Lecture 3: R Basics I

EC7422: Data Science for Economic Analysis

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Why code instead of spreadsheet surgery?

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Gene name errors are widespread in the scientific literature

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Genome Biology **17**, Article number: 177 (2016) | Cite this article

Abstract

The spreadsheet software Microsoft Excel, when used with default settings, is known to convert gene names to dates and floating-point numbers. A programmatic scan of leading genomics journals reveals that approximately one-fifth of papers with supplementary Excel gene lists contain erroneous gene name conversions.

The paper captures a common problem with spreadsheet workflows: once many manual edits accumulate, the data pipeline becomes hard to inspect, explain, and reproduce. In this case, Excel rewrote certain gene codes into dates without warnings, which led to widespread errors in the genetic literature.

Programming fundamentals

Most languages revolve around a small set of ideas:

- Expressions return values
- Operators combine values
- Assignment binds names
- Types shape behavior
- Logic builds conditions
- Control flow directs execution
- Functions package reusable code

These ideas recur across most programming languages. The syntax changes, but the underlying concepts around values, names, types, logic, and functions are broadly transferable.

Setup check

- VSCode `R` interpreter running
- `R` Script file open
- `Ctrl/cmd+enter` sends line to interpreter

The key distinction is conceptual: code is written in the script editor and sent to the `R` interpreter. In VS Code, the interpreter may run inside a terminal pane, but that pane is only the interface, not the shell itself.

Moving from `Stata` to `R`

Some habits carry over; some do not:

- Not limited to one dataset in memory
- Stata commands = R functions
- Less “hand-holding”, need to be more mindful about what you run
- More dependent on external packages

The main transfer from `Stata` is conceptual rather than syntactic. Many familiar tasks still exist, but `R` makes objects, function calls, scripts, and packages much more explicit.

R fundamentals

> “Everything that exists is an object. Everything that happens is a function call.”

All objects can be named, inspected, and reused.

This slogan, attributed to John Chambers (the creator of the S language), is informal, but useful. In R, values, tables, functions, and model results are all objects that can be named, inspected, stored, and passed to other functions.

- Expressions, Operators, And Assignment
- Objects And Types
- Logic And Missingness
- Control Flow
- Functions
- Packages, Comments, Errors, and Help

Arithmetic with operators

Type these in the R interpreter:

```
12 + 3
```

```
[1] 15
```

```
8 - 33
```

```
[1] -25
```

```
20 / 3
```

```
[1] 6.666667
```

```
10^(2 + 1) - 1
```

```
[1] 999
```

+, -, /, and ^ are arithmetic operators.

The R interpreter evaluates each expression and prints the resulting value. At this stage, the value is visible, but not stored under a reusable name.

Evaluation in the interpreter

- The code is an expression
- The interpreter evaluates it
- The printed result is a value
- Nothing saved yet

This is the basic rhythm of interactive work in R: type an expression, let the interpreter evaluate it, inspect the result, and decide whether it is worth storing under a name.

Assignment

<- stores an object in memory and binds a name to it

```
1 coffee_cups <- 3
2 price_per_cup <- 25
```

We can then run operations on those names:

```
1 coffee_cups * price_per_cup
```

```
[1] 75
```

You can also use = for assignment in R, but <- is the **convention**. The main reason is that = is also used for

The key idea is that values exist independently of names. Assignment connects a name to the current value in memory.

Naming rules

Names should be valid and readable:

```
1 1a <- 1
```

```
Error in parse(text = input): <text>:1:2:
unexpected symbol
1: 1a
     ^
```

- Start with a letter
- Case sensitive (`income` and `Income` are different)
- Descriptive beats short (no character limit!)

Names can be rebound / overwritten

```lua
result <- 3
result
```

```
[1] 3
```

```lua
result <- "pass"
result
```

```
[1] "pass"
```

Rebinding changes what the name points to; it does not mutate some permanent meaning attached to the name itself. That is why the same name can later refer to a number, a string, a table, or a function.

