Basic Concepts in Programming/ Introduction to R

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Basic Workflow

- Characterize the problem
- Spell out the steps towards solving the problem
- Materialize the steps in a programming language
- Test and debug

Basic Terminology

- variables
- types
- vectors
- indices
- operators
- functions
- conditionals
- loops
- input/output

Variables

- Placeholders for values
  - In R, you can assign values to a variable using “<-”

```
> a <- 5
> b <- 4
> a + b
[1] 9
> c <- a*b
> c
[1] 20
```

Variable Names in R

- Case-sensitive, so `x` is not the same as `X`.
- Must not begin with numbers (e.g. `1x`) or symbols (e.g. `%x`).
- Must not contain blank spaces or operator symbols:
  - use `subject.list` or `subject_list`
    but **not** `subject list` or `subject-list`

Types

- Different types → different operations
  - In R, the most important types are numbers and strings.

```
> a <- 5          # number
> b <- "Hello" # string
> c <- 1<2
> c
[1] TRUE          # logical
```

Vectors

- In R, the basic values are vectors.

```
a <- c(1,2,5.3,6,-2,4)
       # numeric vector
b <- c("apples","books","cats")
       # character vector
c <- c(TRUE,TRUE,TRUE,FALSE,TRUE,FALSE)
       # logical vector
```

Indices

- Address particular members of an object
  - In R, use square brackets `[]` for indices, and round brackets `()` for functions, e.g., `length()`
  - In R, the first element in a vector has the index 1. Thus, the index of the last element is the length of the vector.

```
> a <- c(37,42,89)
> a[1]
[1] 37
> length(a)
[1] 3
> a[length(a)]
[1] 89
```

Indices

- You can address the same things in different ways
  - Indices can be a vector of integers or logical values. (We will expand on this when we deal with data frames)

```
> a <- c(37,42,89)
> a[1:2]
[1] 37 42
> a[c(1,3)]
[1] 37 89
> a[c(TRUE, FALSE, FALSE)]
[1] 37
> a[a>40]      # where a>40 returns
[1] 42 89      # FALSE TRUE TRUE
```

Operators

- Programming language-dependent
- Common operators in R:

`+ - * / %% ^`	arithmetic
`> >= < <= == !=`	relational
`! & |`	logical
`~`	model formulae
`<- ->`	assignment
`$`	list indexing (the 'element name' operator)
`:`	create a sequence

Exercise 1

- Use R to find all the numbers between 1 and 2000 which are multiples of 317.
- You will need the operators `:` and `%%`

```
> 1:5
[1] 1 2 3 4 5
> 18 %% 5
[1] 3
> 4 %% 2
[1] 0
```

Exercise 1

- Use R to find all the numbers between 1 and 2000 which are multiples of 317.
- Solution:

```
> a <- 1:2000
> a[ a%%317 ==0]
[1]  317  634  951 1268 1585 1902
```

- Follow-up: Use R to find out how many numbers between 1 and 2000 are multiples of 17.

Exercise 2

- Find all the words with less than 6 or more than 8 characters in the vector `c("Maine", "Maryland", "Massachusetts", "Michigan", "Minnesota", "Mississippi", "Missouri", "Montana”).`
- You will need the OR operator `|` and function `nchar()`

```
> a <- "Maryland"
> nchar(a)
[1] 8
```

Exercise 2

- Find all the words with less than 6 or more than 8 characters in the given vector.
- Solution:

```
> a<- c("Maine", "Maryland",
"Massachusetts", "Michigan", "Minnesota",
"Mississippi", "Missouri", "Montana")
> a[nchar(a)>8 | nchar(a)<6]
[1] "Maine" "Massachusetts" "Minnesota"
"Mississippi"
```

- Follow-up: Modify this function to show the number of characters of the returned values.

