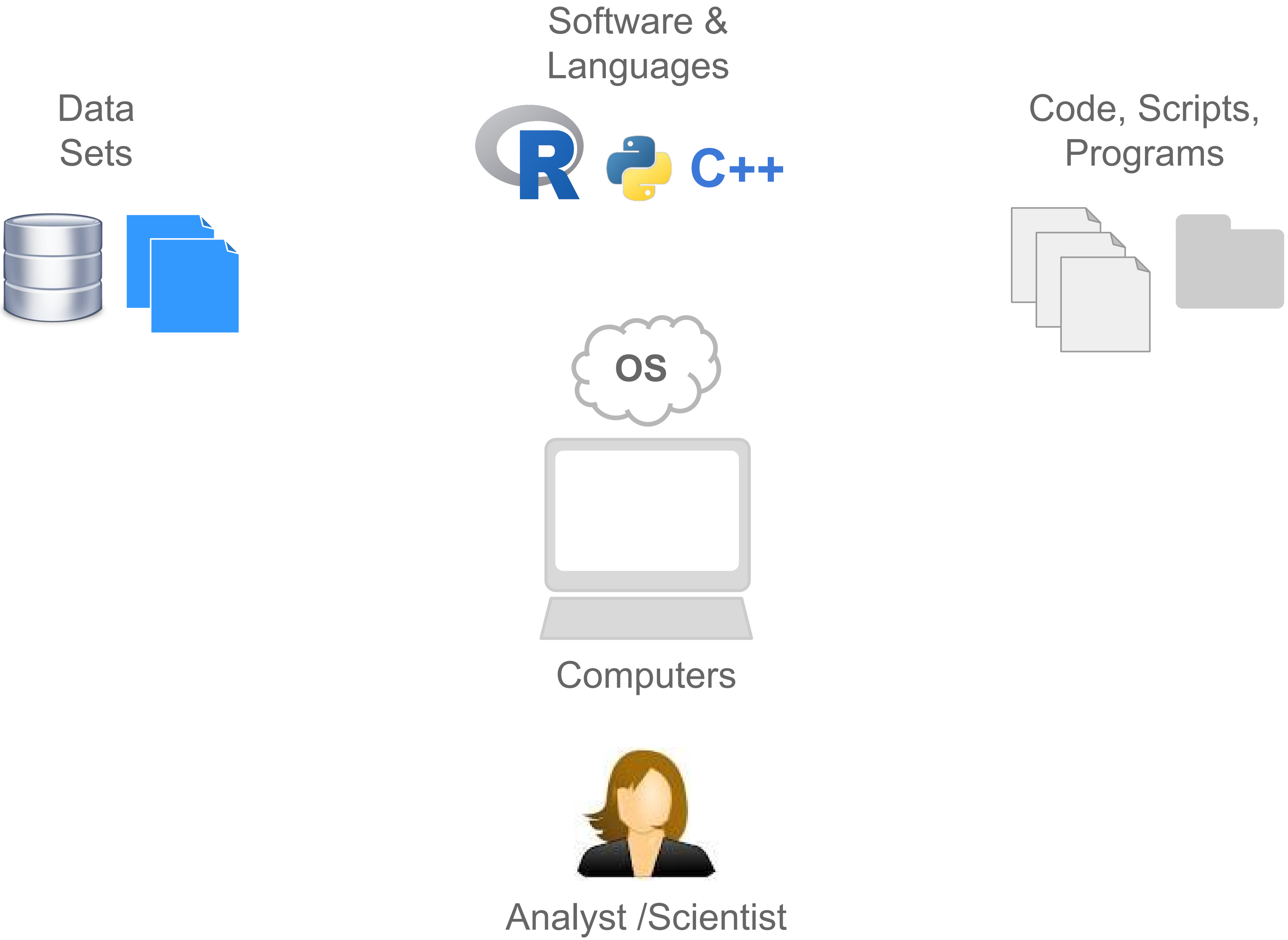
# Data Types and Vectors in R

Stat 133 by Gaston Sanchez

# DCD
# Data Computing Diagram



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# We’ll be working with “Data”