Session memory is temporary

- Objects live in session memory
- Restart R -> gone
- Scripts recreate state

This is one reason scripts matter. A script records how objects are created so the session can be rebuilt from code rather than from memory.

- Expressions, Operators, And Assignment
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Objects, names, functions

Much R code can be read as a sequence of steps:

- Create or retrieve an object
- Bind it to a name
- Pass it to a function
- Get back another object
- Inspect when unsure

This is a compact reading rule rather than a complete theory of R. It is useful because many lines can be understood as: create an object, bind it to a name, pass it to a function, and get another object back.

Example

```
1 score <- 62
2 sqrt(score)
```

```
[1] 7.874008
```

- `score` is a name
- `62` creates a numeric object (a `double`)
- `<-` binds that object to the name `score`
- `sqrt` is a function object
- `sqrt(score)` calls that function

This is the recurring pattern for the course. In `R`, a function name like `mean` refers to an object. Adding parentheses, as in `mean(x)`, calls that function with an input (the object named `x`).

How is an object stored in memory?

- `typeof()` tells us

```
typeof(1.0)
```

```
[1] "double"
```

```
typeof(1L)
```

```
[1] "integer"
```

```
typeof(TRUE)
```

```
[1] "logical"
```

```
typeof("text")
```

```
[1] "character"
```

Remember: everything is an object!

```
typeof(typeof)
```

```
[1] "closure"
```

`typeof()` reports the underlying storage mode of an object. This matters because the storage type influences which operations are possible and how coercion behaves later.

Basic atomic types

Most beginner examples use a few basic storage types:

- `double` numbers with decimals
- `integer` whole numbers
- `logical` true / false
- `character` text

These storage types matter because they determine which operations are valid and how values behave in vectors and tables.

`typeof()` is storage, `class()` is behavior

Storage type and class often overlap, but not always:

```
today <- as.Date("2026-04-07")
typeof(today)
```

```
[1] "double"
```

```
class(today)
```

```
[1] "Date"
```

The storage type tells how the object is represented internally, while the class tells which methods and behaviors are attached to it. Dates are a good example: stored as numbers underneath, but treated as dates by many functions.

Class can change a function's method

The same function name can behave differently for different object classes:

```r
mean(c(1, 2, 3, 4))
```

```
[1] 2.5
```

```r
mean(as.Date(c("2024-01-01", "2025-01-01")))
```

```
[1] "2024-07-02"
```

- Same function name
- Different object classes
- Different methods behind the scenes

This is one reason class matters in `R`. Many functions are generic: the printed name stays the same, but the method used depends on the class of the object supplied. Check with `methods(mean)` to see which methods are available for `mean`. Here we used `mean.default()` for the numeric vector and `mean.Date()` for the date vector.

Live coding: inspect simple objects

- Number
- Text
- Date
- Check `typeof()` / `class()`

This exercise keeps the focus on the inspection habit. The main point is to create a few simple objects and check how R reports their storage mode and class.

- Expressions, Operators, And Assignment
- Objects And Types
- **Logic And Missingness**
- Control Flow
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Logic uses operators

We often need conditions, not just calculations:

```
1 1 == 2
```

```
[1] FALSE
```

```
1 1 < 2
```

```
[1] TRUE
```

```
1 1 == 2 & 1 < 2
```

```
[1] FALSE
```

```
1 1 == 2 | 1 < 2
```

```
[1] TRUE
```

- ==, <, > compare
- &, | combine conditions

Assignment is different from comparison although the symbols look similar. `=` assigns an object to a name, `==` compares two objects. Logical operators like `&` and `|` combine logical values, not numbers. The result of a logical expression is always `TRUE` or `FALSE`.

