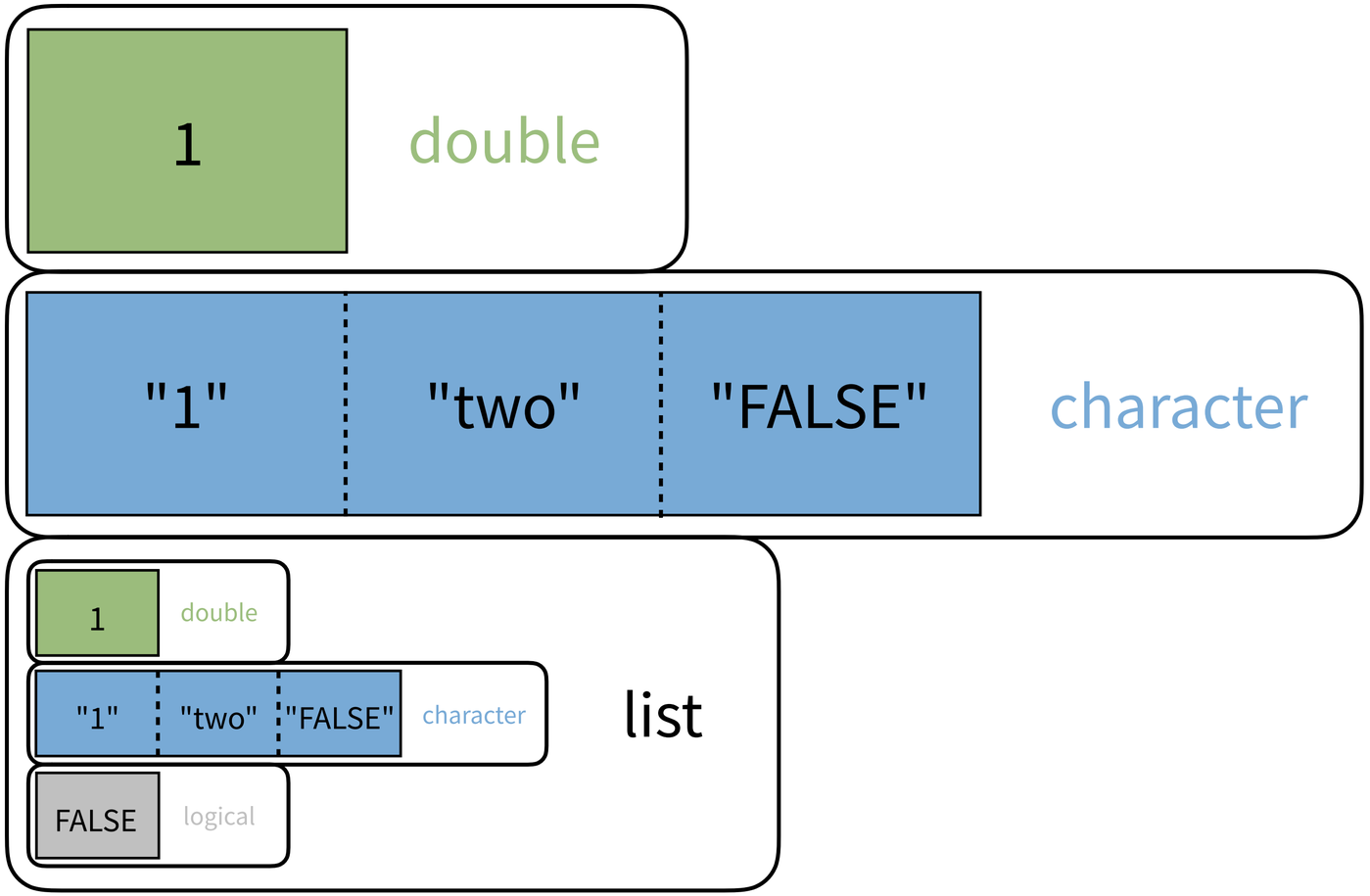
List



Atomic Vector



List



Your Turn 2

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"]
```

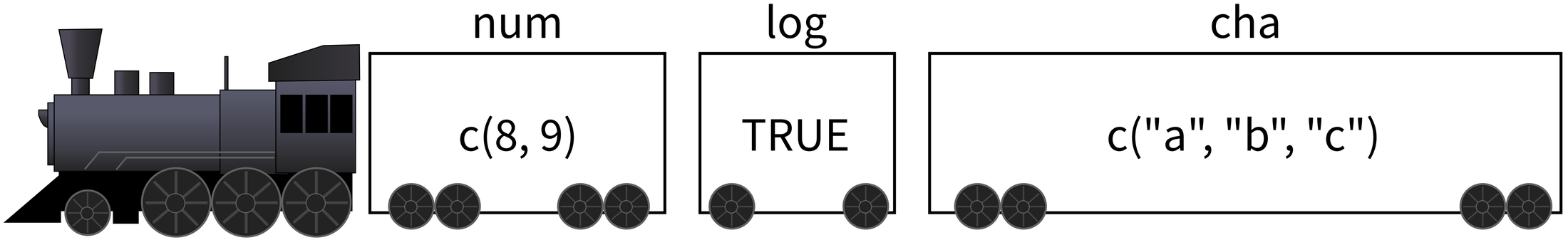
```
$num
[1] 8 9
```