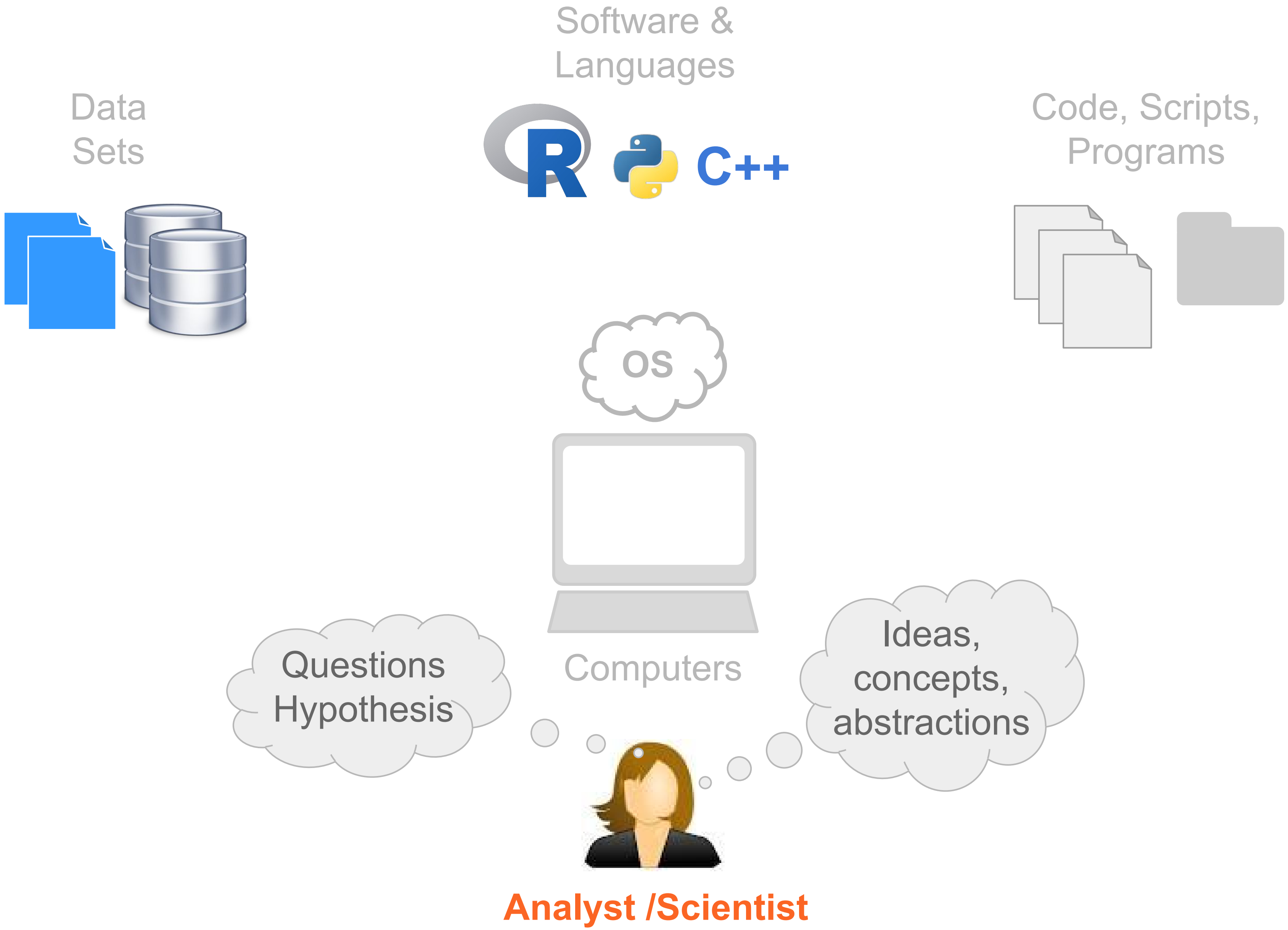
How do statisticians / analysts think of data?

How do computers treat data?

How do data sets get stored?

How do programs “understand” data?

# How do statisticians/scientists think about data?



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Questions Hypothesis

Ideas, concepts, abstractions

Analyst /Scientist

# Data (as in Statistics)

Variables observed on some individuals

**Variable:** characteristic, feature, descriptor

**Individual:** objects, animals, humans, etc

Typical representation in tabular format

# Some data set

| first | last | gender | born | halfblood |
|---|---|---|---|---|
| Harry | Potter | male | 1980 | true |
| Hermione | Granger | female | 1979 | false |
| Luna | Lovegood | female | 1980 | true |
| Ron | Weasley | male | 1981 | false |

