CMDB Bootcamp

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# 1 Homepage

This is the course homepage and digital textbook for CMDB Bootcamp.

#### 1.0.0.1 Instructors

Rajiv McCoy, rajiv.mccoy[at]jhu.edu Mike Sauria, mike.sauria[at]jhu.edu Fred Tan, tan[at]ciwemb.edu

#### 1.0.0.2 Schedule & Logistics

Class is **Tuesdays from 3-3:50PM**, in **UTL G89**.

Please bring your laptop with you to every class.

| Session | Content |
| --- | --- |
| **Session 1:** | The reference genome & genome browsers |
| **Session 2:** | *De novo* mutations |
| **Session 3:** | Linkage disequilibrium |
| **Session 4:** | Simulating evolution |
| **Session 5:** | Population structure – part I |
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| **Session 9:** | Scans for selection – part I |
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| **Session 12:** | Gene expression |
| **Session 13:** | Coronavirus phylogenetics |

# 2 The Unix Shell

## 2.1 Introducing the Shell

## 2.2 Navigating Files and Directories

## 2.3 Working with Files and Directories

# 3 Python

## 3.1 Data Types, Variables, Math

### 3.1.1 Types of Data

**Integers** Integers are whole numbers, without a decimal point. For example:

* 2
* -3
* 0

**Floats** Floats are numbers with a decimal point. For example:

* 1.2
* -3.0
* 26/3 (This one doesn’t actually have a decimal point written in by me, but is a float because the expression evaluates to 8.666)

**Strings** Strings are character data enclosed by single ’ or double ” quotation marks. Any text enclosed by quotes will be treated as a string.

* “My Grandpa’s deck has no pathetic cards”
* ‘85.3’

Note the second example – 85.3 is a float; "85.3" is a string.

**Booleans** A Boolean has two possible values: True and False. These can be expressed interchangeably as 1 or 0, respectively.

### 3.1.2 Variables

A variable is assigned using the equals sign, with this general syntax:

variable\_name = value.

For example:

* composer = "buxtehude"
* year = 1637

The data name can be almost anything. Here are the rules to consider when naming a variable:

* A variable name must start with a letter or underscore
* A variable name can only consist of letters, numbers, or underscores
* Variables are case sensitive (i.e. Python would interpret my\_number, MY\_NUMBER, and My\_Number as different variables)
* Python has a set of “reserved words” that cannot be used as variable names. These are words that already have a set meaning in Python, such as ‘True’, ‘False’, ‘for’, and ‘if’. A full list can be found here: <https://www.programiz.com/python-programming/keywords-identifier>

### 3.1.3 Mathematical Operations

A lot of mathematical operations in Python are straightforward. Here are some of the basic operations we can perform

* + and - – addition and subtraction
* \* and / – multiplication and division
* \*\* – Exponentials

We can perform mathematical operations on values directly:

print(2 + 3)

## 5

or we can operate on variables:

myValue = 4   
print(myValue\*\*2)

## 16

Mathematical conversions will automatically convert integers to floats when appropriate:

print(3 + 2.2)

## 5.2

We can save the output of an expression as a variable:

my\_product = 2 \* 10  
print(my\_product)

## 20

And likewise we can perform mathematical operations on variables, provided these variables store numeric data:

number1 = 7  
print(number1 / 2)

## 3.5

### 3.1.4 Order of operations

Python follows the usual mathematical order of operations. And like usual in math, we can use parenthesis () to enforce a specific order.

print(6 - 7 \* 2 + (8-4) \* 4)

## 8

### 3.1.5 Comparisons

In Python, comparisons will always return a Boolean, i.e. either True or False. We can use the following syntax to compare values:

* < and > to compare greater than/less than
* <= and >= for greater than or equal to/less than or equal to

For example:

print(5.3 < 17)

## True

print(4. >= (8/2))

## True

* == checks if two values are equal. != checks that two values are different.

print((2\*\*3) != (17 - 9))

## False

Note that a single equals sign = is used to assign values. So var1 = 3 is setting var1 equal to 3. However, a double equals sign == is used to compare values. var1 == 3 is checking if the value of var1 is 3.

## 3.2 Built-In Functions and Methods

### 3.2.1 Functions

A **function** is a block of code that performs a task. Python comes with a substantial set of pre-written functions.