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

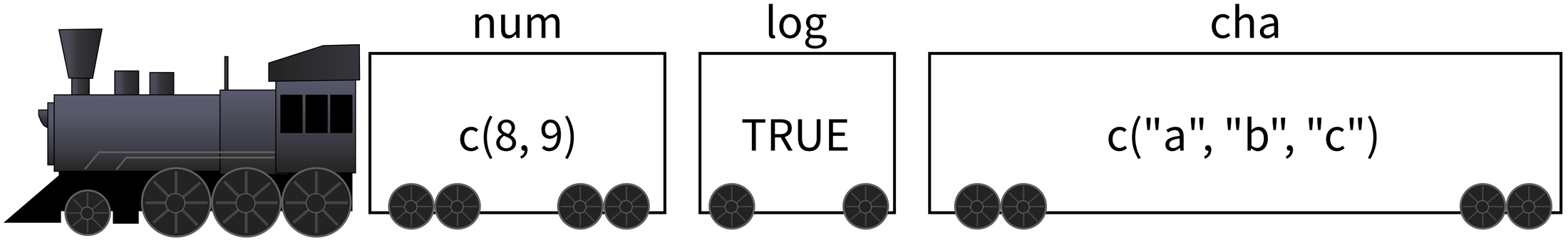
```
a_list$num
```

```
[1] 8 9
```

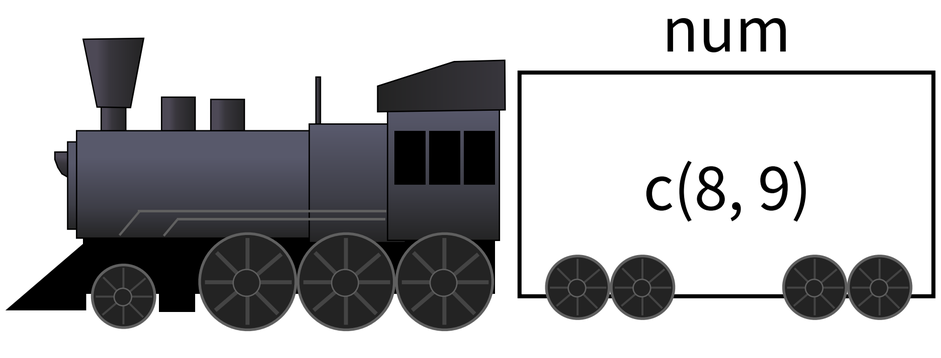
An atomic vector

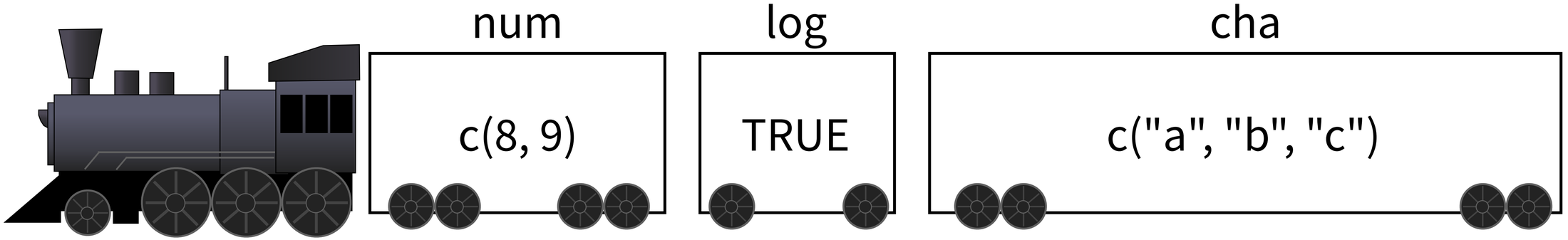