*Typical tabular form: rows for individuals, columns for variables*

# Referring to variables in statistics ...

Quantitative -vs- Qualitative

Continuous -vs- Discrete

Numerical -vs- Categorical

Scales: Ratio, Interval, Ordinal, Nominal

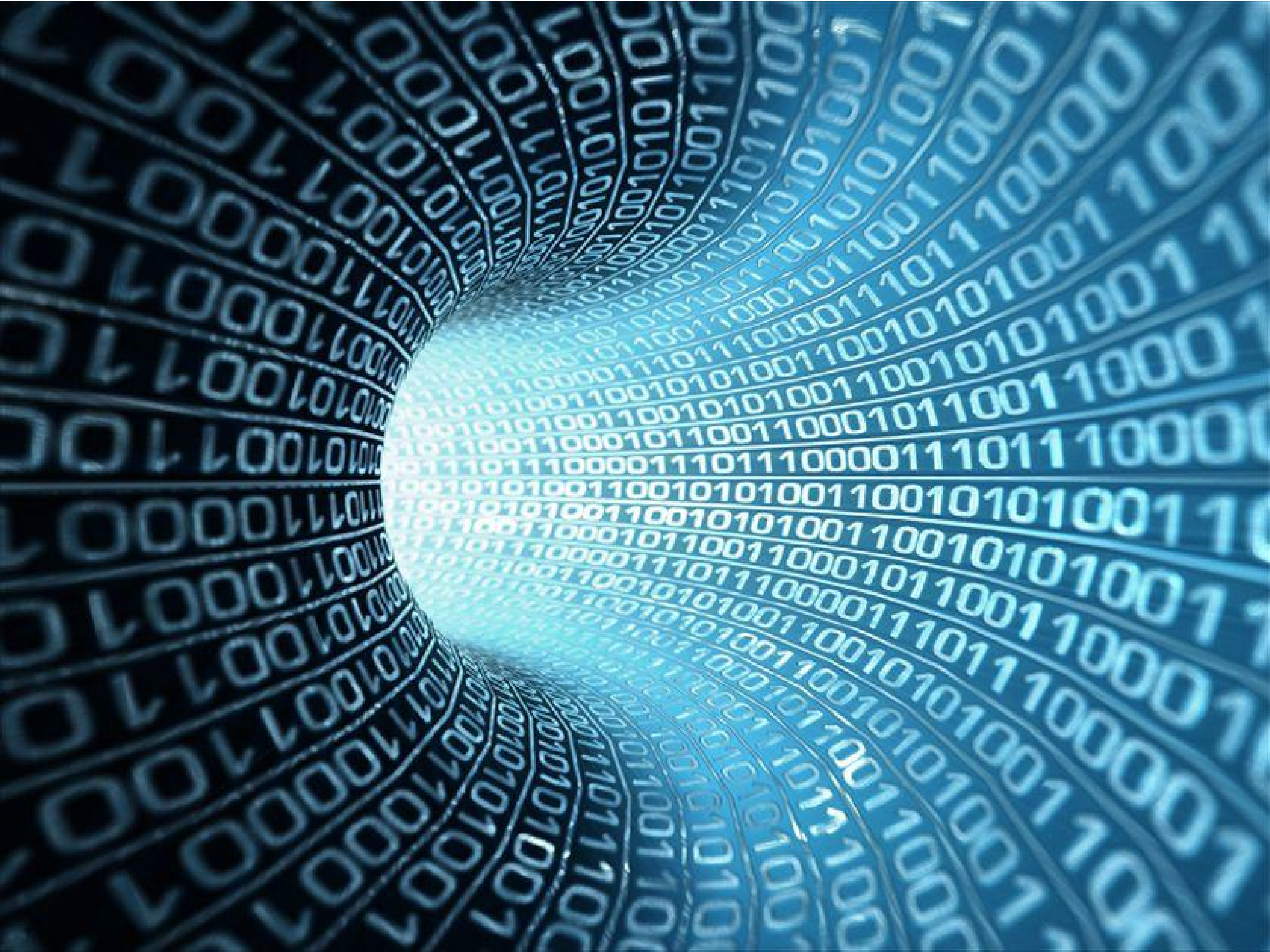
Dependent -vs- Independent

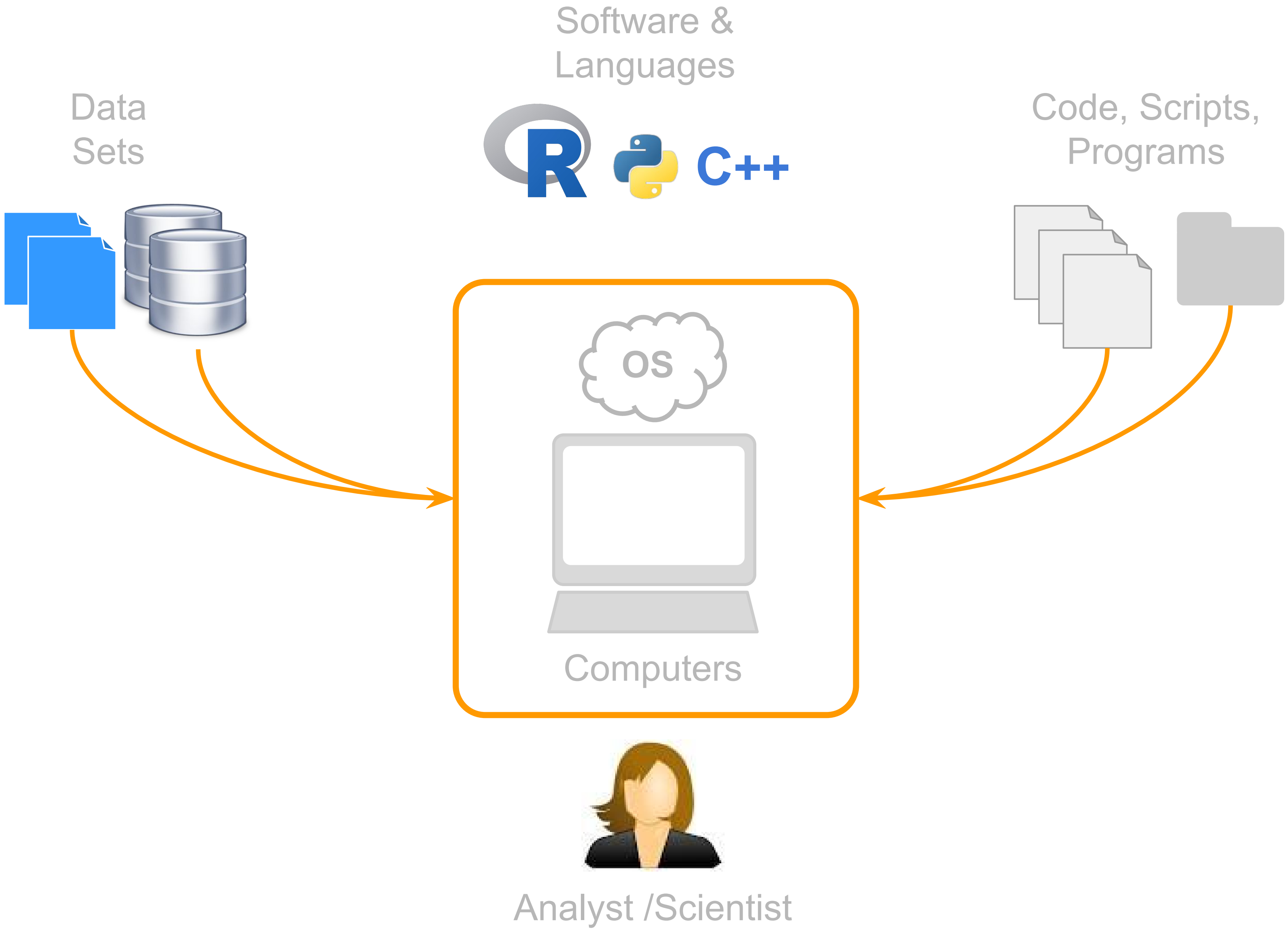
Descriptors (predictors) -vs- Response

Input -vs- Output

Missing values, Censored

# How do computers treat data?





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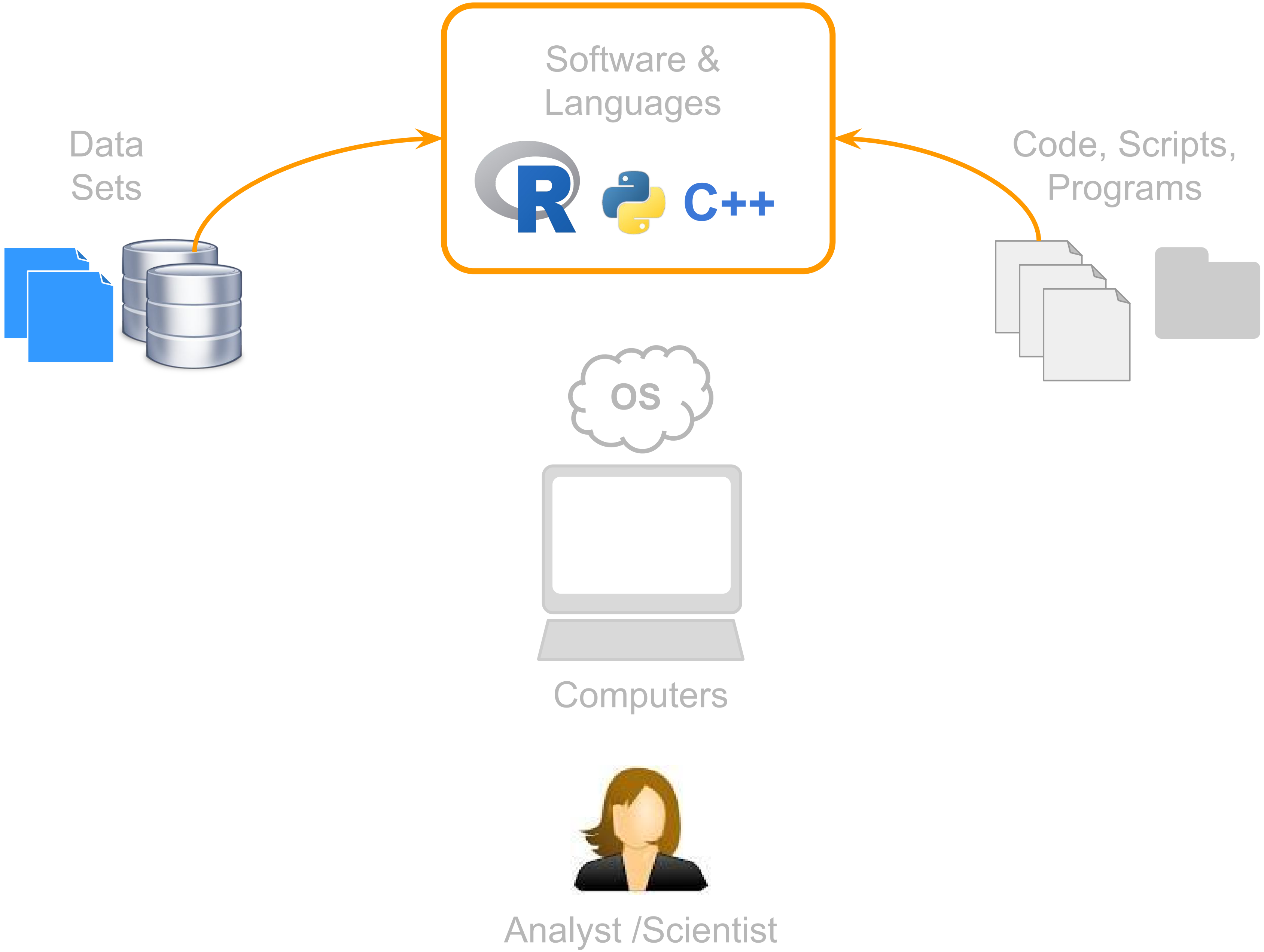
# Data (for computers)

At the lowest level, computers treat all kinds of data in binary format:

**0**’s and **1**’s

# How do programming languages handle data?



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# Data for Software / Languages?

Data Types

*Basic kinds*

Data Structures

*Containers*