***Text on how a function is formulated - name, parentheses, optionally arguments***

***Is it worth talking about named arguments or positional arguments. Be introspective about this***

For example, the print() function displays ***FINISH ME***

***OTHER Built-In FUNCTIONS***’

### 3.2.2 Methods

Every data type that we use in Python (that is, strings, integers, etc.) is associated with a set of functions unique to the data type. These functions are called **methods**. The syntax for using a method is as follows: <objectName>.<methodName>(). For example, the method .upper() belongs to strings and is used to convert a string into capital letters. We can use it with any string either directly on the string itself:

"Quod est superius est sicut quod inferius".upper()

## 'QUOD EST SUPERIUS EST SICUT QUOD INFERIUS'

or by operating on a variable:

pig = "peppa"  
pig.upper()

## 'PEPPA'

Using a method may or not modify the underlying object. For example, the .upper() method shows you the uppercase version of a string but does *not* modify the actual variable that you are operating on. Observe the following code block:

pig = "peppa"  
pig.upper()

We’ve returned the uppercase version of the pig variable, but has this value been saved? No:

print(pig)

## peppa

To actually save the result of this method, we have to use variable assignment, for example like so:

pig = "peppa"  
pig = pig.upper()  
print(pig)

## PEPPA

Some methods *do* in fact modify underlying variables. For example, the list .append() method which we will learn about later *does* change the list if operates on, so in the following code block:

myList = []  
myList.append('apple')

myList is changed by myList.append('apple'). There’s no need to type something like myList = myList.append('apple') - this would in fact be an error. Which methods modify the objects they operate on is something you’ll have to keep track of on a case-by-case basis as you learn new methods.

## 3.3 Type Conversion

## 3.4 String Methods

### 3.4.1 .upper() and .lower()

The .upper() and .lower() methods take a string and convert it to uppercase and lowercase, respectively.

print("out on the wily, windy moors".upper())

## OUT ON THE WILY, WINDY MOORS

aria = "Piangerò La Sorte Mia"  
print(aria.lower())

## piangerò la sorte mia

### 3.4.2 .split()

The .split() method takes a string and splits it into a list, dividing the list on by a regular delimiter. The delimiter is provided as an argument:

print("Eye of newt, toe of frog, wool of bat".split(','))

## ['Eye of newt', ' toe of frog', ' wool of bat']

If no argument is provided, then the string is split on whitespace (that is, it is split whenever a space or tab is encountered).

print("they sowed their isn’t they reaped their same".split())

## ['they', 'sowed', 'their', 'isn’t', 'they', 'reaped', 'their', 'same']

### 3.4.3 .join()

The .join() method is the inverse of .split() - takes a list and converts it into a string, with list elements separated by a delimiter. The general syntax is: "<delimiter>".join(<list to join>)

'.'.join(["39","3299","-76","620277"])

## '39.3299.-76.620277'

We can provide a space as a delimiter:

"".join(["I", "found", "a", "fox", "caught", "by", "dogs"])

## 'Ifoundafoxcaughtbydogs'

If we do not provide a delimiter, then the strings are directly concatenated:

"".join(["here", "in", "after"])

## 'hereinafter'

### 3.4.4 .rstrip(), .lstrip(), .strip()

These three functions remove any instances of unwanted characters on either the right side, left side, or both sides of a string, respectively. You can provide the characters you want to remove as an argument:

"ricercar........,,,,,,".rstrip(",.")

## 'ricercar'

Without an argument, we remove spaces:

" gradus ad Parnassum ".lstrip()

## 'gradus ad Parnassum '

Note that in the above example we strip the spaces to the left of the main text, but we *do not* remove the spaces from the middle or right end of the text.

## 3.5 Lists

Each variable has stored a single piece of information, e.g. a single integer or a discrete string. Lists allow us to store multiple items together?

A list is a sequential group of variables, denoted in Python by square brackets [], with individual entries separated by commas. A few of the neat properties of lists are:

* Lists have a preserved order. The list [1, 5, 3, 7] will always store those numbers in the same order.
* Lists can mix data types. ["mercury", 13, 5.3, False] is a valid list which contains every data type we’ve seen so far.
* Lists can also contain other lists: ["sulfur", 12, [3, 2], 18]
* Lists can have identical values repeatedly. This is valid list design: [“tomato”, “tomato”, “tomato”, 3, “tomato”]

### 3.5.1 Indexing

What if we want to extract a specific value from a list? We can use indexing. To index in Python, we use the following syntax: variable\_name[index], with index being an integer referring to the position we wish to extract.

alchemists = ["Zosimos", "Oresme", "Flamel", "pseudo-Aristotle"]  
print(alchemists[1])

## Oresme

Notice that when we printed the item at position 1, we printed out the second entry in my\_list. This is because in Python, **indexes start at 0**. So to print out the first entry, we would use alchemists[0].