```
lst <- list(num = c(8,9), log = TRUE, cha = c("a", "b", "c"))
```

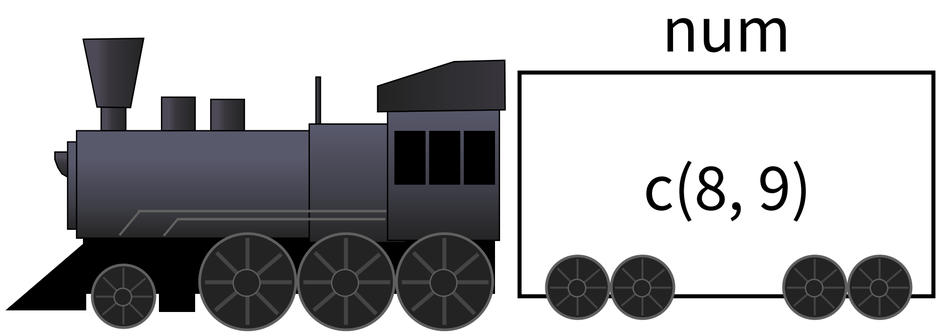



```
lst["num"]
```



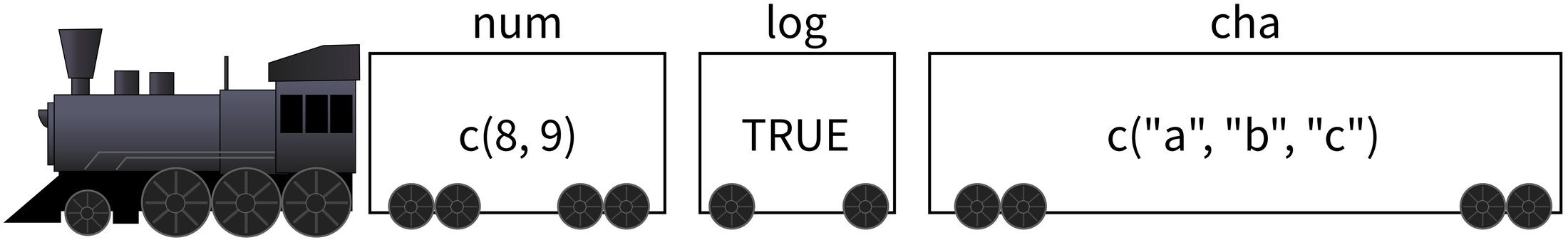


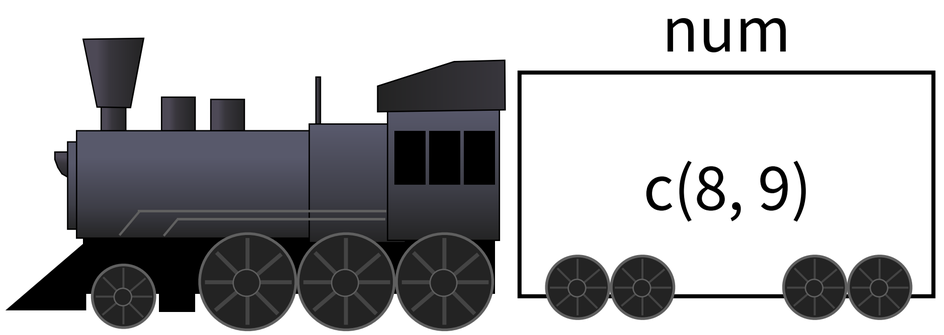

```
lst["num"]
```




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

c(8, 9)






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

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

c(8, 9)

```
lst$num
```

c(8, 9)

Your Turn 3

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

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

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

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