# Data Types (for programming languages)

Also refer to as *data primitives* or primitive types

They serve as the building blocks (i.e. they are like the atoms)

# Common Data Types (for programming languages)

- Integers (i.e. whole numbers)
- Real numbers (i.e. decimal numbers)
- Boolean (i.e. logical)
- Character (i.e. strings)

# Common Data Types (for programming languages)

In many programming languages, everytime you create an object or a variable, you are forced to declare its type:

```
char first_name

int age
```

*(you don't have to do this in R)*

# Data Types in R

# Data types in R

- **Integer** (whole numbers)
- **Double** (real, decimal numbers)
- **Logical** (boolean)
- **Character** (or strings)
- **Complex (rarely used)*
- **Raw (rarely used)*

# Data Types (primitives)

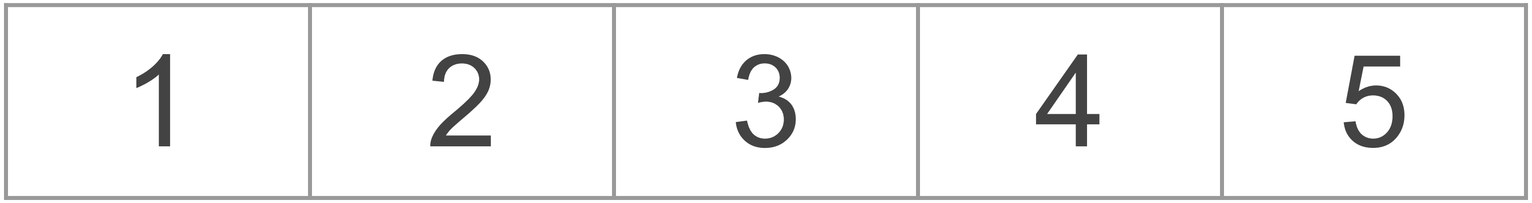
```
1L       # integer
2.5      # double (real)
TRUE     # logical
"hello"  # character
1 + 3i   # complex
```