A couple interesting things we can do with indexing:

* To print multiple consecutive number, we can provie two numbers separated by a colon :. Note that the first number is inclusive and the second number is exclusive. For example, in the sample below, we provide the index 1:3. This prints out the item at position 1 (‘Oresme’), the item at position 2 (‘Flamel’) and not the item at position 3 (‘pseudo-Aristotle’).

print(alchemists[1:3])

## ['Oresme', 'Flamel']

* We can index in reverse. To index from the end of the list, we use negative numbers.

print(alchemists[-1])  
print(alchemists[-2])  
print(alchemists[-3])

## pseudo-Aristotle

## Flamel

## Oresme

What if we have a list within a list? Consider the following list:

my\_list = [1, 2, [3, 4], 5]

How would we point to the number 3 in this list?

First, we can point to the interior list. The interior list is the third item in the list, so it is at position 2 (remember, indexing in Python starts at 0). So we can access the interior list with my\_list[2].

Within the interior list, 3 is the first item, so it is at position 0. It can be accessed with the syntax my\_list[2][0]

my\_list = [1, 2, [3, 4], 5]  
print(my\_list[2])  
print(my\_list[2][0])

## [3, 4]

## 3

#### 3.5.1.1 Indexing Strings

We can also apply indexing to extract substrings from within a string. This is done identically to how we index a list:

creature = 'stingray'  
print(creature[0:5])

## sting

### 3.5.2 Adding to lists - Append

One last interesting thing we can do with lists is we can add entries to the end of a list. We do this using the append() method, which is used with the following syntax:

list\_name.append(item)

For an example:

florilegium = ['marigold', 'thistle', 'wormwood']  
florilegium.append('tansy')  
print(florilegium)

## ['marigold', 'thistle', 'wormwood', 'tansy']

## 3.6 For Loops

In Python, we will often want to perform an action more than once. For example, if we have a list, we might want to operate on every item within the list one by one.

One way to do this is to make use of a for loop, which is structured like this:

for <temporary\_variable> in <thing to loop through>:  
 {do something}

For example:

stations = ["Three Note Oddity", "Radio Londres", "Cherry Ripe", "Swedish Rhapsody"]  
  
for i in stations:  
 print(i)

## Three Note Oddity  
## Radio Londres  
## Cherry Ripe  
## Swedish Rhapsody

Here is how the loop works:

In the line for i in stations: we are defining the temporary variable i (the name of this variable is arbitrary). We are also saying that we are looping through stations. So in this first iteration of the for loop, i takes on the value of the first item in stations, that is “Three Note Oddity”. Now we perform all of the indented code, which here is just a single print() statement.

Now we go back and set the value of i to that of the second entry in stations, or “Radio Londres”. We execute all of the indented code, printing out “Radio Londres”.

Now we go back and set the value of i to that of the third value in stations, or “Cherry Ripe”. And we keep on doing this until there is nothing left in my\_list.

In the above example, there was a single indented line in the bodyo of the loop, but the for loop can be arbitrarily long. Here is an example of a for loop structured in the same way, but with more going on in the body of the loop:

my\_list = [1, 4, 6, 9, 10, 2]  
  
for i in my\_list:  
 i = i + 3  
 i = i \*\* 2  
 print(i)

## 16  
## 49  
## 81  
## 144  
## 169  
## 25

We can also use a for loop to perform an action a set number of times, even when we don’t have a list to loop through. To do so, we can use the range() function. We’ll use this function a ton throughout the course. When we run the range() function with a single integer inside the paranthesis, it generates a sequence of numbers from 0 up to and not including the number provided. So to run a function 3 times, we would provide the for loop with range(3) (i.e. [0, 1, 2]).

for i in range(3):  
 print(i)

## 0  
## 1  
## 2

So far, the body of our for loops has always referenced the temporary variable i. We can also use a for loop to run a block of code repeatedly without actually manipulating the temporary variable within that block:

for i in range(6):  
 print("All work and no play")

## All work and no play  
## All work and no play  
## All work and no play  
## All work and no play  
## All work and no play  
## All work and no play

## 3.7 Reading in Data and Text Parsing

***FILL***

## 3.8 Modules

Often, we need to make use of functions beyond those that are packaged with Python. To do this, we can import a **module**, or a collection of pre-written functions. A module is imported with the following syntax: import <module name>. For example, to import the popular plotting module Matplotlib, we write:

import matplotlib.pyplot

To use a function from this module, we need to reference both the package name and the function name, with the general syntax: moduleName.functionName(). To user Matplotlib’s show() function, we would write:

matplotlib.pyplot.show()

What if you don’t want to write out matplotlib.pyplot in full each time that you run a Matplotlib function? To simplify this, we can give our modules a shorthand name. For example:

import matplotlib.pyplot as plt

Now, instead of writing out matplotlib.pyplot, we can just write plt. The previous matplotlib.pyplot.show() command is shortened to:

plt.show()