A practical condition

```
1 exam_score <- 58
2 exam_score >= 50
```

```
[1] TRUE
```

```
1 exam_score >= 50 & exam_score < 70
```

```
[1] TRUE
```

```
1 exam_score < 50 | exam_score > 90
```

```
[1] FALSE
```

Precedence

Let's say we want to check if a variable is larger than two other variables:

```
1 x <- 3; y <- 1; z <- 4
2 x > y & z
```

```
[1] TRUE
```

Logical operators (>, ==, etc) are evaluated before Boolean (& and |).

```
1 3 > 1
```

```
[1] TRUE
```

```
1 TRUE & 4
```

```
[1] TRUE
```

To get it right we need to be explicit:

```
1 x > y & x > z
```

```
[1] FALSE
```

Logical operators bind tighter than Boolean operators, so `x > y & z` is parsed as `(x > y) & z`, not `x > (y & z)`. The second operand `z` (which is `4`) is then coerced to logical: R runs `as.logical(4)`, and all non-zero numbers become `TRUE`, only `0` becomes `FALSE`. This is a common source of bugs when the intended logic is not made explicit.

Decimal comparisons need care

Decimal numbers are stored as floating points (`double`), which can lead to surprising results:

```r
0.3 == 0.3
```

```
[1] TRUE
```

```r
0.1 + 0.2 == 0.3
```

```
[1] FALSE
```

Use a tolerance-based check instead:

```r
isTRUE(all.equal(0.1 + 0.2, 0.3))
```

```
[1] TRUE
```

```r
abs((0.1 + 0.2) - 0.3) < 1e-8
```

```
[1] TRUE
```

This is not an R quirk; it is a general feature of floating-point arithmetic in modern programming languages.

! negates a logical result

! flips TRUE to FALSE and FALSE to TRUE:

```
1 !TRUE
```

```
[1] FALSE
```

```
1 !(1 < 3)
```

```
[1] FALSE
```

- Useful for “not”
- Common in filters

`Not available` = NA

`NA` is a **missing value indicator**

- `NA` is not zero
- `NA` is not false
- `NA` is not equal to itself!

```
NA > 0
```

```
[1] NA
```

```
NA == FALSE
```

```
[1] NA
```

```
NA == NA
```

```
[1] NA
```

Unlike Stata, missing values are not treated as very large numbers. Missingness often propagates through calculations until it is handled explicitly.

`is.na()` checks missingness

`is.na()` returns `TRUE` for missing values:

- `TRUE` means missing
- `FALSE` means observed

```
1 is.na(NA)
```

```
[1] TRUE
```

```
1 is.na(3)
```

```
[1] FALSE
```

`is.na()` is the standard way to test for missingness. On longer objects it returns one logical result per element; that becomes especially important when working with vectors and tables.

Special values in numeric work

Some numeric operations do not return ordinary finite numbers or `NA`:

- `Inf` / `-Inf` from dividing by zero
- `NaN` from undefined numeric operations

```
1 / 0
```

```
[1] Inf
```

```
0 / 0
```

```
[1] NaN
```

`is.na()` catches both `NA` and `NaN`, use `is.nan()` to catch only `NaN`:

```
is.na(NaN)
```

```
[1] TRUE
```

```
is.nan(NA)
```

```
[1] FALSE
```

```
is.nan(NaN)
```

```
[1] TRUE
```

These values are easy to confuse, but they mean different things. `NA` means a value is missing, while `NaN` means a numeric calculation itself was undefined.

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Control flow decides what runs

- Logic creates conditions
- Control flow uses them
- Branch or repeat as needed

Without control flow, code runs from top to bottom in a fixed order. Control-flow tools make execution depend on conditions or repetition, which is what turns isolated expressions into small programs.

`if` / `else`

Use `if` / `else` when one logical value should choose one branch:

```
if (condition) "do this" else "do that"
```

`condition` is a single logical value that determines which expression is evaluated and returned.

```
1 if (1 == 3) "foo" else "bar"
```

```
[1] "bar"
```

`if` / `else` is a control-flow tool: the result depends on whether a condition evaluates to `TRUE` or `FALSE`. The important restriction is that the condition must be a single logical value.

