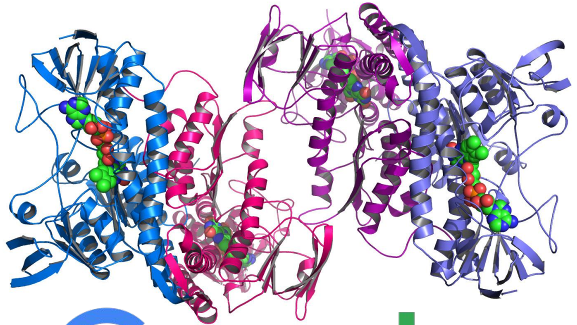
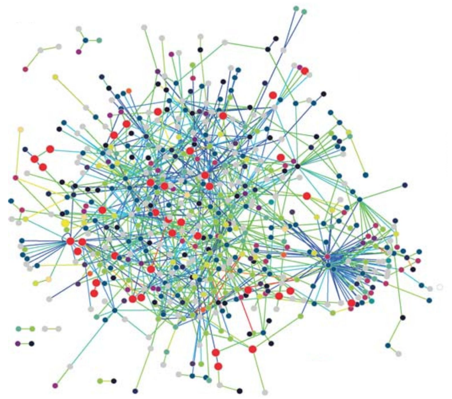
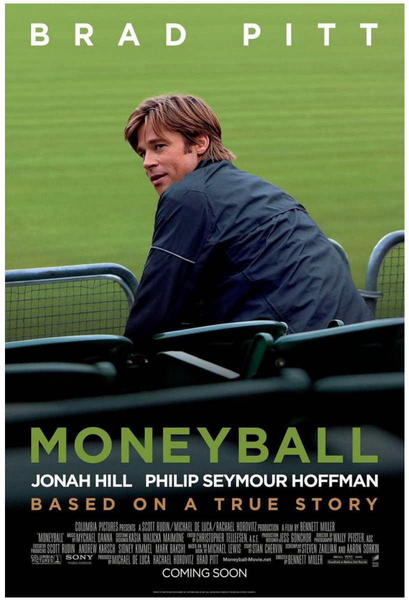
STATS 507
Data Analysis in Python

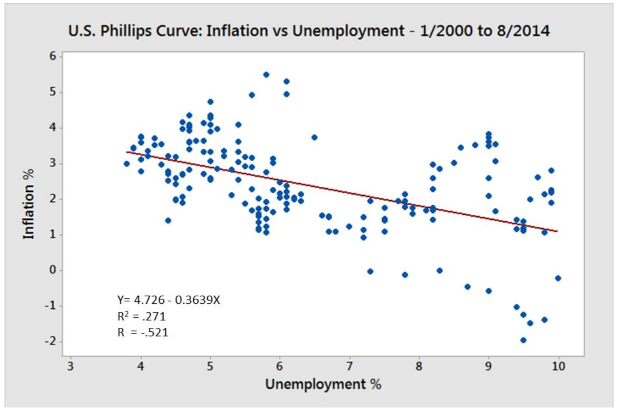
Lecture 0: Introduction and Administrivia

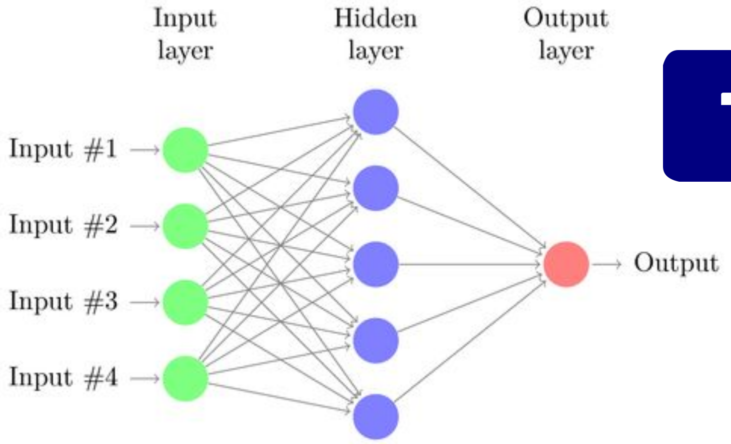
“Data science” has completely changed our world











Course goals

- Establish a broad background in Python programming
- Prepare you for the inevitable coding interview
- Survey popular tools in academia/industry for data analysis and exploration
- Learn how to read documentation and quickly get new tools up and running
- Learn basic distributed computing frameworks

These tools will be obsolete some day...

...but not your ability to learn new frameworks and solve problems!

Course structure

Unit 1: Introduction to Python
Data types, functions, Jupyter, classes, objects, functional programming

Unit 2: Numerical Computing and Data Visualization
numpy, scipy, matplotlib

Unit 3: Dealing with structured data
regular expressions, retrieving web data, SQL, Python pandas, APIs

Unit 4: Big data and parallel programming
Basics of the UNIX command line, ssh, Hadoop, Spark, TensorFlow

Schedule (tentative) and other information available on course webpage:
www.umich.edu/~klevin/teaching/Winter2019/STATS507

Prerequisites

I assume that you have *some* background in programming and statistics

Come speak to me if:

- this is your first programming course
- you have never taken a probability or statistics course

This course is probably not for you if:

- you have no programming background

Course information

Instructor: Keith Levin

- Email: `klevin@umich.edu`
- Office: 272 WH
- OH: TBA
  or by appointment

GSI: Roger Fan

- Email: `rogerfan@umich.edu`
- OH: TBA

Textbook: None

- Readings posted to the website

Grading: 10-12 HWs,

- Weighted approximately equally
- No midterm, no final
- No class project
- Late days (see syllabus)

See syllabus on Canvas or at
umich.edu/~klevin/teaching/Winter2019/STATS507/syllabus.pdf

A Note on Enrollment and the Waitlist

This is an immensely popular course...

… which is excellent, but it means that there are… a lot of you.

Waitlist:

The waitlist is handled by the statistics office. I have no control of it!

Please do not email me asking for overrides. I cannot grant them.

Please direct all enrollment questions to the statistics office: **stat-um@umich.edu**

Before we continue...

Readings:

For the first half of the course, readings will be given in both

Allen B. Downey's *Think Python* and

Charles Severance's *Python for Everybody*

You can do the readings out of either one, whichever you prefer!

Later, we'll make exclusive use of Severance

A Note on Readings

I will post weekly readings throughout the course

I would prefer if you do the readings before lecture...

  ...but I recognize this is not always possible...

  ...and if you find that you learn better seeing lecture first, then that’s fine.

Some of the readings consist of technical documentation

  It is a goal of this course to get you comfortable reading docs!

  Read and understand what you can, google terms you don’t understand…

  ...and it’s okay to set things aside to come back to later!

Policies

Don’t plagiarize!

- You may discuss homeworks with your fellow students...
- ...but you must submit your own work
- Disclose in your homework whom (if anyone) you worked with

Late homeworks are not allowed!

- Instead, we have “late days”, of which you get 7
- One late day extends HW deadline by 24 hours
- **Note:** homework deadlines may not be extended beyond 11:59pm on the scheduled day of the final (Thursday, May 2nd).

Refer to the syllabus for details.

Survey time!

1. Raise your hand if you have used Python before.
2. Raise your hand if you have used jupyter/iPython in the past.
3. Raise your hand if you have used the UNIX/Linux command line.
4. Raise your hand if you have used the Python `matplotlib` package.
5. Raise your hand if you prefer Canvas over a course webpage

Things to do very soon:

Pick an editor/IDE for python

or just use a text editor, or just write directly in jupyter

Familiarize yourself with jupyter:

https://jupyter.readthedocs.io/en/latest/content-quickstart.html

Get a flux/fladoop username

Fill out form here: http://arc-ts.umich.edu/hpcform/

List me (Keith Levin, klevin@umich.edu) as your “advisor”

Include a note that you are in STATS507 and need access to Fladoop

Note: we will use only Python 3 in this course. Check that you have Python 3 installed on your machine and that it is running properly.

Other things

HW1 is posted to canvas and the website. **Get started now!**

If you run into trouble, come to office hours for help

- But also please post to the discussion board on Canvas
- If you're having trouble, at least one of your classmates is, too
- You'll learn more by explaining things to each other than by reading stackexchange posts!

Email policy:

I will **not** provide tech support over email!

If you are having trouble, post to the discussion board and/or come to OHs!

STATS 507
Data Analysis in Python

Lecture 1: Introduction to Python

Python: Overview

Python is a **dynamically typed**, **interpreted** programming language

- Created by Guido van Rossum in 1991
- Maintained by the Python Software Foundation

Design philosophy: simple, readable code

Python syntax differs from R, Java, C/C++, MATLAB

- whitespace delimited
- limited use of brackets, semicolons, etc

Image credit: https://www.python.org/community/logos/

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limited use of brackets, semicolons, etc

In many languages, when you declare a variable, you must specify the variable's **type** (e.g., int, double, Boolean, string). Python does not require this.