# Vectors in R

# R vectors

A vector is the **most basic** data structure in R

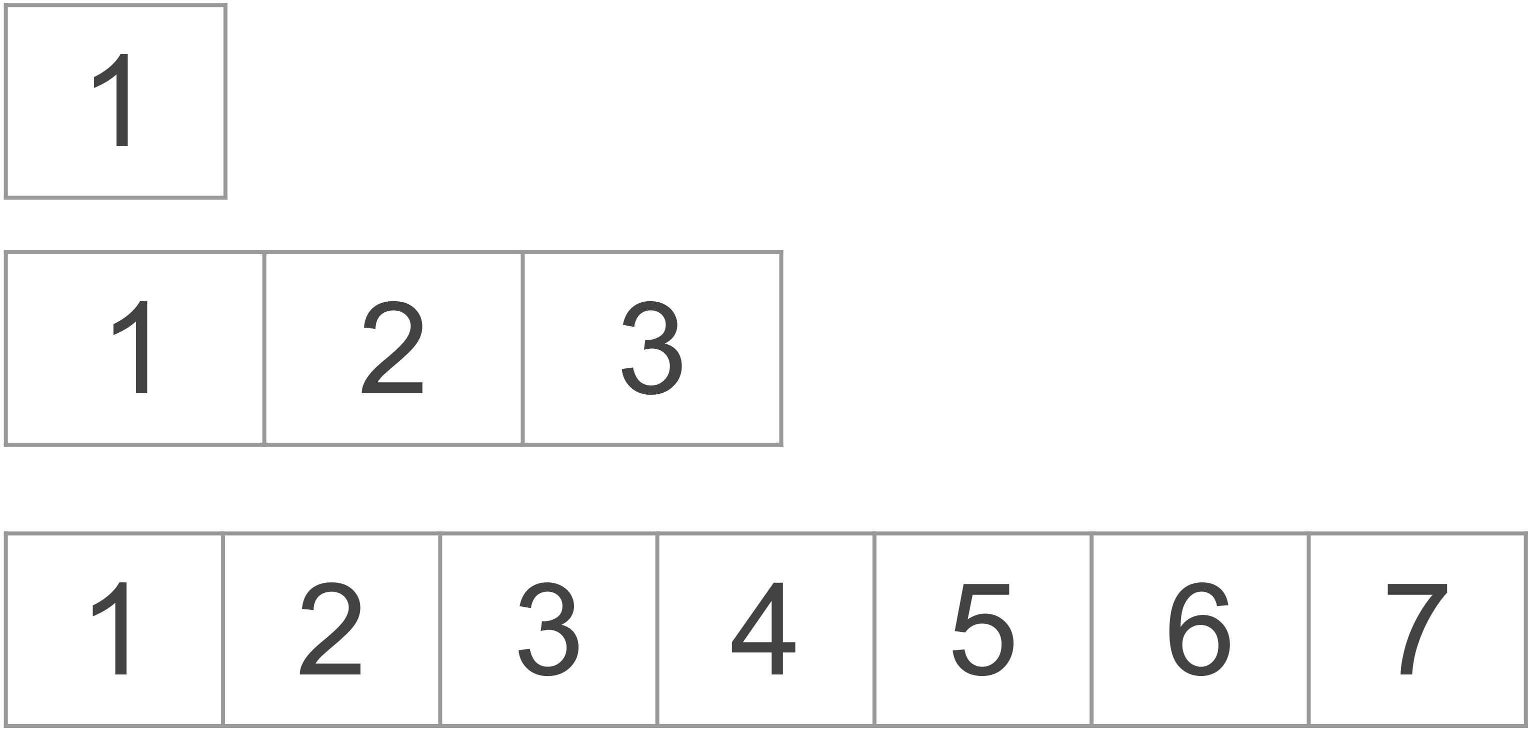
Vectors are contiguous cells containing data



| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

# R vectors

Can be of any length (including zero)



# Different kinds of vectors

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | *numeric* |

| | | | | |
|---|---|---|---|---|
| TRUE | FALSE | TRUE | FALSE | *logical* |

| | | | | |
|---|---|---|---|---|
| "I" | "you" | "we" | "they" | *character* |

# Common *(and not so common*)* data types in R

An **integer** vector stores integers

A **double** vector stores regular (real) numbers

A **character** vector stores character strings

A **logical** vector stores TRUE and FALSE values

***A *complex*** *vector stores complex numbers*

**A **raw** vector stores raw bytes*

# “Scalars” = one element vectors

```
x <- 1L        # integer
y <- 2.5       # real
z <- TRUE      # logical
w <- "hello"  # character
u <- 1 + 3i    # complex
```

# R parlance: Types and Modes

The function `typeof()` returns the type of data: this is how the values are stored internally in R.

In S terminology, instead of talking about **types** we talk about **modes**.

The function `mode()` returns the “mode” of an R object.

# Data types and modes

*A bit confusing at the beginning*

| value | example | mode | type |
|---|---|---|---|
| integer | `1L, 2L` | `numeric` | `integer` |
| real | `1, -0.5` | `numeric` | `double` |
| complex | `3 + 5i` | `complex` | `complex` |
| logical | `TRUE, FALSE` | `logical` | `logical` |
| character | `“hello”` | `character` | `character` |

You will typically be using the **mode**

# Special Values

# There are some special data values in R

`NULL` = null object

`NA` = Not available (missing value)

`Inf` = positive infinite

`-Inf` = negative infinite

`NaN` = Not a Number (different from NA)

# Atomicity

Vectors are

**atomic** structures

# Examples

```
x <- c(1, 2, 3, 4, 5)

y <- c("one", "two", "three")

z <- c(TRUE, FALSE, TRUE)
```

# Atomic vectors

Vectors are atomic structures

The values in a vector must be **ALL** of the same type!

Either all integers, or reals, or complex, or characters, of logicals

You CANNOT have a vector of different data types

# Coercion

What happens if you mix different data values in a vector?