Prefer the multi-line form

```
if (TRUE) {
    "yes"
} else {
    "no"
}
```

```
[1] "yes"
```

The one-line form is valid, but the multi-line form is usually easier to read, extend, and debug. Braces and line breaks matter more once conditions and returned expressions become longer.

`for` loops repeat a block

```
for (i in 1:4) {
    print(i^2)
}
```

```
[1] 1
[1] 4
[1] 9
[1] 16
```

- Repeats one recipe
- `i` takes one value at a time
- Basic control-flow tool

A `for` loop runs the same block repeatedly while a name takes different values in turn. Here `1:4` is a short way to generate the sequence from 1 to 4.

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Why functions matter

Functions make code more reusable:

- Same recipe, new inputs
- Less repetition
- Easier testing
- Easier debugging

Functions package a small piece of logic so it can be reused with different inputs. This is one of the main ways programming scales beyond one-off commands typed directly into the interpreter.

Functions: inputs and output

A function call passes inputs to a function and returns a value:

```r
sqrt(16)
```

```
[1] 4
```

```r
round(pi, digits = 3)
```

```
[1] 3.142
```

```r
abs(-12)
```

```
[1] 12
```

- Inputs go in
- A value comes back

When a function is called, `R` evaluates the call and produces a result. In simple cases it helps to think of the arguments being matched to the function's parameter names and the function body then being evaluated with those values.

A function call has structure

```
1 round(pi, digits = 3)
```

```
[1] 3.142
```

- `round` is the function
- `pi` is the first argument
- `digits = 3` names another argument
- The call returns `3.142`

This example separates four ideas that are easy to blur together: the function object itself, the values passed in, the names of optional arguments, and the value returned by the call. That distinction carries over directly to other programming languages.

Functions are objects too

```
1 typeof(mean)
```

```
[1] "closure"
```

```
1 class(mean)
```

```
[1] "function"
```

Functions are ordinary objects in R: they can be inspected, named, stored, and then called with arguments.

A function definition has three parts

```
add_bonus <- function(score, bonus = 5) {
    score + bonus
}
```

- Name on the left
- **Arguments** inside `function(...)`
- Returned expression inside `{ ... }`

The function definition creates a new function object and stores it under the name `add_bonus`. When the function is called, `score` and `bonus` are bound to the supplied arguments, and the expression inside the body is evaluated. Here the returned value comes from the last expression, `score + bonus`.

Named and default arguments

Inside function calls, `=` names an argument. Functions can also provide defaults:

```r
add_bonus <- function(score, bonus = 5) {
    score + bonus
}

add_bonus(55)
```

```
[1] 60
```

```r
add_bonus(55, bonus = 10)
```

```
[1] 65
```

Default arguments make a function easier to reuse because common choices do not have to be repeated every time. Naming an argument inside the call makes it explicit which parameter is being changed.

Functions use local names

```
x <- 10
show_local <- function() {
    x <- 20
    x
}
c(show_local(), x)
```

```
[1] 20 10
```

- Function call creates local names
- Local assignment stays local
- Outer name unchanged

When a function runs, it uses its own local names. Rebinding a name inside the function does not automatically overwrite a name with the same spelling outside the function.

Name lookup can go outward

```r
x <- 10
add_outer_x <- function(z) {
    z + x
}
add_outer_x(5)
```

```
[1] 15
```

- Local names first
- Then surrounding names
- Convenient, but easy to hide dependencies - avoid

If a name is not found inside the function, R can look outward to the surrounding environment. That is useful, but it can also make code harder to understand when important inputs are not passed explicitly as arguments.

Pipes (|>) make nesting less awkward

```
mean(c(seq(0, 10), rep(NA, 10)), na.rm = TRUE)
```

```
[1] 5
```

is the same as

```
seq(0, 10) |>
  c(rep(NA, 10)) |>
  mean(na.rm = TRUE)
```

```
[1] 5
```

- Piped content enters the first argument of the next function
- Avoids nested parentheses
- Reads left to right
- Still a function call, just different syntax

Write your own function

```r
return_smaller <- function(v1, v2) {
    min(v1, v2)
}

return_smaller(3, 8)
```

```
[1] 3
```

This is a deliberately small example: the main point is not the task itself but the pattern. A function definition gives a name to a reusable computation, and a later call runs that computation on new inputs.