Image credit: https://www.python.org/community/logos/

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Some languages (e.g., C/C++ and Java) are **compiled**: we write code, from which we get a runnable program via **compilation**. In contrast, Python is **interpreted**: A program, called the **interpreter**, runs our code directly, line by line.

Compiled vs interpreted languages: compiled languages are (generally) faster than interpreted languages, typically at the cost of being more complicated.

Image credit: https://www.python.org/community/logos/

Running Python

Several options for running Python on your computer

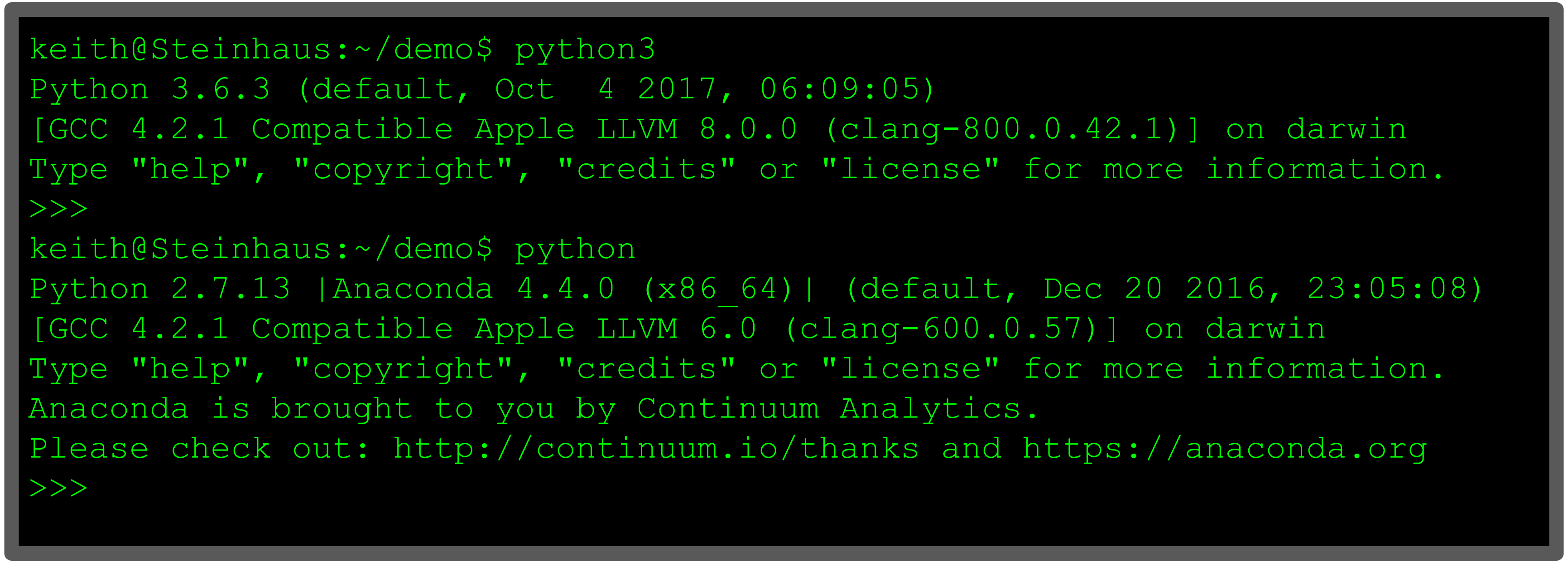
- Python interpreter
- Jupyter: https://jupyter.org/
- PythonAnywhere: https://www.pythonanywhere.com/
- Suggestions from Allen Downey:
  - http://www.allendowney.com/wp/books/think-python-2e/

Your homeworks must be handed in as Jupyter notebooks

- But you should also be comfortable with the interpreter and running Python on the command line
- Installing Jupyter: https://jupyter.readthedocs.io/en/latest/install.html
  - **Note:** Jupyter recommends Anaconda: https://www.anaconda.com/
    - I mildly recommend against Anaconda, but it's your choice

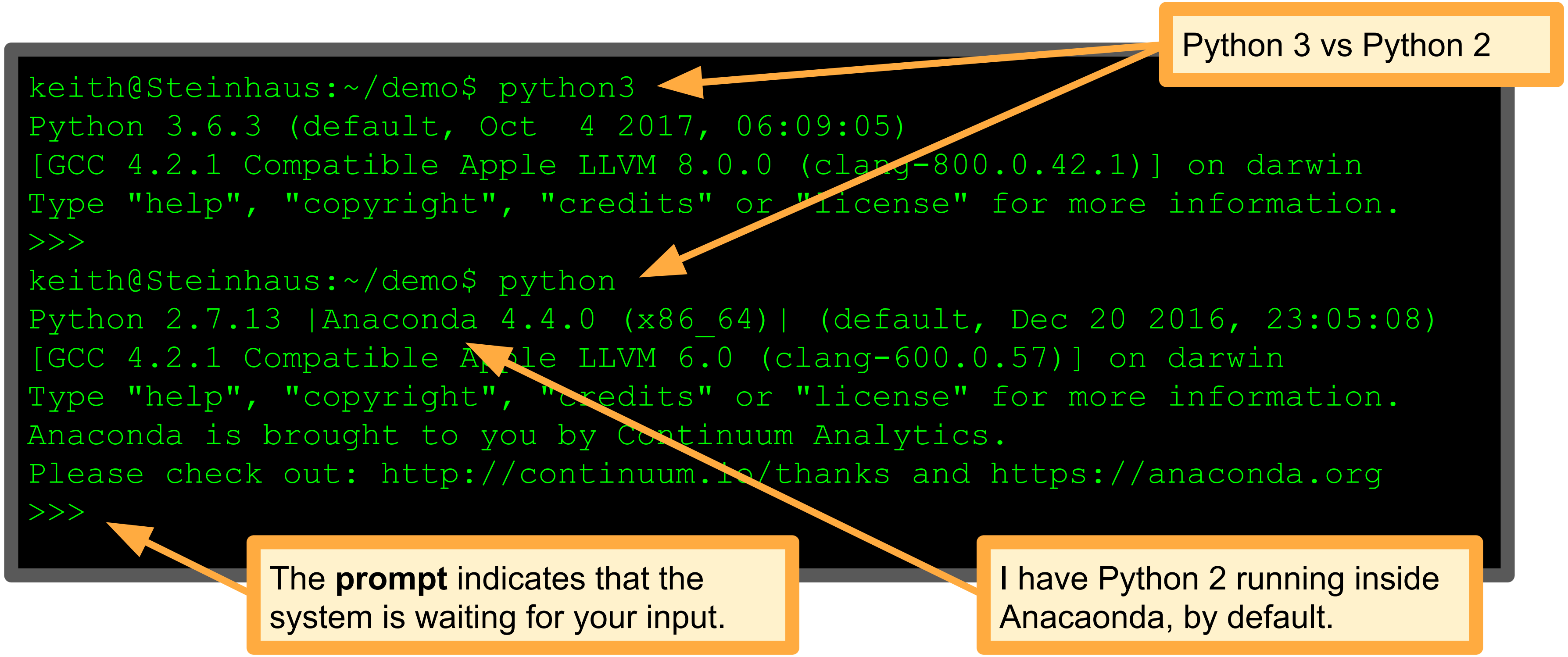
Image credit: https://www.python.org/community/logos/

Python Interpreter on the Command Line



```
keith@Steinhaus:~/demo$ python3
Python 3.6.3 (default, Oct  4 2017, 06:09:05)
[GCC 4.2.1 Compatible Apple LLVM 8.0.0 (clang-800.0.42.1)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>>
keith@Steinhaus:~/demo$ python
Python 2.7.13 |Anaconda 4.4.0 (x86_64)| (default, Dec 20 2016, 23:05:08)
[GCC 4.2.1 Compatible Apple LLVM 6.0 (clang-600.0.57)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
Anaconda is brought to you by Continuum Analytics.
Please check out: http://continuum.io/thanks and https://anaconda.org
>>>
```