```
# [1] 2 1 0 1 2
```

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

```
# Error in abs(lst) : non-numeric argument to mathematical
function
```

Take aways

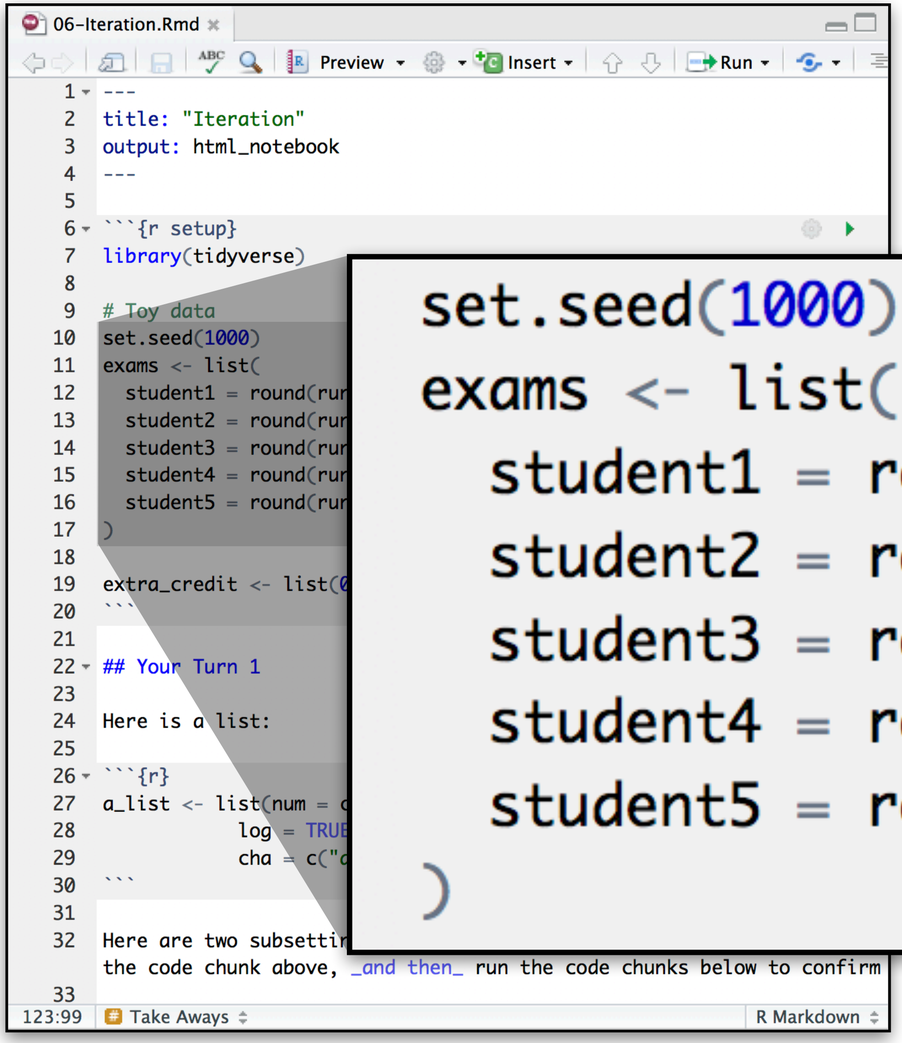
Lists are a useful way to organize data.

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

Iteration

Toy data

Suppose we have the exam scores of five students…



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?

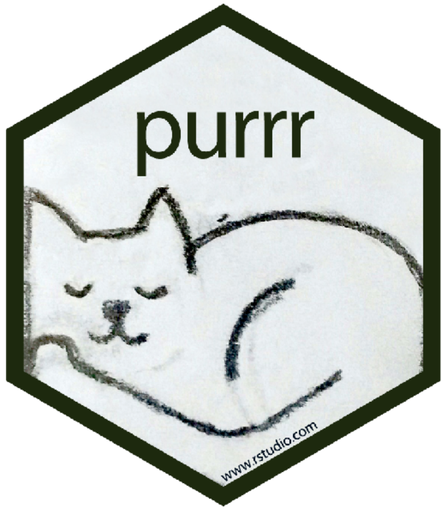
```
list(student1 = mean(exams$student1),
     student2 = mean(exams$student2),
     student3 = mean(exams$student3),
     student4 = mean(exams$student4),
     student5 = mean(exams$student5))
```