Live coding: tiny function

- Add 10
- Give it a default
- Test two different inputs

This exercise combines the ideas from the previous slides: defining a function, adding a default argument, and then calling it with different inputs.

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Packages extend R

Packages add functions, datasets, and tools:

```
1 install.packages("ggplot2")
2 library(ggplot2)
```

- Install once
- Load when needed
- Read package documentation

Base R already does a lot, but packages are a central part of the language. Most real projects use a mix of base functions and contributed packages.

`package::function()` syntax

This pattern makes the source of a function explicit:

```
readr::read_csv("data.csv")
stats::filter(x, rep(1 / 3, 3))
```

- Avoid name conflicts
- Clarify provenance

Different packages can export functions with the same name. Writing `package::function()` avoids ambiguity and makes it clear which implementation is being used.

Comments start with

Comments are text for humans. The interpreter ignores them:

```r
# Drop missing values before computing the mean
average_non_missing <- mean(x, na.rm = TRUE)
```

- Add intent
- Add context
- Add warnings when needed

Comments are useful when they explain intent, assumptions, or gotchas that are not obvious from the code itself. They are not part of the computation.

Prefer comments that add context

```r
# Less helpful:
# Calculate the mean
m <- mean(x, na.rm = TRUE)

# Better:
average_non_missing <- mean(x, na.rm = TRUE)
```

- Clear names first
- Comments for context
- Avoid narrating obvious code

Self-explanatory names do most of the work. Comments are most useful when they explain why something is done, not simply what a line already says.

A short debugging checklist

- Read the error
- Check names
- Print object
- Check type / class
- Get help

This checklist is intentionally basic. Many early bugs come from a misspelled name, a wrong object type, or an incorrect assumption about what a function expects.

Read the error

```
1 my_data <- data.frame(a = c(1, 2), b = c(3,
2 my_dat[1]
```

```
Error:
! object 'my_dat' not found
```

- `my_data` exists
- `my_dat` does not

The important habit is to read the error literally before guessing at a fix. In this example the problem is not indexing syntax or object type; it is simply that the name in the second line does not match the name that was created.

Understanding error messages

```
1 dat = data.frame(a = c(1,2),
2                  b = c(3,4))
3 data[1]
```

```
Error in `data[1]`:
! object of type 'closure' is not subsettable
```

!?!?

```
1 typeof(data)
```

```
[1] "closure"
```

```
1 typeof(dat)
```

```
[1] "list"
```

Learning to read error messages will help you find coding errors.

Check names

```
1 exists("my_data")
```

```
[1] TRUE
```

```
1 exists("my_dat")
```

```
[1] FALSE
```

- Exact spelling matters
- One letter can break the code

Many early errors are simple naming problems. Before changing code, check whether the object name being used actually exists in memory.

Print object

```
1 my_data
```

```
  a b
1 1 3
2 2 4
```

- Check visible values
- Check obvious surprises

Printing the object is often the fastest way to catch a wrong value, a wrong shape, or a mistaken assumption about what the object contains.

Check type / class

```
1 typeof(my_data)
```

```
[1] "list"
```

```
1 class(my_data)
```