Python Interpreter on the Command Line



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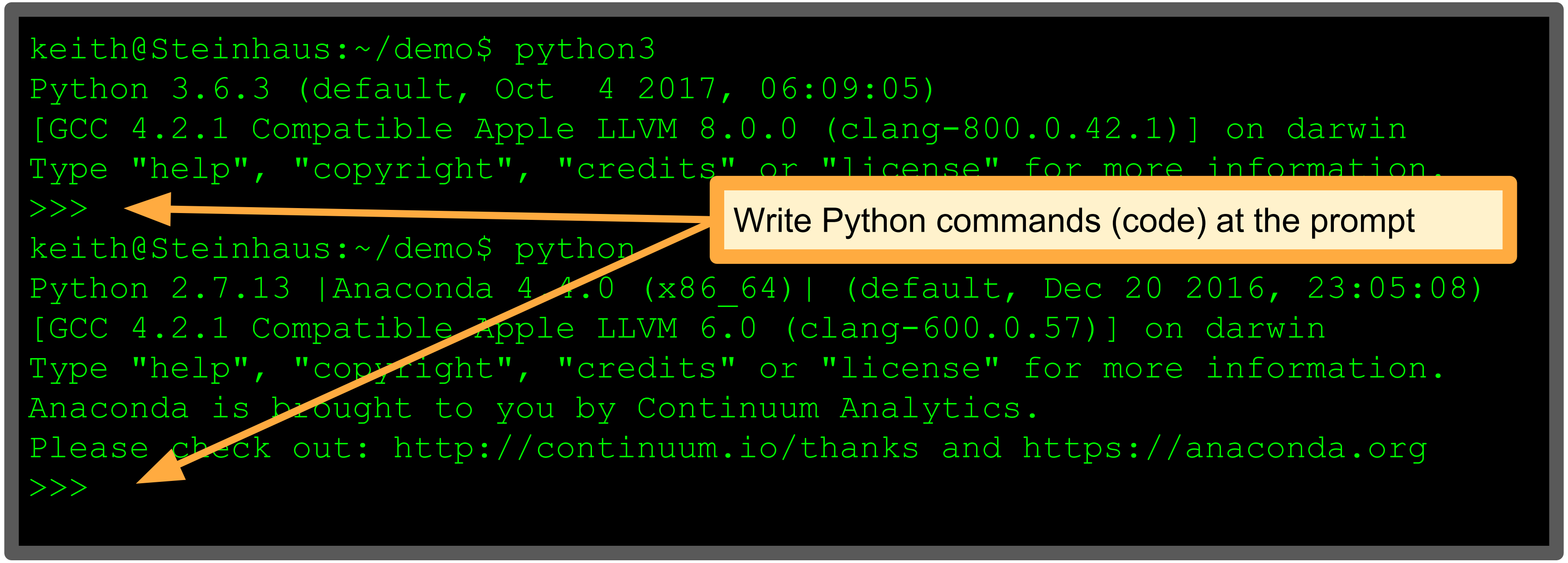
Type "help", "copyright", "credits" or "license" for more information.
Anaconda is brought to you by Continuum Analytics.
Please check out: http://continuum.io/thanks and https://anaconda.org
>>>
```

Python 3 vs Python 2

The **prompt** indicates that the system is waiting for your input.

I have Python 2 running inside Anacaonda, by default.

Python Interpreter on the Command Line



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Type "help", "copyright", "credits" or "license" for more information.
Anaconda is brought to you by Continuum Analytics.
Please check out: http://continuum.io/thanks and https://anaconda.org
>>>
```

Python in Jupyter

Creates “notebook files” for running **Ju**lia, **Py**thon and **R**

Example notebook:

https://nbviewer.jupyter.org/github/jrjohansson/scientific-python-lectures/blob/master/Lecture-4-Matplotlib.ipynb

Clean, well-organized presentation of code, text and images, in one document

Installation: https://jupyter.readthedocs.io/en/latest/install.html

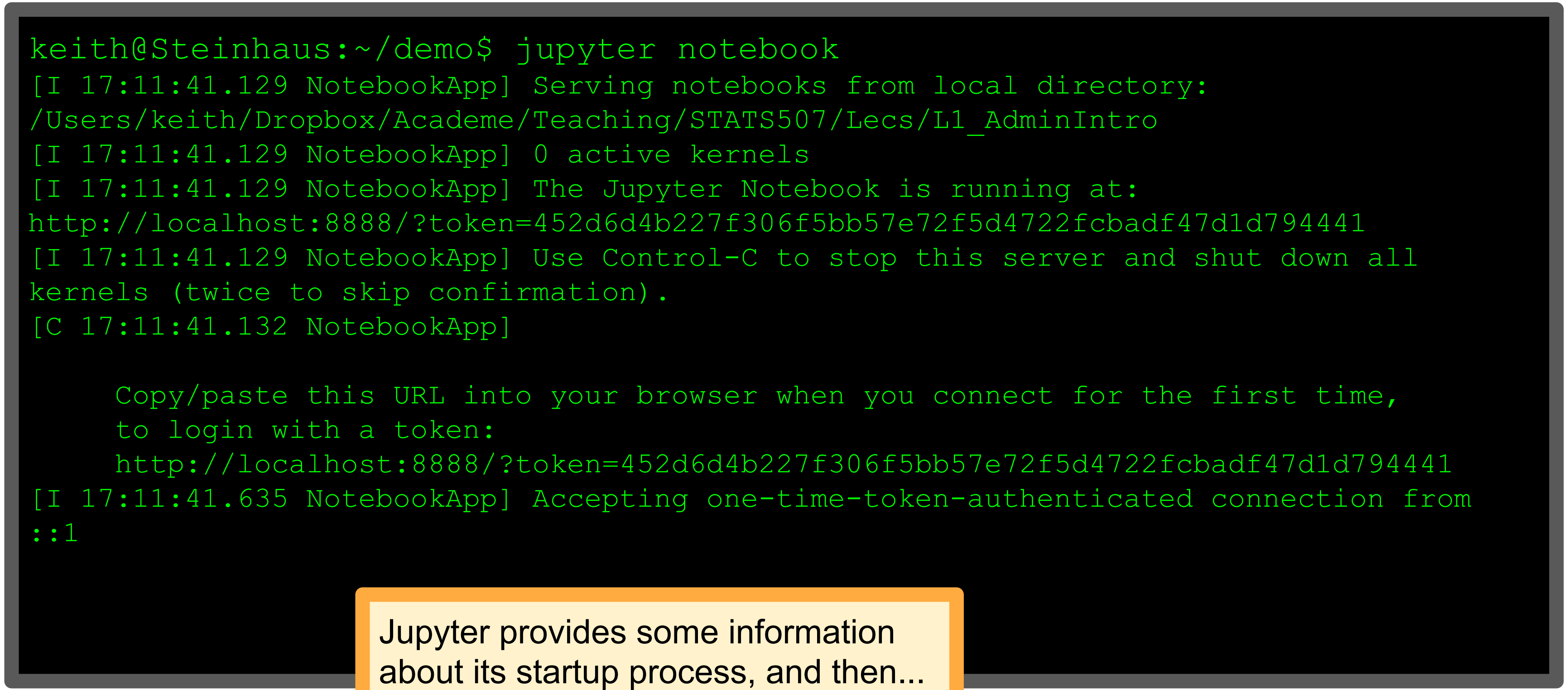
Documentation on running: https://jupyter.readthedocs.io/en/latest/running.html

Good tutorials:

https://www.datacamp.com/community/tutorials/tutorial-jupyter-notebook

https://jupyter-notebook-beginner-guide.readthedocs.io/en/latest/execute.html

Running Jupyter

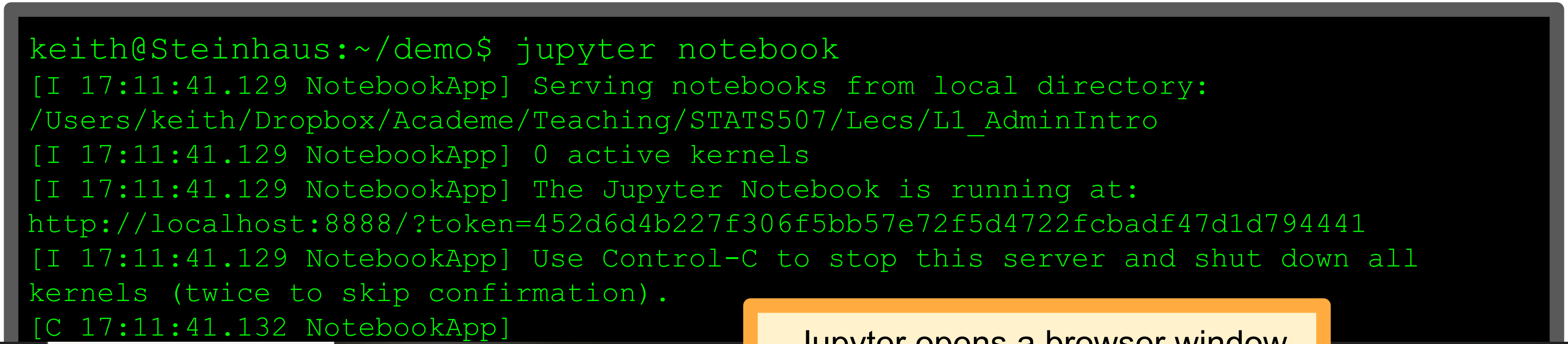


```
keith@Steinhaus:~/demo$ jupyter notebook
[I 17:11:41.129 NotebookApp] Serving notebooks from local directory:
/Users/keith/Dropbox/Academe/Teaching/STATS507/Lecs/L1_AdminIntro
[I 17:11:41.129 NotebookApp] 0 active kernels
[I 17:11:41.129 NotebookApp] The Jupyter Notebook is running at:
http://localhost:8888/?token=452d6d4b227f306f5bb57e72f5d4722fcbadf47d1d794441
[I 17:11:41.129 NotebookApp] Use Control-C to stop this server and shut down all
kernels (twice to skip confirmation).
[C 17:11:41.132 NotebookApp]

    Copy/paste this URL into your browser when you connect for the first time,
    to login with a token:
    http://localhost:8888/?token=452d6d4b227f306f5bb57e72f5d4722fcbadf47d1d794441
[I 17:11:41.635 NotebookApp] Accepting one-time-token-authenticated connection from
::1
```

Jupyter provides some information about its startup process, and then...