## 3.9 Plotting

In this course, we will use the library Matplotlib for plotting. For concision, we will import the matplotlib.pyplot module with the name plt, as such:

import matplotlib.pyplot as plt

## 3.10 Errors

# 4 Git

## 4.1 Tracking Changes

## 4.2 Ignoring Things

# Authors

| Credits | Names |
| --- | --- |
| **Pedagogy** |  |
| Instructor | [Rajiv McCoy](https://mccoy-lab.org/) |
| Content Author | [Stephanie Yan](https://stephaniemyan.github.io/) |
| Content Author | [Kate Weaver](https://kweav.github.io/) |
| **Website** |  |
| Template | [Jeff Leek](https://jtleek.com/) & [The Johns Hopkins Data Science Lab](https://jhudatascience.org/index.html) |
| Design Inspiration | [Ali Madooei](https://engineering.jhu.edu/faculty/ali-madooei/) & [JHU Data Structures](https://cs226sp22.github.io/) |
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## ─ Session info ───────────────────────────────────────────────────────────────  
## setting value   
## version R version 4.0.2 (2020-06-22)  
## os Ubuntu 20.04.5 LTS   
## system x86\_64, linux-gnu   
## ui X11   
## language (EN)   
## collate en\_US.UTF-8   
## ctype en\_US.UTF-8   
## tz Etc/UTC   
## date 2023-08-09   
##   
## ─ Packages ───────────────────────────────────────────────────────────────────  
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## assertthat 0.2.1 2019-03-21 [1] RSPM (R 4.0.5)   
## bookdown 0.24 2023-03-28 [1] Github (rstudio/bookdown@88bc4ea)   
## cachem 1.0.7 2023-02-24 [1] CRAN (R 4.0.2)   
## callr 3.5.0 2020-10-08 [1] RSPM (R 4.0.2)   
## cli 3.6.1 2023-03-23 [1] CRAN (R 4.0.2)   
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## devtools 2.3.2 2020-09-18 [1] RSPM (R 4.0.3)   
## digest 0.6.25 2020-02-23 [1] RSPM (R 4.0.0)   
## ellipsis 0.3.1 2020-05-15 [1] RSPM (R 4.0.3)   
## evaluate 0.20 2023-01-17 [1] CRAN (R 4.0.2)   
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## fastmap 1.1.1 2023-02-24 [1] CRAN (R 4.0.2)   
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## jsonlite 1.7.1 2020-09-07 [1] RSPM (R 4.0.2)   
## knitr 1.33 2023-03-28 [1] Github (yihui/knitr@a1052d1)   
## lattice 0.20-41 2020-04-02 [2] CRAN (R 4.0.2)   
## lifecycle 1.0.3 2022-10-07 [1] CRAN (R 4.0.2)   
## magrittr 2.0.3 2022-03-30 [1] CRAN (R 4.0.2)   
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## ps 1.4.0 2020-10-07 [1] RSPM (R 4.0.2)   
## R6 2.4.1 2019-11-12 [1] RSPM (R 4.0.0)   
## rappdirs 0.3.3 2021-01-31 [1] CRAN (R 4.0.2)   
## Rcpp 1.0.10 2023-01-22 [1] CRAN (R 4.0.2)   
## readr 1.4.0 2020-10-05 [1] RSPM (R 4.0.2)   
## remotes 2.2.0 2020-07-21 [1] RSPM (R 4.0.3)   
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## rlang 1.1.0 2023-03-14 [1] CRAN (R 4.0.2)   
## rmarkdown 2.10 2023-03-28 [1] Github (rstudio/rmarkdown@02d3c25)  
## rprojroot 2.0.3 2022-04-02 [1] CRAN (R 4.0.2)   
## rstudioapi 0.11 2020-02-07 [1] RSPM (R 4.0.0)   
## sessioninfo 1.1.1 2018-11-05 [1] RSPM (R 4.0.3)   
## stringi 1.5.3 2020-09-09 [1] RSPM (R 4.0.3)   
## stringr 1.4.0 2019-02-10 [1] RSPM (R 4.0.3)   
## testthat 3.0.1 2023-03-28 [1] Github (R-lib/testthat@e99155a)   
## tibble 3.2.1 2023-03-20 [1] CRAN (R 4.0.2)   
## usethis 1.6.3 2020-09-17 [1] RSPM (R 4.0.2)   
## utf8 1.1.4 2018-05-24 [1] RSPM (R 4.0.3)   
## vctrs 0.6.1 2023-03-22 [1] CRAN (R 4.0.2)   
## withr 2.3.0 2020-09-22 [1] RSPM (R 4.0.2)   
## xfun 0.26 2023-03-28 [1] Github (yihui/xfun@74c2a66)   
## yaml 2.2.1 2020-02-01 [1] RSPM (R 4.0.3)   
##   
## [1] /usr/local/lib/R/site-library  
## [2] /usr/local/lib/R/library