# Mixing data types within a vector?

```
x <- c(1, 2, 3, "four", "five")


y <- c(TRUE, FALSE, 3, 4)


z <- c(TRUE, 1L, 2 + 3i, pi)
```

# Implicit Coercion

If you mix different data values, R will **implicitly coerce** them so they are ALL of the same type

```
x <- c(1, 2, 3, "four", "five")


y <- c(TRUE, FALSE, 3, 4)
```

# How does R coerce data types in vectors?

R follows two basic rules of implicit coercion

1) If a character is present, R will coerce everything else to characters

2) If a vector contains logicals and numbers, R will convert the logicals to numbers (TRUE to 1, FALSE to 0)

# Coercion functions

R provides a set of explicit coercion functions that allow you to “convert” one type of data into another

- `as.character()`
- `as.numeric()`
- `as.integer()`
- `as.logical()`

# Subsetting and Indexing

# Bracket notation for vectors

```
object[index]
```

# Bracket Notation System

To extract values from R objects use brackets: **[ ]**

Inside the brackets specify vector(s) of indices

Use as many indices, separated by commas, as dimensions in the object

Vector(s) of indices can be numbers, logicals, and sometimes characters

# Bracket Notation System

```
# some vector
x <- c(2, 4, 6, 8)

# adding names
names(x) <- letters[1:4]
```

# Numeric index

```
# first element
x[1]

# second element
x[2]

# last element
x[length(x)]
```

# Numeric index

```
# first 3 elements
x[1:3]

# non-consecutive elements
x[c(1, 3)]

# different order
x[c(3, 2, 4, 1)]
```

# Logical index

```
# first element
x[c(TRUE, FALSE, FALSE, FALSE)]

# elements equal to 2
x[x == 2]

# elements different to 2
x[x != 2]
```

# Logical index

```
# elements greater than 1
x[x > 1]

# try this
x[TRUE]

# what about this?
x[as.logical(c(0, 1, pi, -10))]
```

# Character index

```
# element names "a"
x["a"]

# "b" and "d"
x[c("b", "d")]

# what about this?
x[rep("a", 5)]
```

# Vectorization

# Vectorization

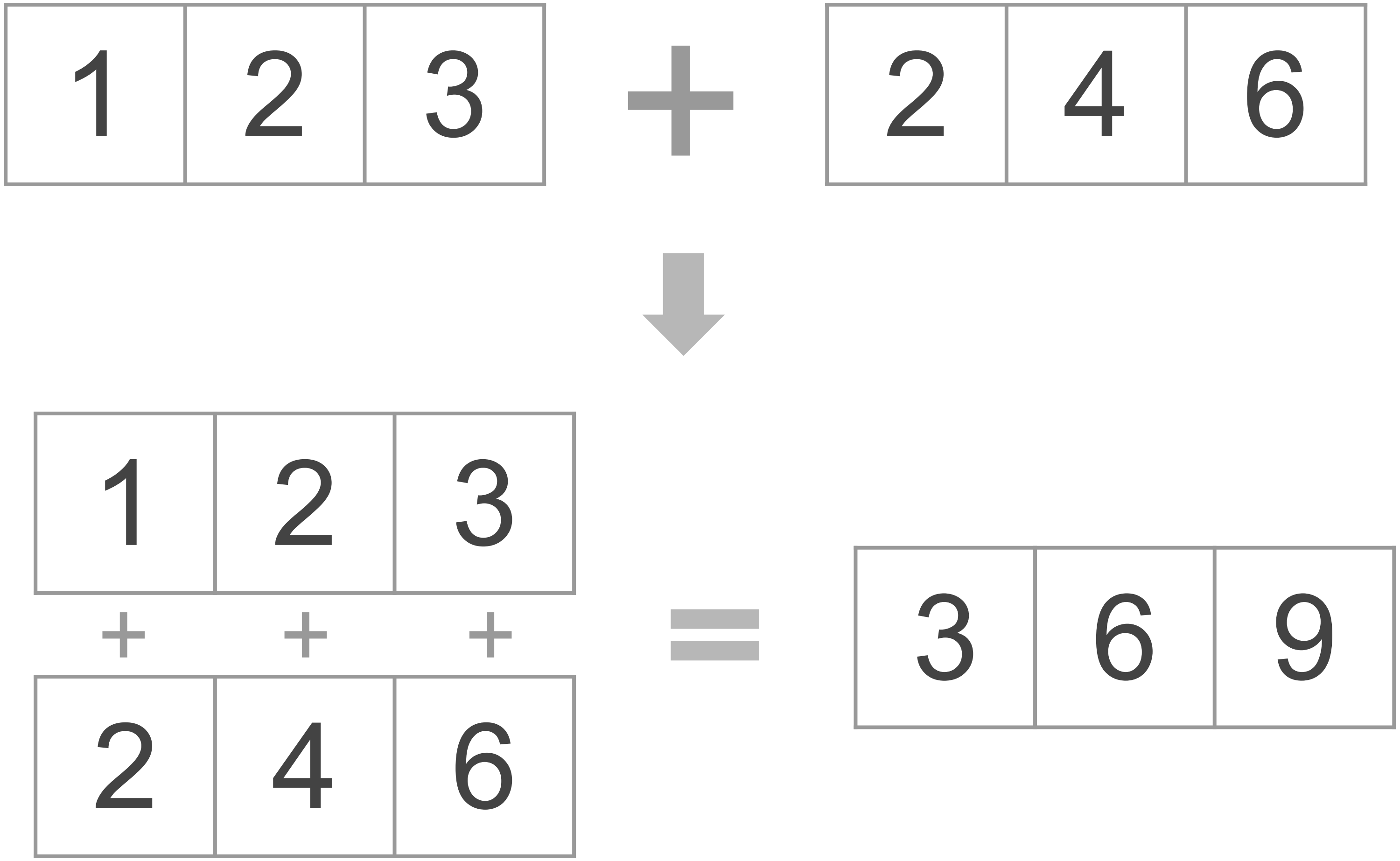
A **vectorized** computation is any computation that when applied to a vector operates on all of its elements

```
c(1, 2, 3) + c(3, 2, 1)

c(1, 2, 3) * c(3, 2, 1)

c(1, 2, 3) ^ c(3, 2, 1)
```

# Vectorized code



# Recycling

# Recycling

When vectorized computations are applied, some problems may occur when dealing with two vectors of different length

```
c(2, 1) + c(1, 2, 3)

c(1, 2, 3, 4) + c(1, 2)
```