Functions

- R has a wide range of built-in functions.

```
length(c(4,2,9))
[1] 3
max(c(1,2,4,2,5,-1,1))
[1] 5
sum(c(1,2,3,4))
[1] 10
mean(c(0.5, 3.4, 8.9, 4,4, 6.7))
[1] 4.583333
sd(c(0.5, 3.4, 8.9, 4,4, 6.7))
[1] 2.893729
```

Functions

- Use `help()` to look up functions
- You can also write your own functions

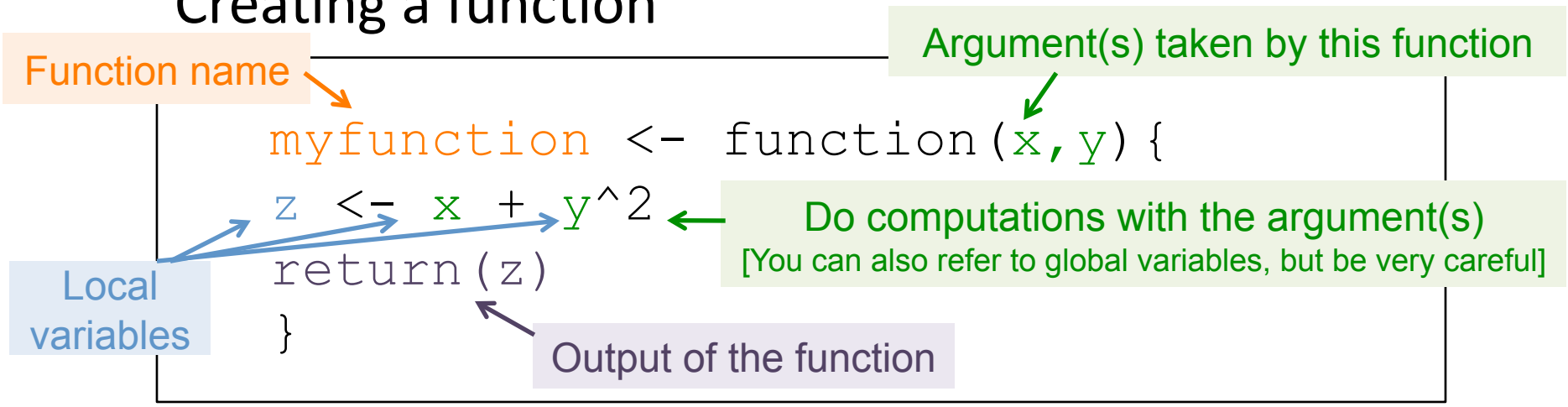
```
> myfunction <- function(x,y){
+  z <- x + y^2
+ return(z)
+ }
> answer <- myfunction(3,4)
> answer
[1] 19
```

- Local vs. global variables

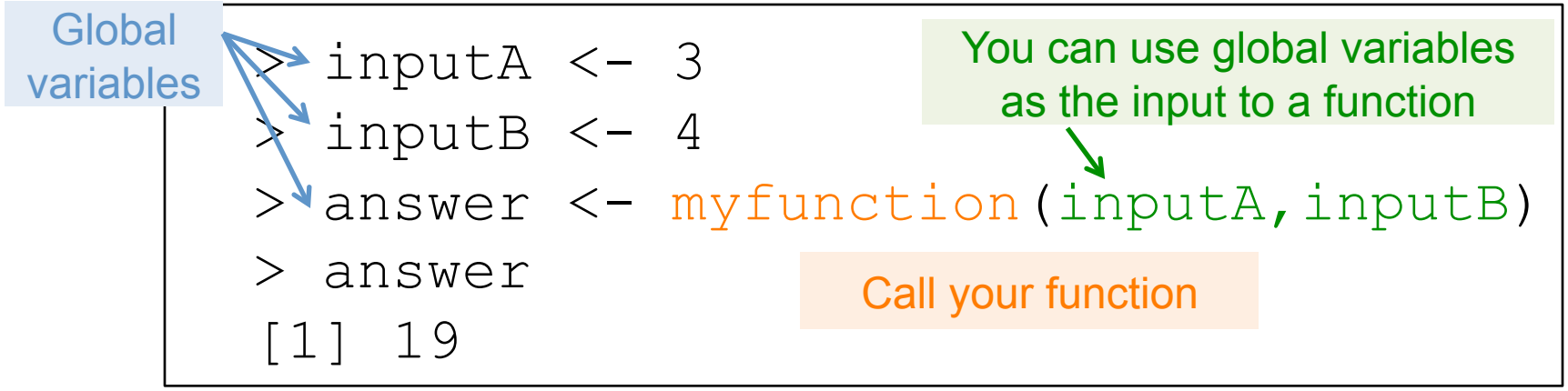
Please download
the new slides and exercises

Functions

Creating a function



Calling/Using your function



Exercise 3

- Write a function that returns the product of the minimum and maximum of the input vector.
- You will need max() and min().