```
$student1
[1] 71.4

$student2
[1] 74.6

$student3
[1] 70.2

$student4
[1] 75.1

$student5
[1] 79.1
```

Is there a better way?

purrr

purrr



Functions for iteration.

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

Your Turn 4

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

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

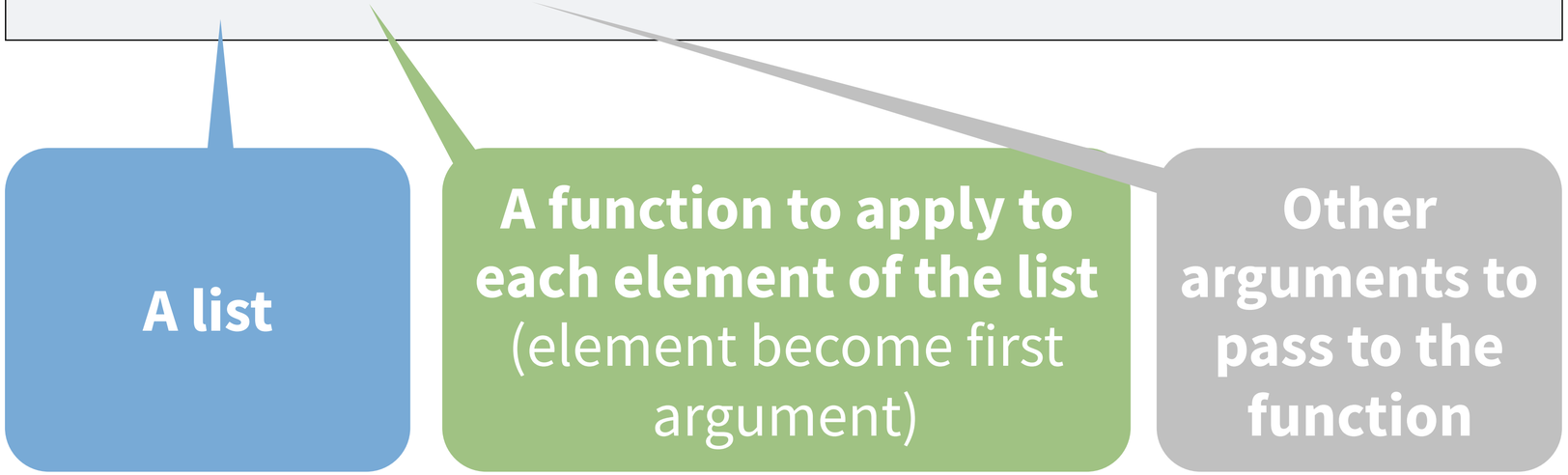
```
exams %>% map(mean)
```

```
$student1
[1] 71.4

$student2
[1] 74.6

$student3
[1] 70.2

$student4
[1] 75.1

$student5
[1] 79.1
```

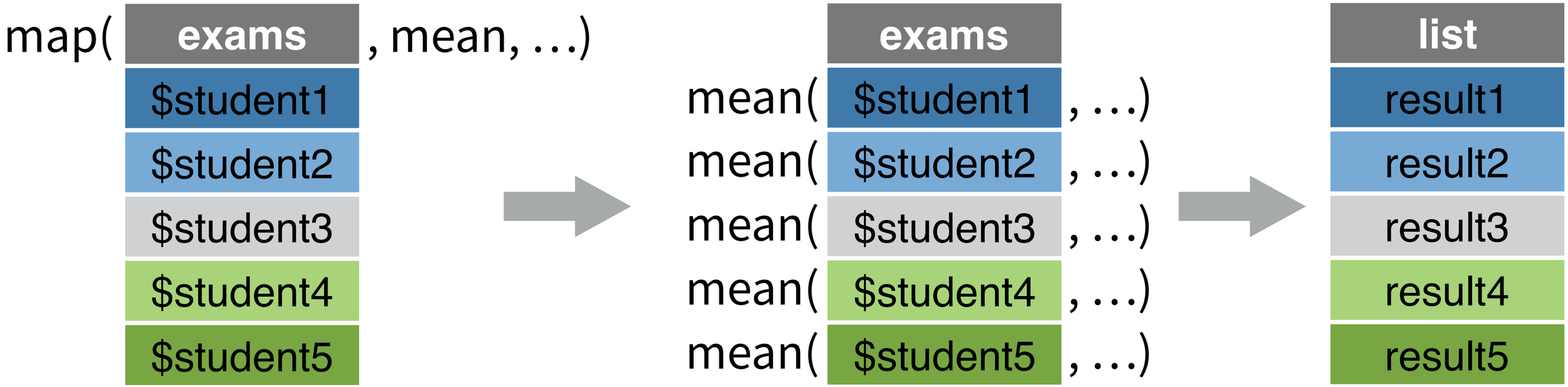
map()

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

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



map()



Your Turn 5

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

```
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 6

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

```
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**?

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 7

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

Define a new function, and pass in its name