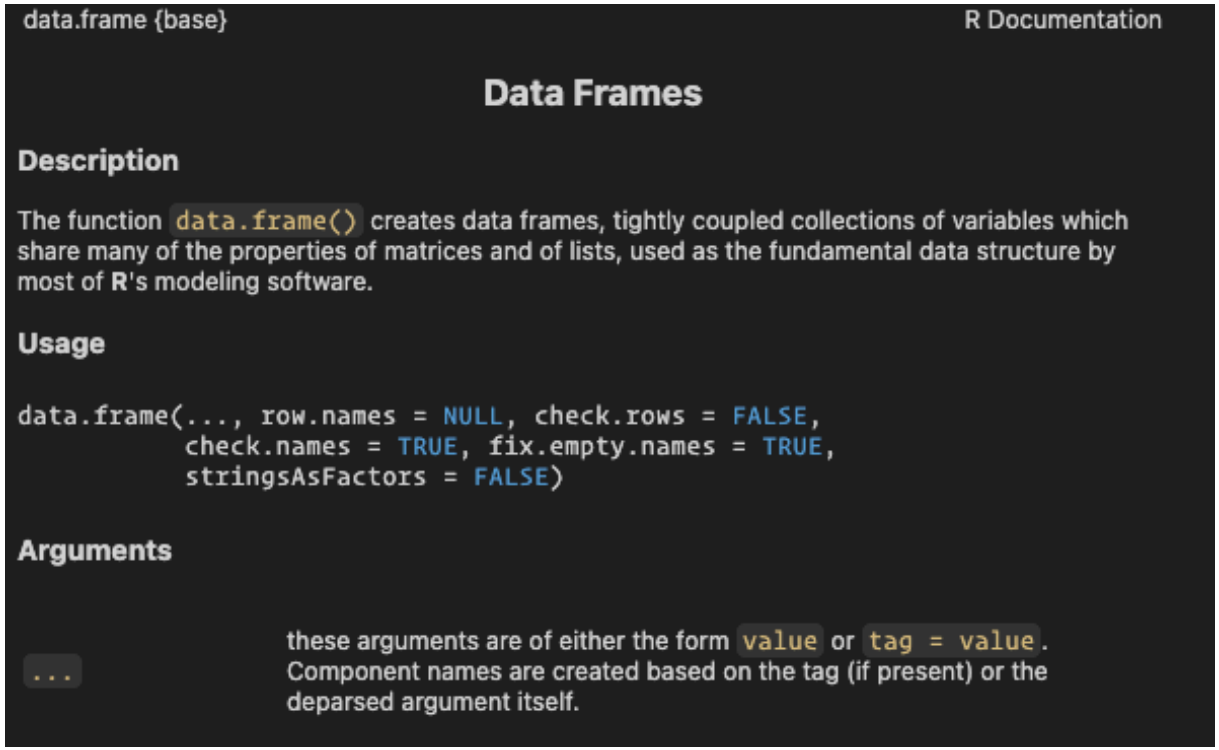
```
[1] "data.frame"
```

- Storage and behavior both matter
- Different objects support different operations

An expression may fail simply because the object is not the kind of thing the code expects. Checking both `typeof()` and `class()` helps narrow that down.

Get help

- `?mean`
- `?data.frame`
- `args(mean)`



data.frame {base} R Documentation

Data Frames

Description

The function `data.frame()` creates data frames, tightly coupled collections of variables which share many of the properties of matrices and of lists, used as the fundamental data structure by most of **R**'s modeling software.

Usage

```
data.frame(..., row.names = NULL, check.rows = FALSE,
           check.names = TRUE, fix.empty.names = TRUE,
           stringsAsFactors = FALSE)
```

Arguments

`...`	these arguments are of either the form `value` or `tag = value`. Component names are created based on the tag (if present) or the deparsed argument itself.

Help pages describe what a function does, what arguments it accepts, and what kind of object it returns. `args()` is a quick way to inspect the argument names without reading the full help page.

Package docs and vignettes

Package documentation is often the best starting point:

```
help(package = "ggplot2")
vignette(package = "ggplot2")
```

- Help page for the package
- List available vignettes

Function help pages answer small local questions. Vignettes are better when the goal is to understand a package's overall workflow, conventions, and typical usage patterns.

Main takeaways

- Expressions return values
- Assignment creates reusable names
- Types shape behavior
- Logic is explicit
- Control flow shapes execution
- Functions package reusable work
- Packages extend the language
- Help and errors are part of the workflow

Next lecture: Vectors, Tables, and Tidy Thinking