Exercise 3

- Write a function that returns the product of the minimum and maximum of the input vector.
- Solution:

```
exercise3 <- function(x){
   product <- max(x)* min(x)
   return(product)
 }
```

```
> exercise3(c(7,-3,2,30))
[1] -90
```

Test your function

- Follow-up: Modify this function to consider the maximum and minimum of *the absolute value* of the input vector. [Hint: use abs()]

Exercise 4

- Write a function that converts temperatures from Celsius to Fahrenheit.
- $[°F] = {}^{9}\!/_{5}\,[°C] + 32$

Exercise 4

- Write a function that converts temperatures from Celsius to Fahrenheit, where [°F] = $^{9}/_{5}$ [°C] + 32.
- Solution:

```
exercise4.c2f <- function(celsius){
 fahreheit <- (celsius*9/5)+32
 return(fahreheit)
  }
```

```
> exercise4.c2f(20)
[1] 68
```

Test your function

- Follow-up: Write a function that converts from Fahrenheit to Celsius.

Exercise 5

- Write a function that finds all the numbers within a vector `x` that are multiples of an integer `y`. [a general version of Ex. 1]

Exercise 5

- Write a function that finds all the numbers within a vector `x` that are multiples of an integer `y`. [a general version of Ex. 1]
- Solution:

```
exercise5 <- function(x,y){
   z<- x[(x%%y)==0]
   return(z)
 }
```

```
> ans5 <- exercise5(1:2000,317)
```

Conditionals

- Carry out an operation when a condition is satisfied, e.g., if A is true then do B, otherwise do C (or nothing)
- Example (finding the absolute value of an input without using `abs()`):

```
> ifelse(x<0,-x,x)
> if (x<0) {-x} else {x}
```

- *Quick exercise*: try to input a vector and see how these two functions differ

Conditionals

- Compare `ifelse` and `if`:

```
abs.ifelse <- function(x){
 result <- ifelse(x<0,-x,x)
 return(result)
 }
```

Test your function

```
> a <- -10
> abs.ifelse(a)
[1] 10
>
> b <- c(2,3,-4)
> abs.ifelse(b)
[1] 2 3 4
```

Conditionals

- Compare `ifelse` and `if`:

```
abs.if <- function(x){
 if (x<0) {result <- -x} else {result <- x}
 return(result)
 }
```

Test your function

```
> a <- -10
> abs.if(a)
[1] 10
> b <- c(2,3,-4)
> abs.if(b)
[1]  2  3 -4
Warning message:
In if (x < 0) { :
  the condition has length > 1 and only the first
element will be used
```

Conditionals

- `ifelse` evaluates each element in turn.
  - Good for setting values of variables based on a vector of logical conditions
  - e.g., taking the absolute value of a vector
- `if` evaluates only the first element. All other elements are ignored.
  - Use this for *flow control – to execute one or more statements based on a condition*

Exercise 6

- Write a function that takes two arguments, `x` and `y`, and outputs a message about whether `x` exists in `y`.
- You will need the operator `%in%`.

```
> content<- c("D2","V4","B6","N5","F3")
> "N5" %in% content
[1] TRUE
> "N4" %in% content
[1] FALSE
```

- Optional: You might also need `cat()`.

```
> a <- "apple"
> b <- "tree"
> cat(a,b)
apple tree
```

Exercise 6

- Write a function that takes two arguments, `x` and `y`, and outputs a message about whether `x` exists in `y`.
- Solution:

```
exercise6 <- function(x,y){
  if (x %in% y) {
    cat(x,"exists in",y)
    }
  else {
    cat(x,"does not exist in",y)
    }
}
```

```
> target <- c("D2")
> content <- c("C1","B4","D2","F5")
> exercise6(target, content)
D2 exists in C1 B4 D2 F5
```

Loops

- For-loops
  - repeat an action for a predetermined number of times
  - the value of the local variable changes in each iteration

```
> for (i in 3:5){
+   print(i)
+ }
[1] 3
[1] 4
[1] 5
```

For **each element in this vector** the local variable is set to the value of that element and the *statements in the loop* are evaluated.