```
double_best <- function(x) {
  (sum(x) + max(x)) / (length(x) + 1)
}

exams %>%
  map_dbl(double_best)
## student1   student2   student3   student4   student5
## 72.85703   76.30779   72.12398   77.39862   80.94991
```

Use an anonymous function

```
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
```

Use a purrr ~ (formula) shortcut

```
exams %>%
  map_dbl(~ (sum(.x) + max(.x)) / (length(.x) + 1))

## student1   student2   student3   student4   student5
## 72.85703   76.30779   72.12398   77.39862   80.94991
```

More on this approach at: https://github.com/cwickham/purrr-tutorial

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()

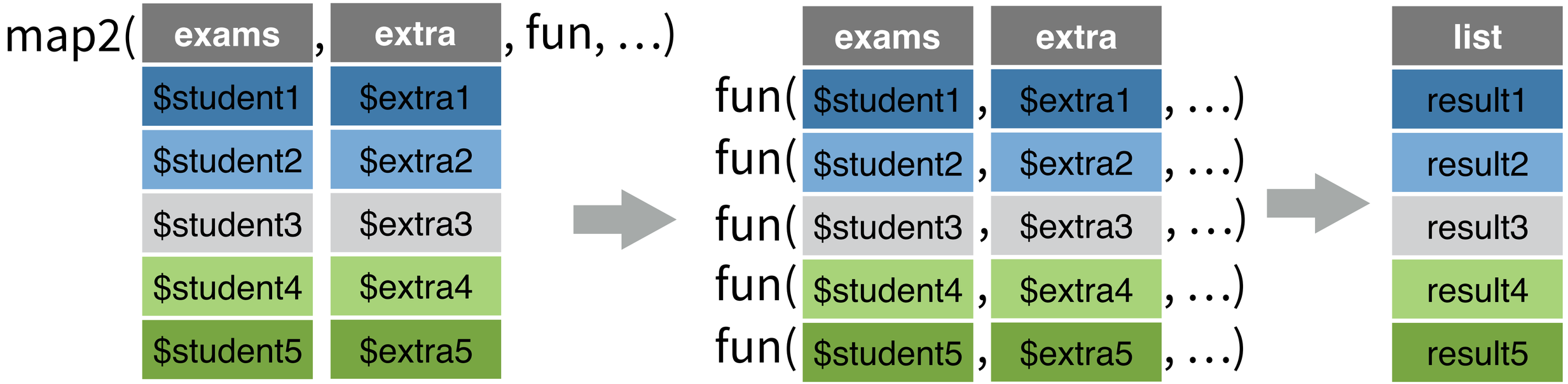
Applies a function to every element of two lists.
Returns the results as a list.

```
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()