Running Jupyter



```
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[I 17:11:41.129 NotebookApp] Use Control-C to stop this server and shut down all
kernels (twice to skip confirmation).
[C 17:11:41.132 NotebookApp]
```
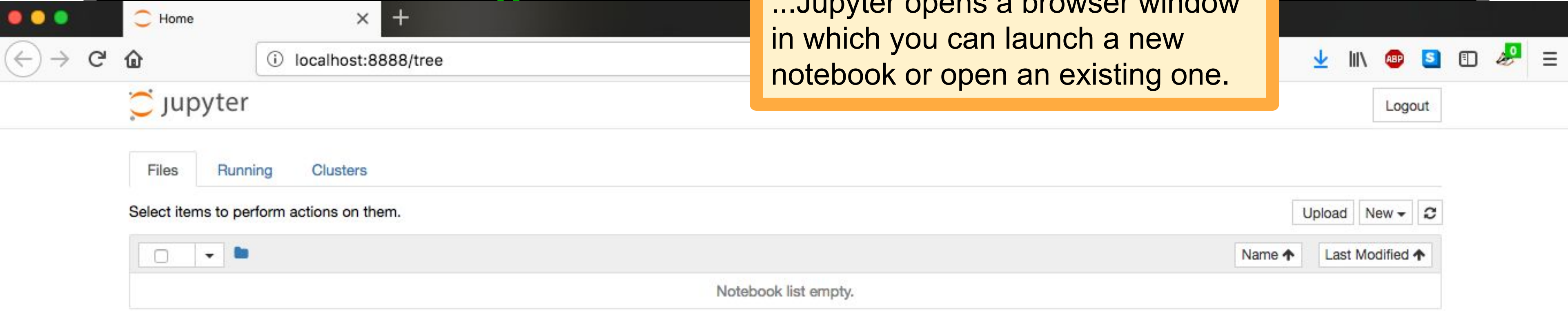
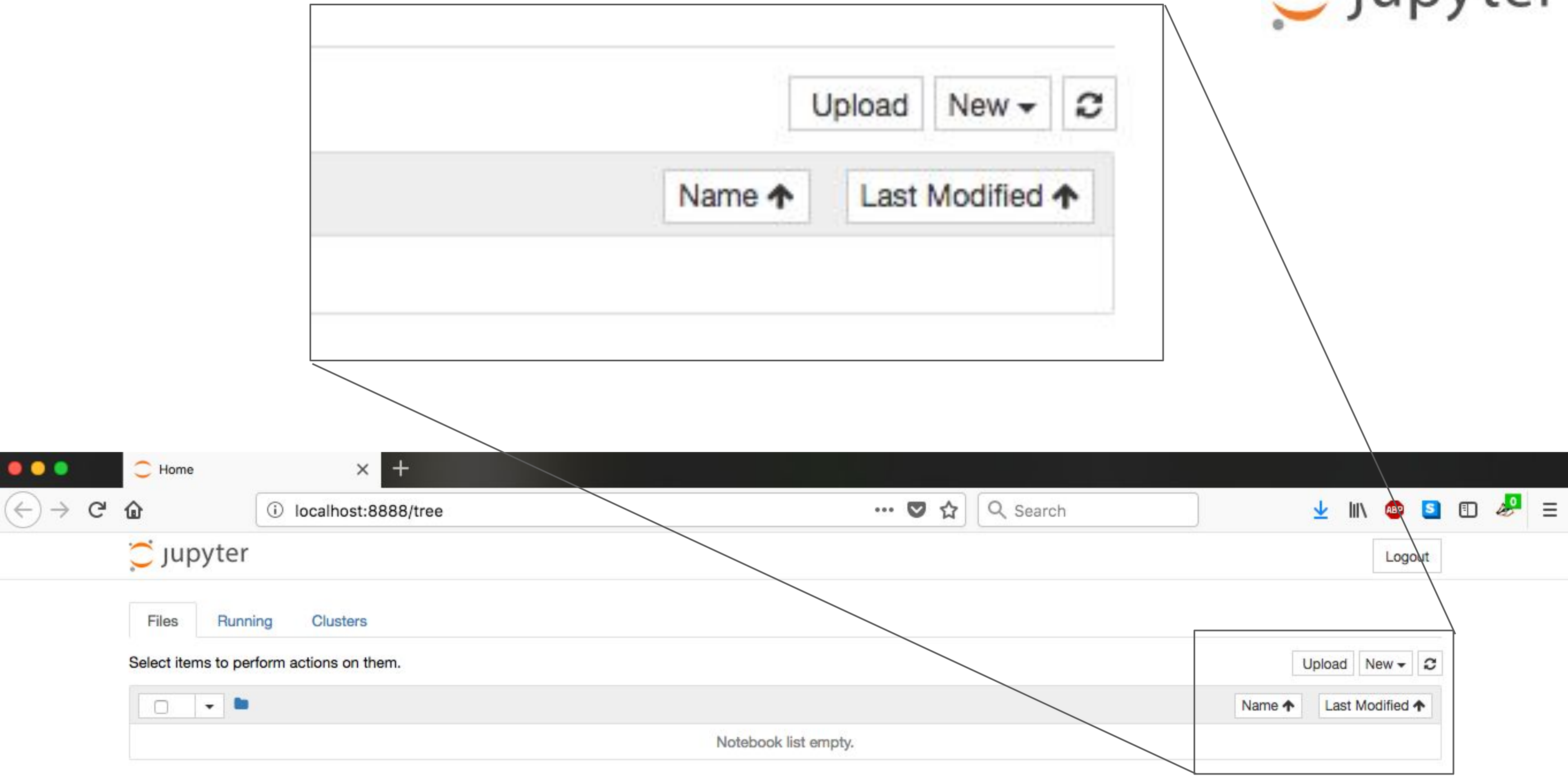



...Jupyter opens a browser window in which you can launch a new notebook or open an existing one.



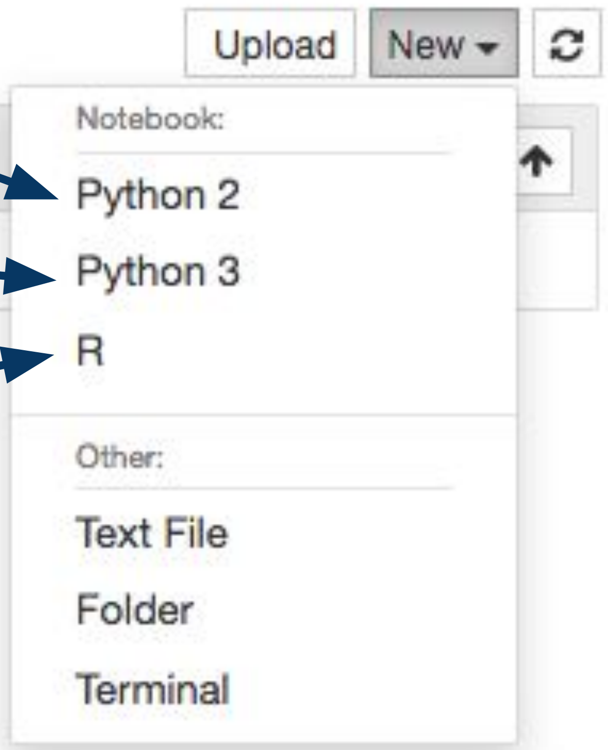
Select items to perform actions on them.

Notebook list empty.

Creates a new notebook file running Python 2.

Creates a new notebook file running Python 3.

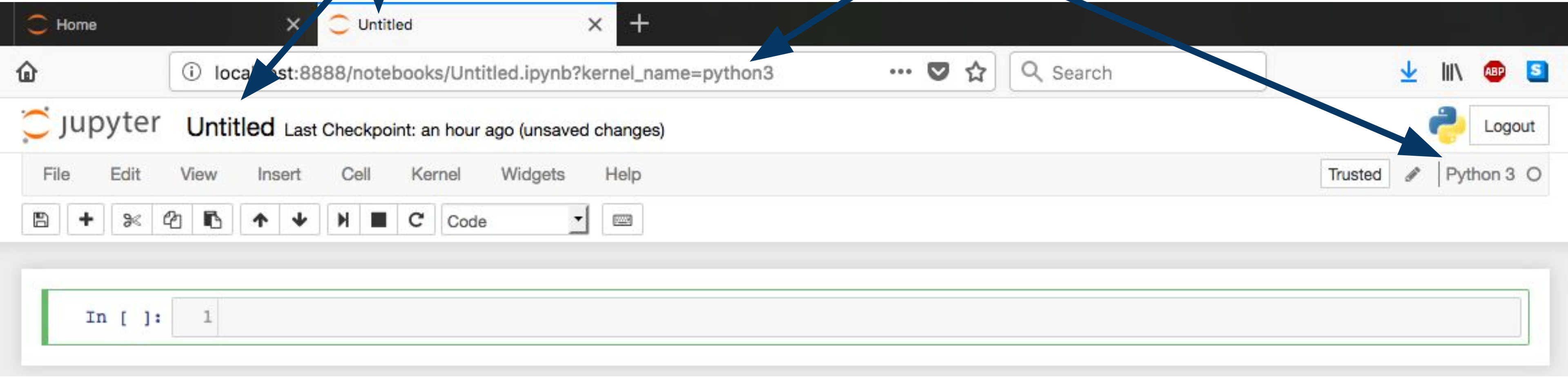
Creates a new notebook file running R.