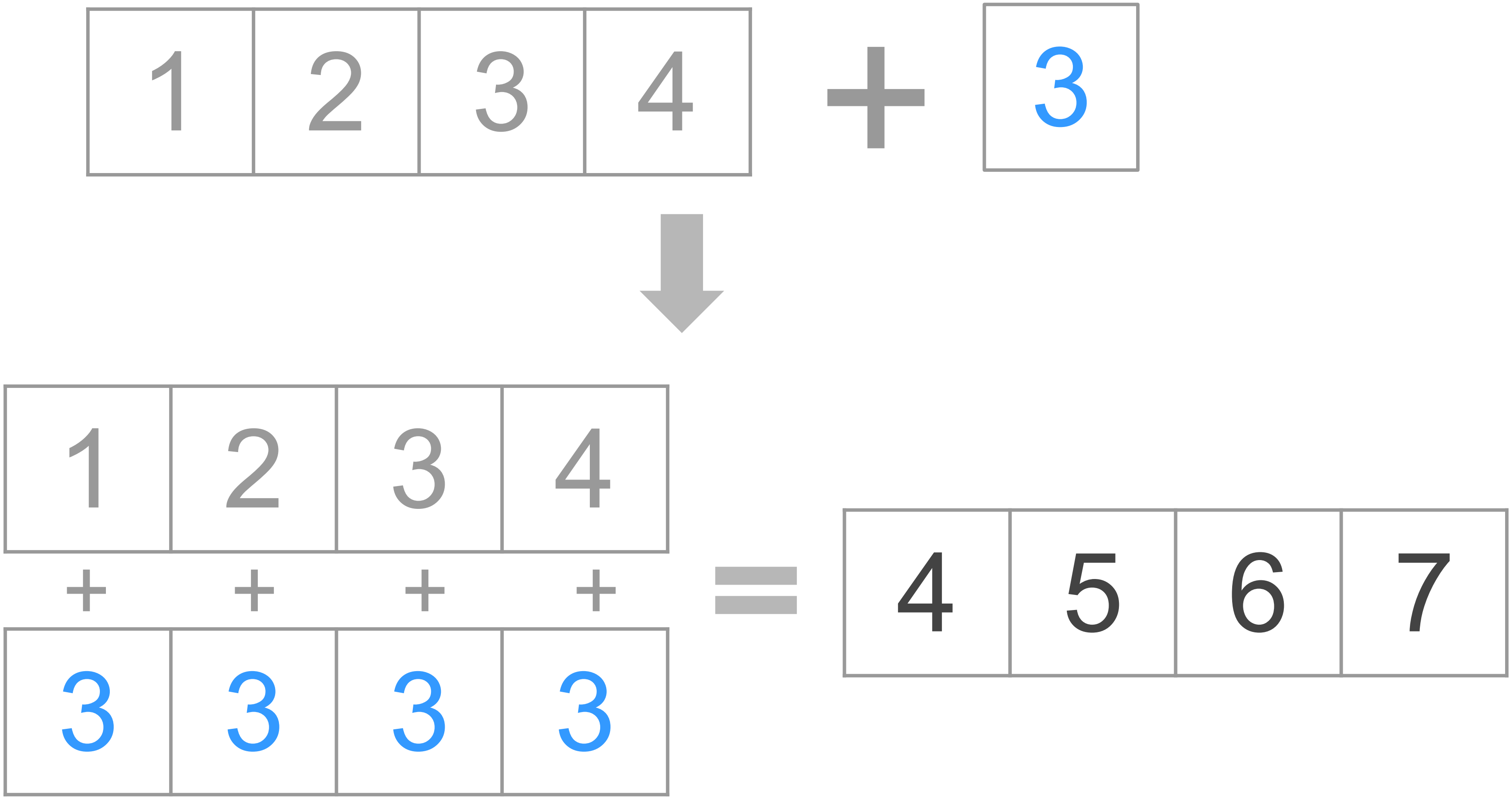
## Recycling Rule

The recycling rule can be very useful, like when operating between a vector and a “scalar”