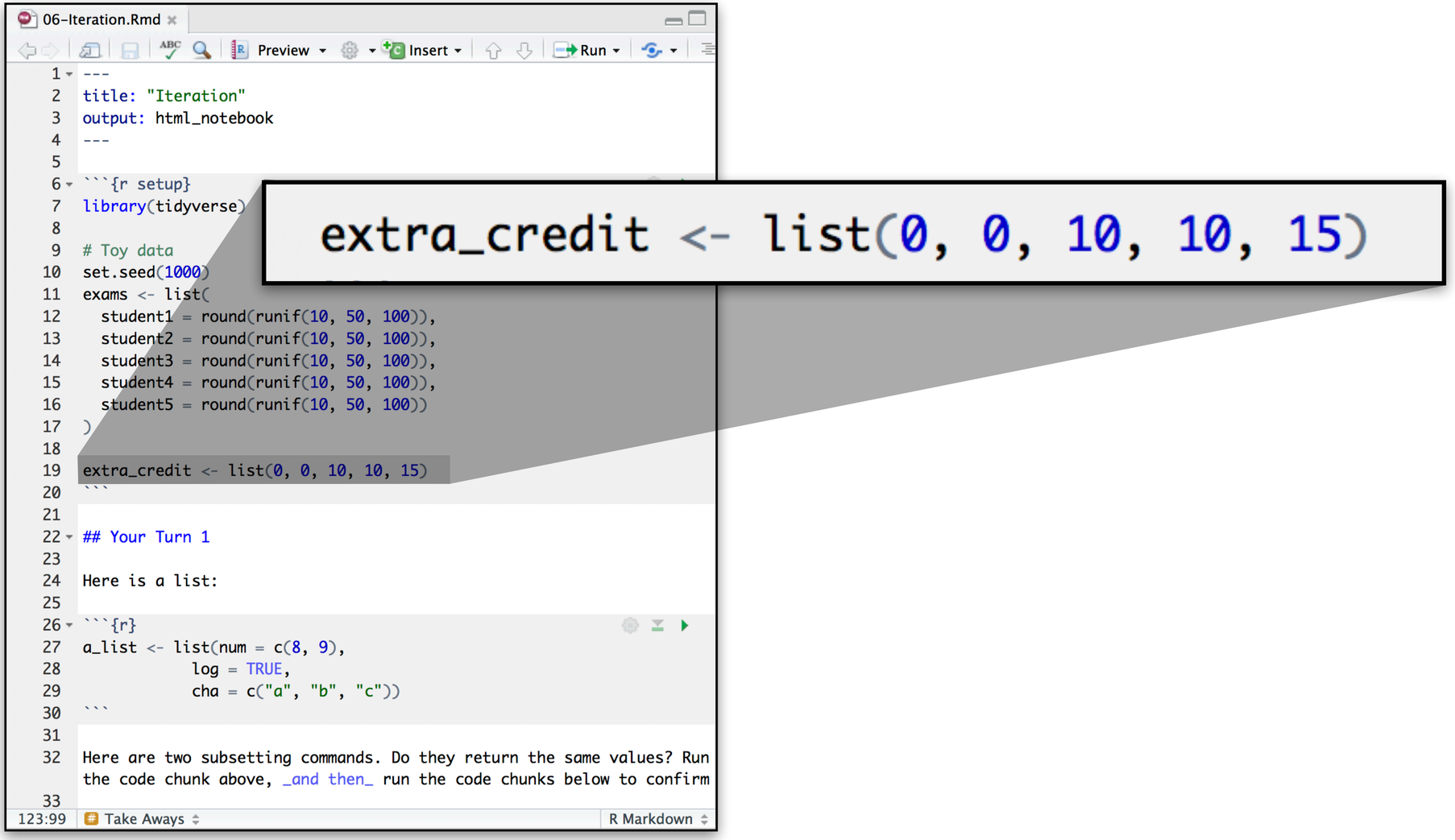


map functions

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…



Your Turn 8

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.

The grades with extra credit…

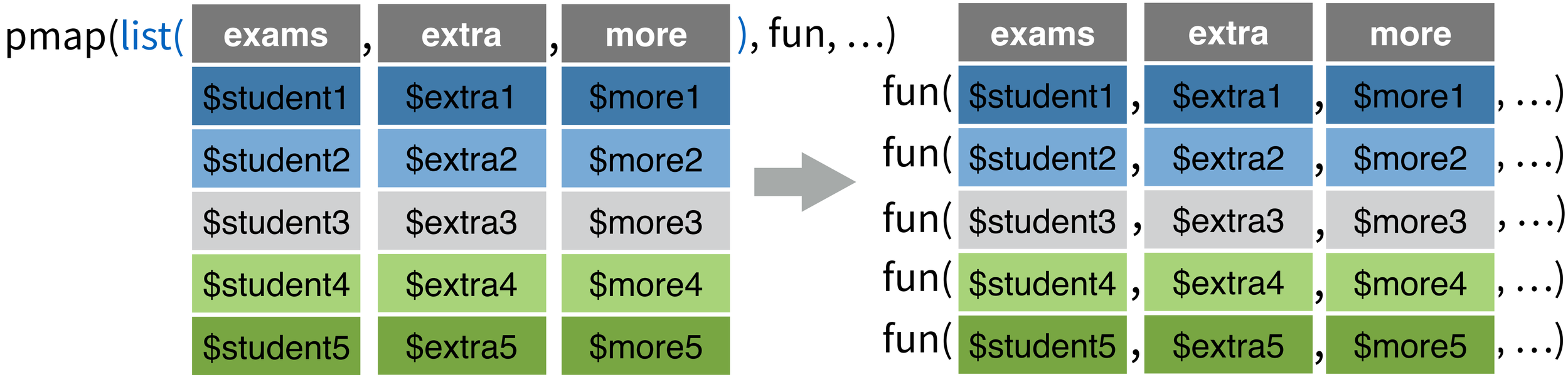
```
exams %>%
  map2_dbl(extra_credit, function(x, y) mean(x) + y)
```

```
## 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