Note: Jupyter can also run other programming languages, such as Julia, if they are installed.

Notebook doesn't have a title, yet.

Running Python 3


Home
Untitled
localhost:8888/notebooks/Untitled.ipynb?kernel_name=python3
Search
jupyter
Untitled Last Checkpoint: an hour ago (unsaved changes)
Logout
File
Edit
View
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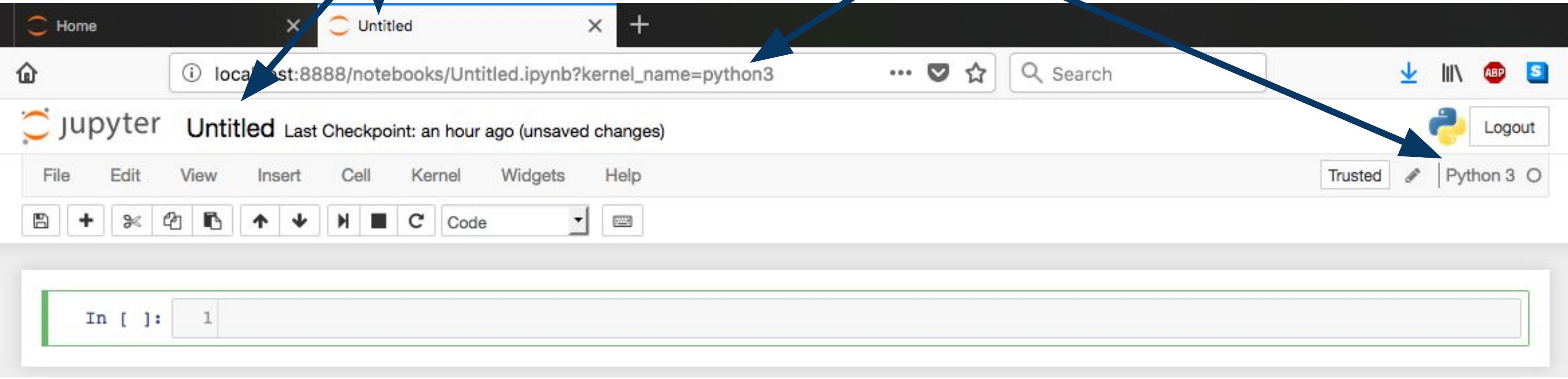
Cell
Kernel
Widgets
Help
Trusted
Python 3
Code
In [ ]:
1

Notebook doesn't have a title, yet.

Running Python 3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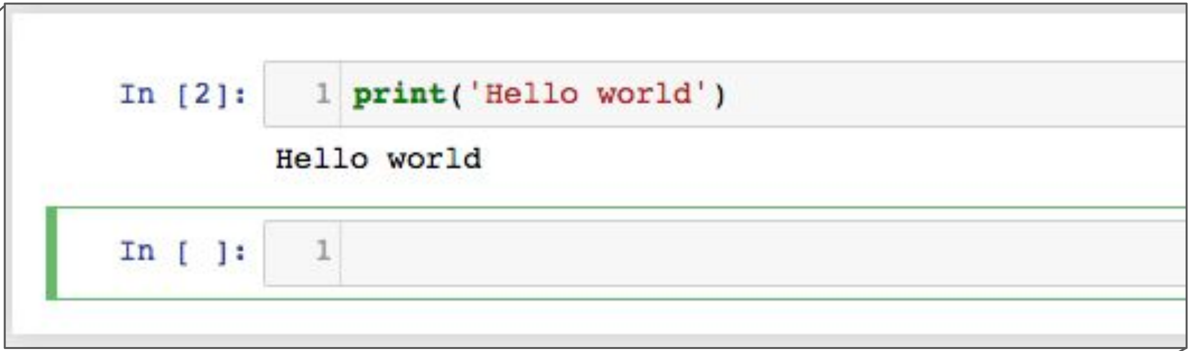
In [ ]:

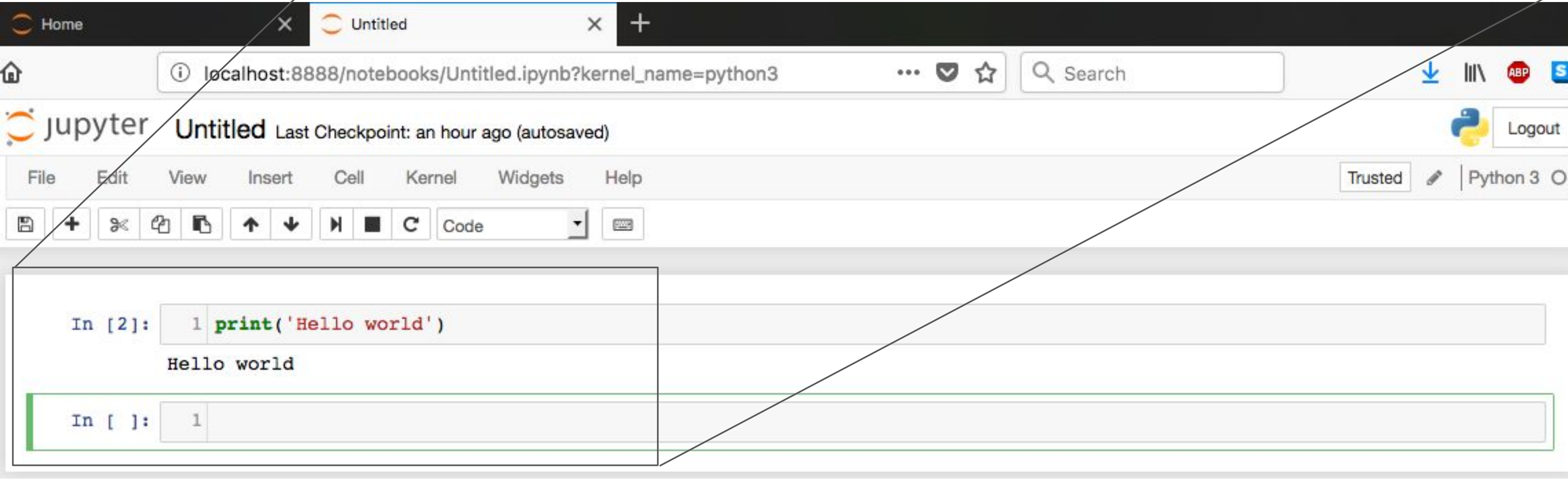
I'll leave it to you to learn about the other features by reading the documentation. For now, the green-highlighted box is most important. That's where we write Python code.

Write code in the highlighted box, then press shift+enter to run the code in that box...


```
In [2]: print('Hello world')

        Hello world

In [ ]:
```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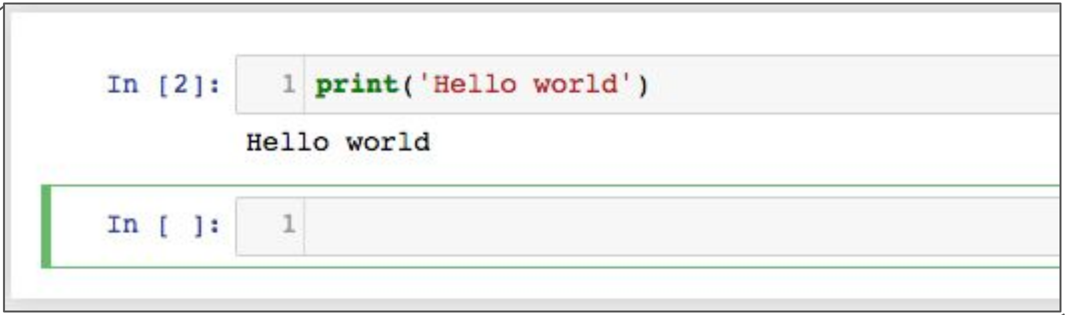