Loops

- For-loops
  - another example:

```
> x <- c("Happy","New","Year")
> for (i in x) {print(i)}
[1] "Happy"
[1] "New"
[1] "Year"
> for (i in x[2:length(x)]) {print(i)}
[1] "New"
[1] "Year"
```

Loops

- For-loops
  - What is the difference?

```
> x <- c("Happy","New","Year")
> for (i in x[2:length(x)]) {print(i)}
[1] "New"
[1] "Year”
```

```
> for (i in 2:length(x)) {print(x[i])}
[1] "New"
[1] "Year"
```

Exercise 7

- Using a for-loop, write a function that prints each of the values in a vector, followed by "Even" if it is divisible by 2 and "Odd" otherwise.
- You can use `cat()` to display the number and the string together

```
> a<- "R Course"
> cat(a, "Day 2")
R Course Day 2
```

Exercise 7

- Using a for-loop, write a function that prints each of the values in a vector, followed by “Even” if it is divisible by 2 and “Odd” otherwise.
- Solution:

```
> exercise7 <- function(x){
+  for (i in x){
+    if (i%%2==0) {result <- "Even”
+       } else {result <- "Odd”}
+    cat(i,result,"\n")
+  }
+ }
> exercise7(c(95,46))
95 Odd
46 Even
```

“\n” is a line break

Exercise 7

- Follow-up: modify this function to print “Not an integer” (instead of “Odd”) if a value is not an integer [Hint: you can use %% to determine is a number is an integer]

Exercise 8

- Using two for-loops, print 1 instance of "`Apples`" followed by 4 instances of "`Oranges`", and do this 3 times.

Exercise 8

- Using two for-loops, print 1 instance of "Apples" followed by 4 instances of "Oranges", and do this 3 times.
- Solution:

```
for (i in 1:3){
  print ("Apples")
  for (j in 1:4){
    print ("Oranges")
  }
}
```

- Follow-up: Make this a function that can do the same action to different word pairs.

Exercise 8

- Follow-up: Make this a function that can do the same action to different word pairs.

```
exercise8 <- function(word1,word2){
  for (i in 1:3){
    print (word1)
    for (j in 1:4){
      print (word2)
    }
  }
}
```

```
> exercise8("Apples","Oranges")
```

Loops

- While-loops
  - similar to for-loops, execute some codes repeatedly until a condition is satisfied

```
> i <- 1
> while (i <= 3) {
+     print(i)
+     i <- i + 1
+ }
[1] 1
[1] 2
[1] 3
```

Exercise 9

- Using a while-loop, write a function that computes the sum of the values in a vector. [Call it `my_sum()`. This should give the same result as R's built-in `sum()` function.]

Exercise 9

- Using a while-loop, write a function that computes the sum of the values in a vector.
- Solution:

```
my_sum <- function(x){
  i <- 1
  temp.sum <- 0
  while (i <= length(x)) {
   temp.sum <- temp.sum + x[i]
   i <- i + 1
  }
  return(temp.sum)
}
```

Exercise 10

- Using a while-loop, compute the factorial of 53. [This should give the same result as `factorial(53)`.]
- Follow-up: Make this a function. [Call it `my_factorial()`]

Exercise 10

- Follow-up: Make this a function that computes the factorial of an input. [Call it `my_factorial()`]
- Solution:

```
my_factorial <- function (x) {
   fac <- 1
   while (x > 0) {
     fac <- fac * x
     x <- x - 1
   }
   return(fac)
}
```