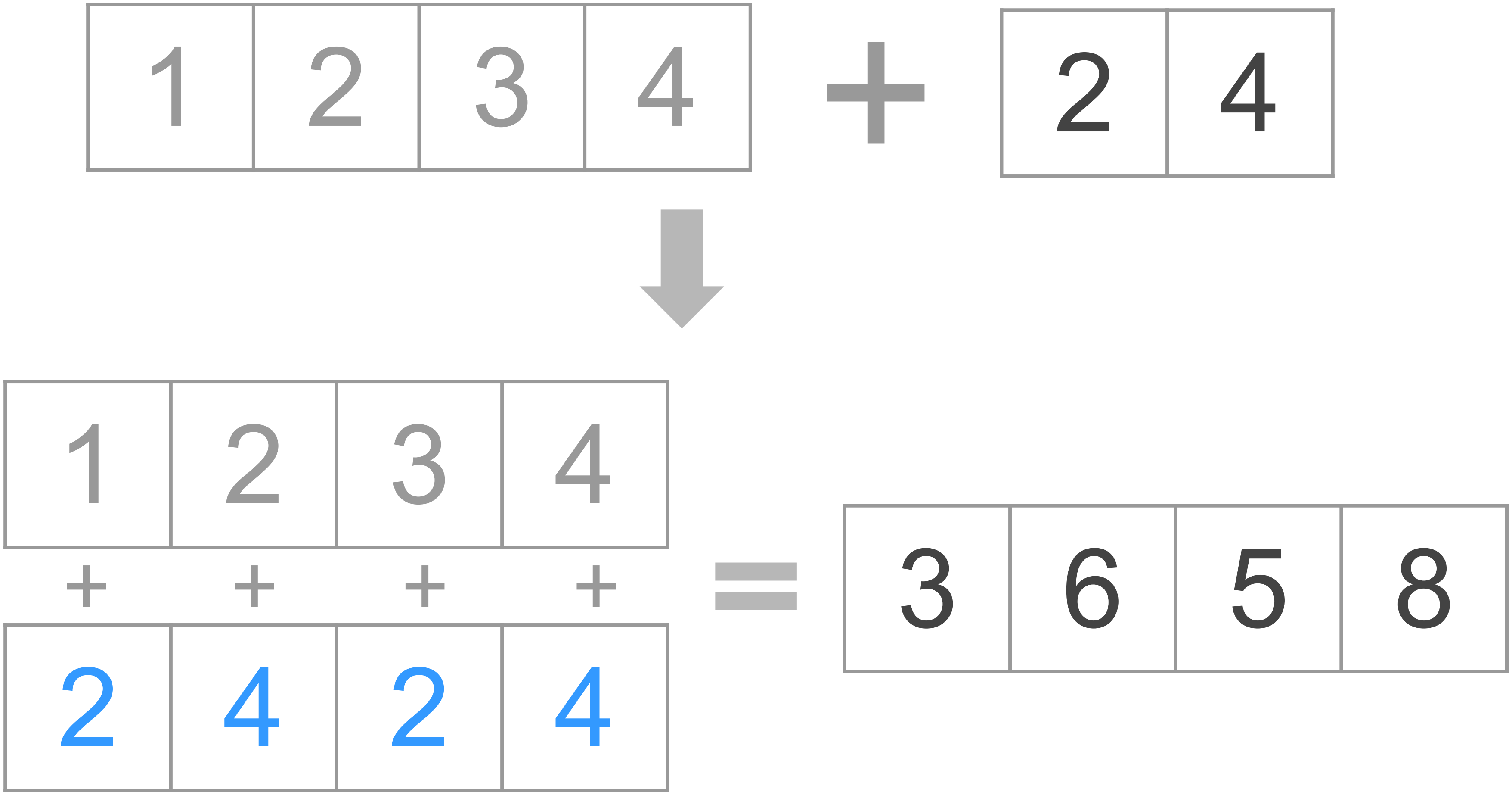
```
x <- c(2, 4, 6, 8)

x + 3
```

# Recycling (and vectorization)



# Recycling (and vectorization)

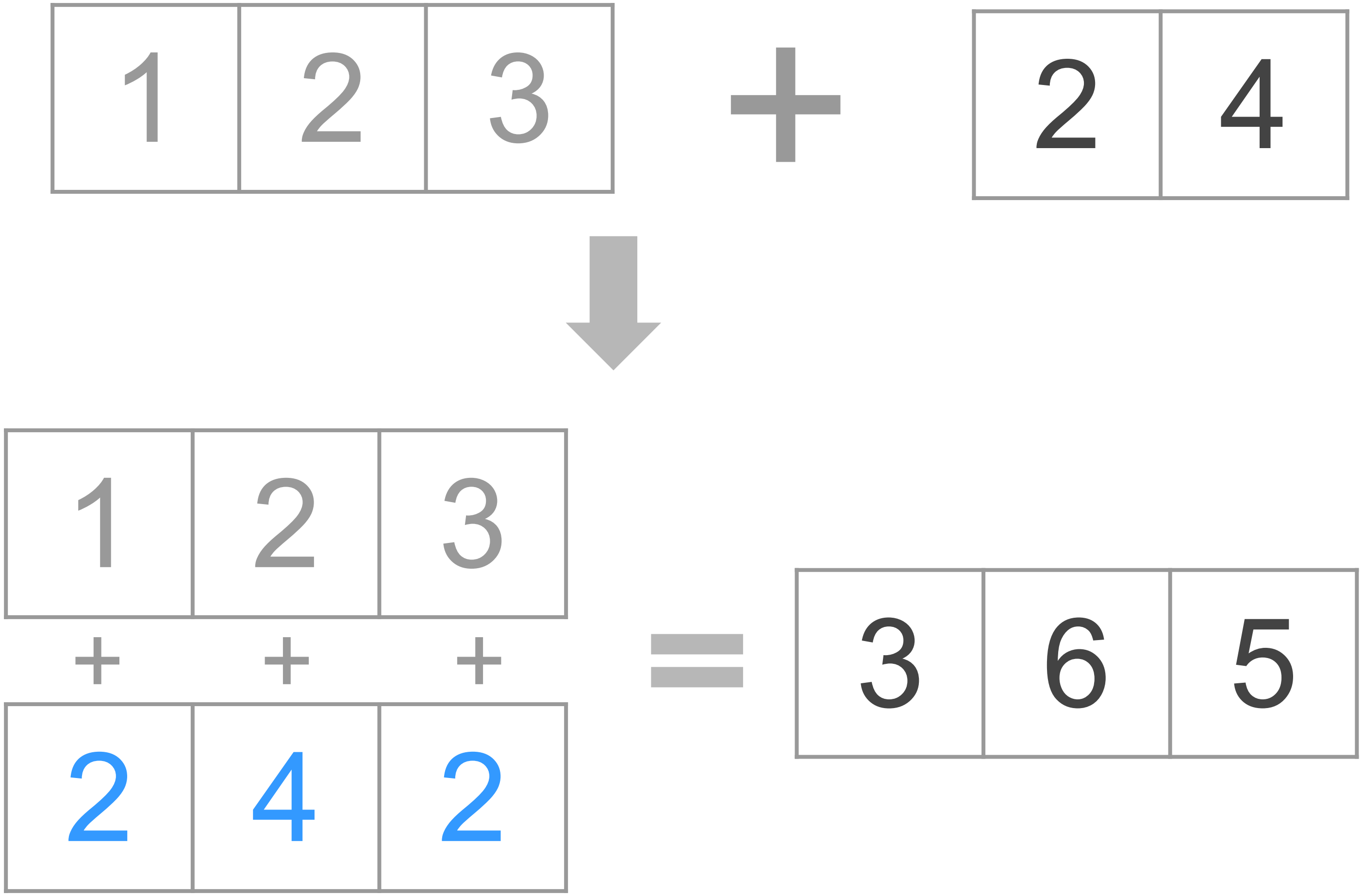


1 2 3 4 + 2 4

1 2 3 4
+ + + +
2 4 2 4
= 3 6 5 8

Gaston Sanchez

# Recycling (and vectorization)



1 2 3 + 2 4

1 2 3

+ + +

2 4 2

= 3 6 5