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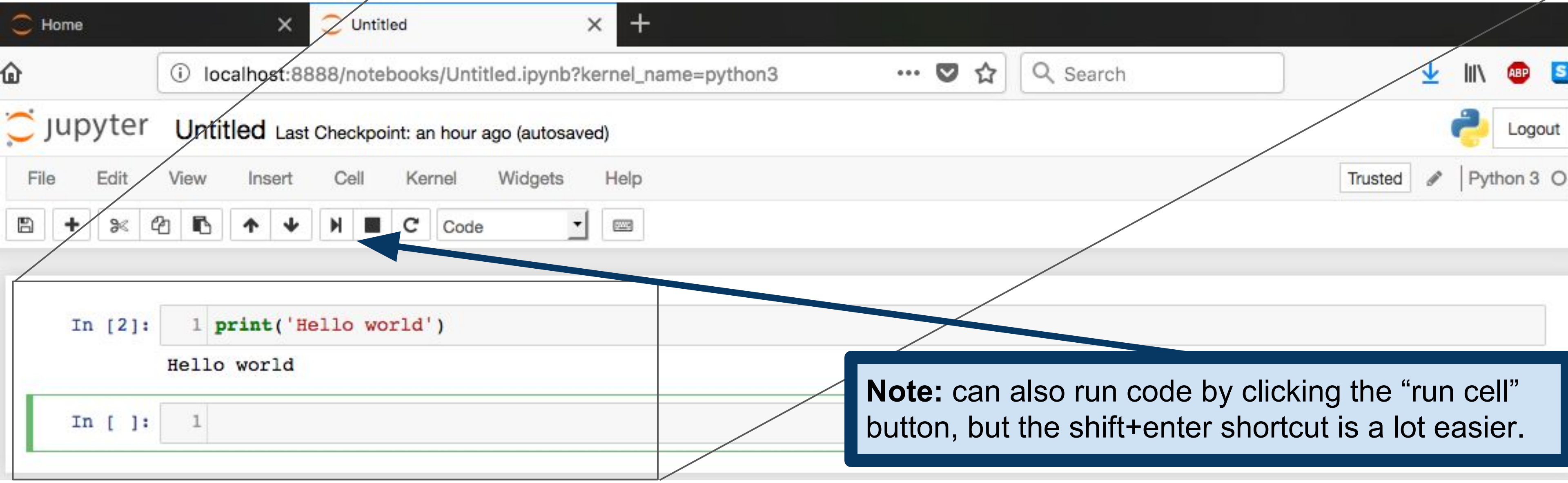
In [ ]:
```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Code

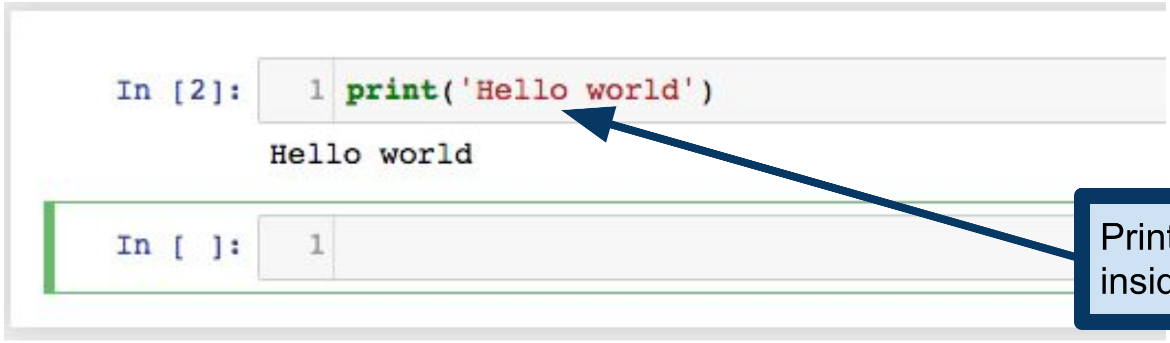
```
In [2]:  print('Hello world')

         Hello world

In [ ]:
```

Note: can also run code by clicking the “run cell” button, but the shift+enter shortcut is a lot easier.

Our first function: `print`



```
In [2]: print('Hello world')

Hello world

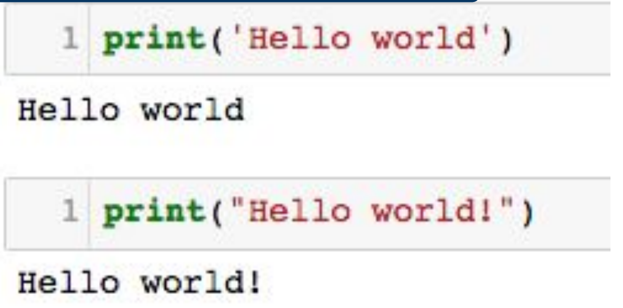
In [ ]:
```

Print displays whatever is inside the quotation marks.

If you haven't already guessed, print takes a Python **string** and prints it. Of course, "print" here means to display a string, not literally print it on a printer!

Note: if you know Python 2, you'll notice that print is a bit different in Python 3. That is because in Python 2, print was a **statement**, whereas in Python 3, print is a **function**.

Can also use double quotes



```
print('Hello world')

Hello world

print("Hello world!")

Hello world!
```

Arithmetic in Python

```
1+2
```
```
3
```

Use + to add numbers.

```
2*3
```
```
6
```

Use * to multiply.

```
2*3 - 1
```
```
5
```

Order of operations is just like you learned in elementary school.

```
2**7
```
```
128
```

Python is weird in that it uses `**` for exponentiation instead of the more common `^`.

/ for division.

```
6/3
```
```
2.0
```

```
8/3
```
```
2.6666666666666665
```

`//` performs division but rounds down.

```
8//3
```
```
2
```

`%` is modulo. `x%y` is remainder when `x` is divided by `y`.

```
8%3
```
```
2
```

Data Types

Programs work with **values**, which come with different **types**

Examples:

- The value `42` is an **integer**
- The value `2.71828` is a **floating point number** (i.e., decimal number)
- The value `“bird”` is a **string** (i.e., a *string of characters*)

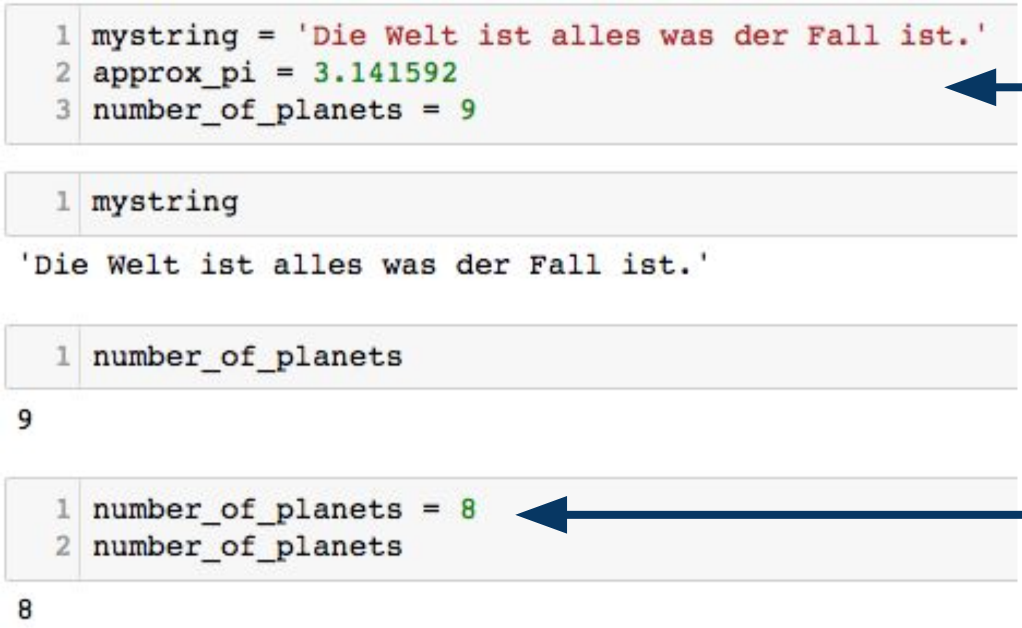
Variable’s type determines what operations we can and can’t perform

- e.g., `2*3` makes sense, but what is `‘cat’*‘dog’`?
- (We’ll come back to this in more detail in a few slides)

Variables in Python

Variable is a name that refers to a value

Assign a value to a variable via **variable assignment**



```
mystring = 'Die Welt ist alles was der Fall ist.'
approx_pi = 3.141592
number_of_planets = 9
```

Assign values to three variables

```
mystring
```

```
'Die Welt ist alles was der Fall ist.'
```

```
number_of_planets
```

```
9
```

```
number_of_planets = 8
number_of_planets
```

```
8
```

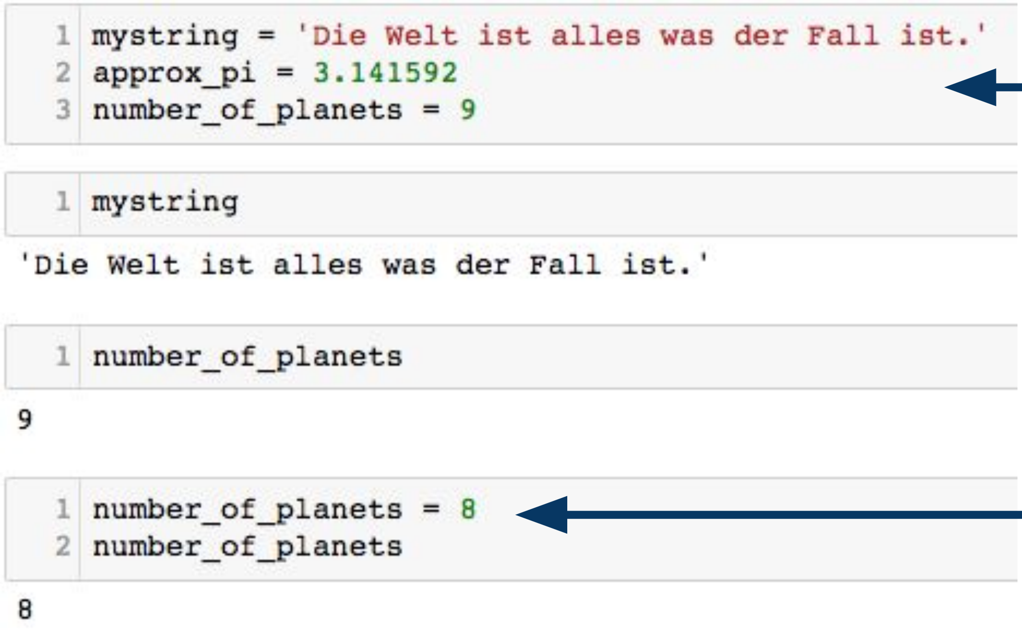
Change the value of `number_of_planets` via another assignment statement.

Variables in Python

Variable is a name that refers to a value

Note: unlike some languages (e.g., C/C++ and Java), you don't need to tell Python the type of a variable when you declare it. Instead, Python figures out the type of a variable automatically. Python uses what is called **duck typing**, which we will return to in a few lectures.

Assign a value to a variable via **variable assignment**



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```

```python
mystring
```

```
'Die Welt ist alles was der Fall ist.'
```

```python
number_of_planets
```

```
9
```

```python
number_of_planets = 8
number_of_planets
```

```
8
```

Assign values to three variables

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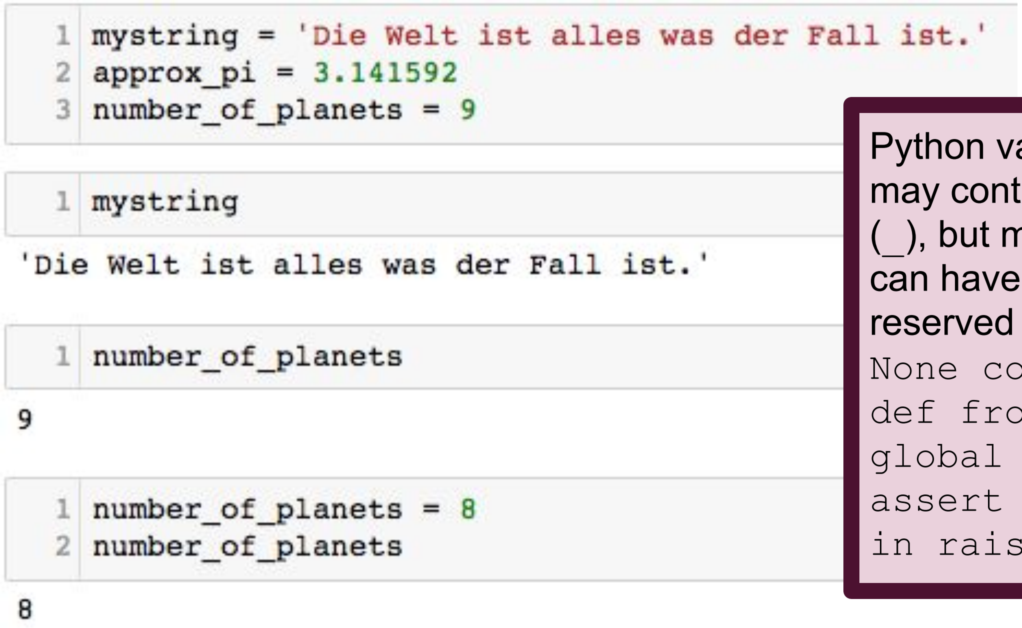

```
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```

```
mystring
```

```
'Die Welt ist alles was der Fall ist.'
```

```
number_of_planets
```

```
9
```

```
number_of_planets = 8
number_of_planets
```

```
8
```

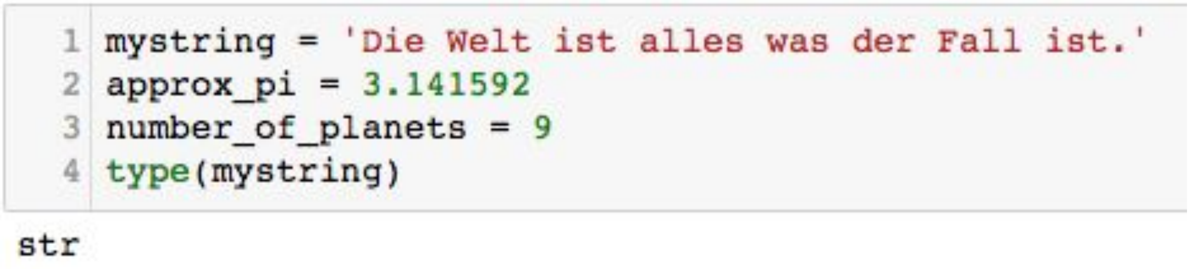
Python variable names can be arbitrarily long, and may contain any letters, numbers and underscore (_), but may not start with a number. Variables can have any name, except for the Python 3 reserved keywords:

```
None continue for lambda try True
def from nonlocal while and del
global not with as elif if or yield
assert else import pass break except
in raise
```

Variables in Python

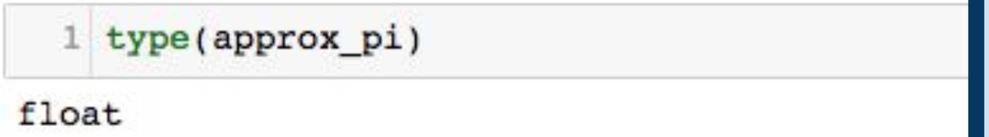
Sometimes we do need to know the type of a variable

Python `type()` function does this for us



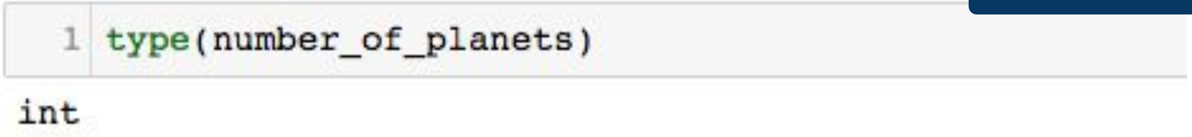
```python
mystring = 'Die Welt ist alles was der Fall ist.'
approx_pi = 3.141592
number_of_planets = 9
type(mystring)
```

```
str
```



```python
type(approx_pi)
```

```
float
```



```python
type(number_of_planets)
```

```
int
```

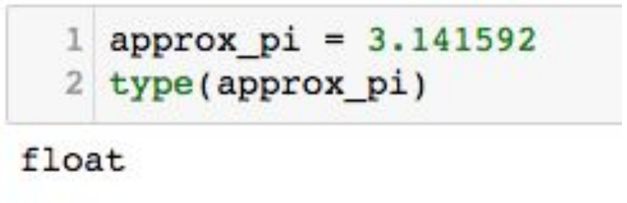
Recall that `type` is one of the Python reserved words. Syntax highlighting shows it as green, indicating that it is a special word in Python.

Variables in Python

Note: changing a variable to a different type is often called **casting** a variable to that type.

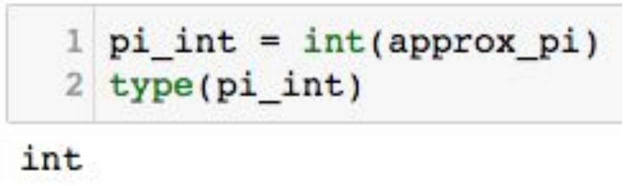
We can (sometimes) change the type of a Python variable

Convert a `float` to an `int`:



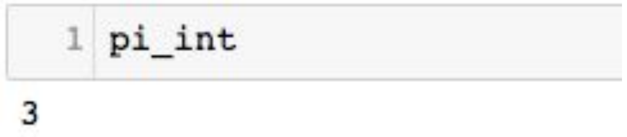
```
approx_pi = 3.141592
type(approx_pi)
```

```
float
```



```
pi_int = int(approx_pi)
type(pi_int)
```

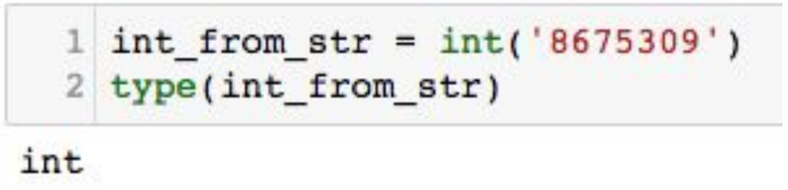
```
int
```



```
pi_int
```

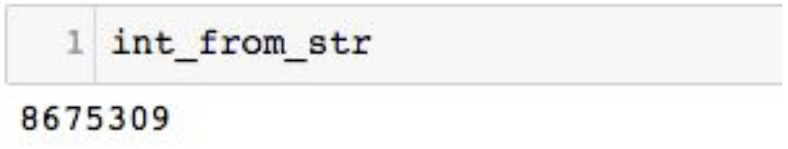
```
3
```

Convert a `string` to an `int`:



```
int_from_str = int('8675309')
type(int_from_str)
```

```
int
```



```
int_from_str
```

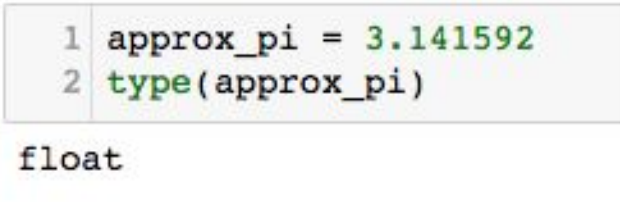
```
8675309
```

Variables in Python

Note: changing a variable to a different type is often called **casting** a variable to that type.

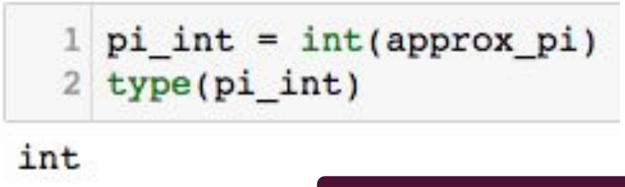
We can (sometimes) change the type of a Python variable

Convert a `float` to an `int`:



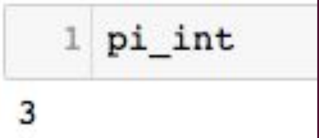
```
approx_pi = 3.141592
type(approx_pi)
```

```
float
```



```
pi_int = int(approx_pi)
type(pi_int)
```

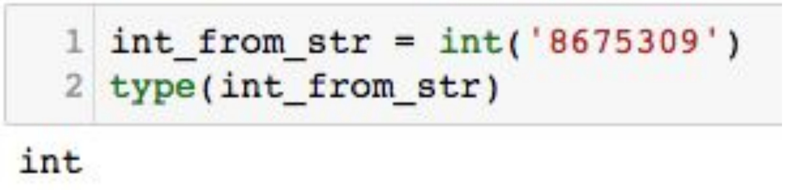
```
int
```



```
pi_int
```

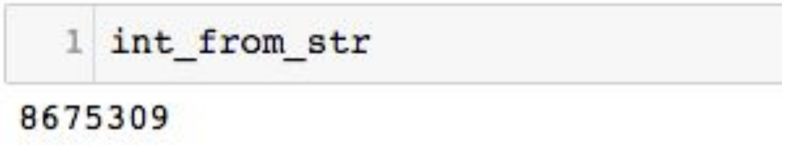
```
3
```

Convert a `string` to an `int`:



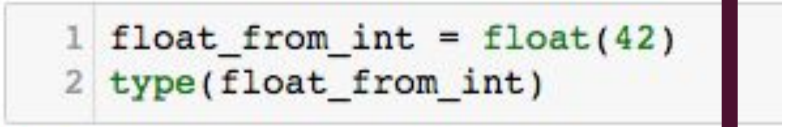
```
int_from_str = int('8675309')
type(int_from_str)
```

```
int
```



```
int_from_str
```

```
8675309
```



```
float_from_int = float(42)
type(float_from_int)
```

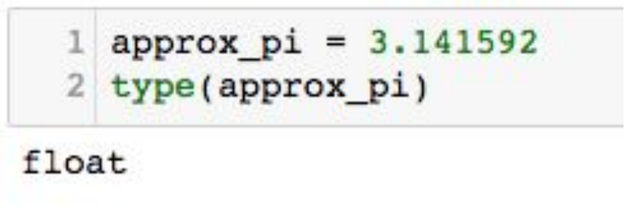
Test your understanding: what should be the value of `float_from_int`?

Variables in Python

Note: changing a variable to a different type is often called **casting** a variable to that type.

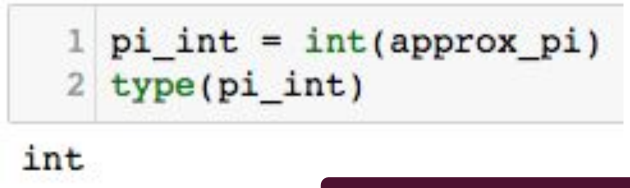
We can (sometimes) change the type of a Python variable

Convert a `float` to an `int`:



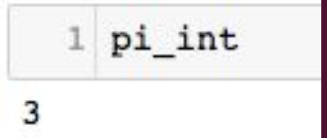
```
approx_pi = 3.141592
type(approx_pi)
```

```
float
```



```
pi_int = int(approx_pi)
type(pi_int)
```

```
int
```

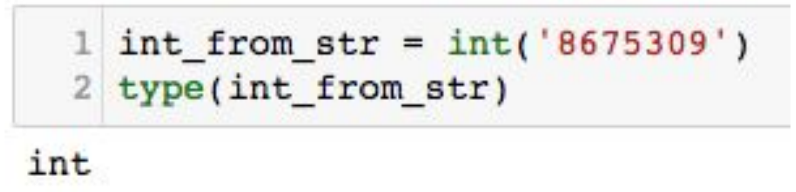


```
pi_int
```

```
3
```

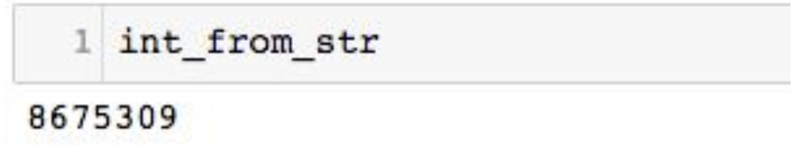
Test your understanding: what should be the value of `float_from_int`?

Convert a `string` to an `int`:



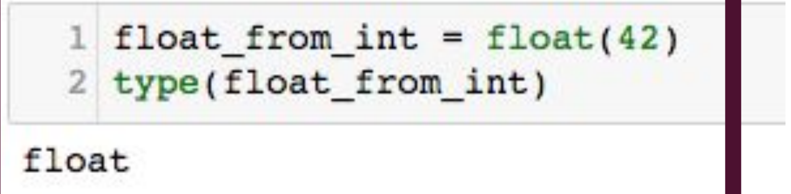
```
int_from_str = int('8675309')
type(int_from_str)
```

```
int
```



```
int_from_str
```

```
8675309
```



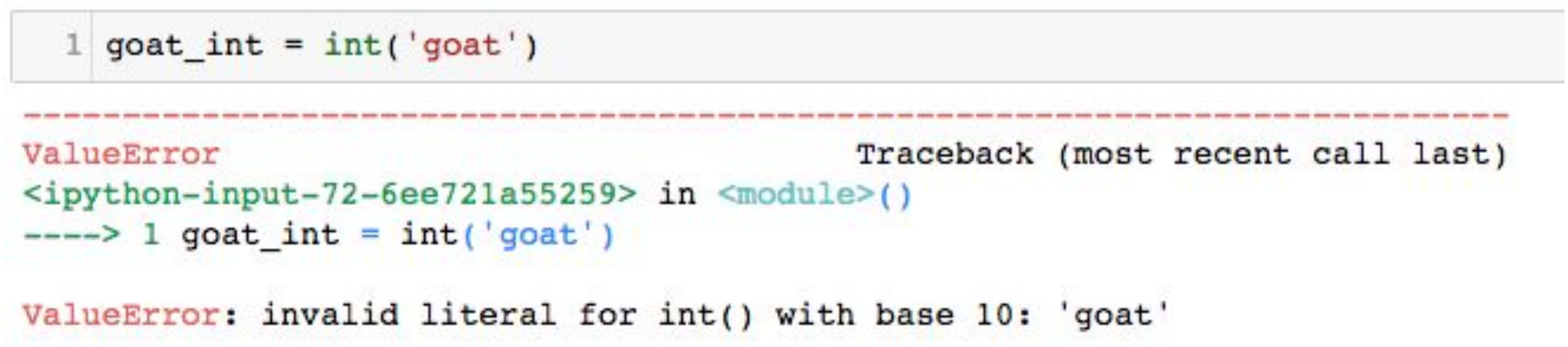
```
float_from_int = float(42)
type(float_from_int)
```

```
float
```

Variables in Python

We can (sometimes) change the type of a Python variable

But if we try to cast to a type that doesn't make sense...



```
goat_int = int('goat')
```

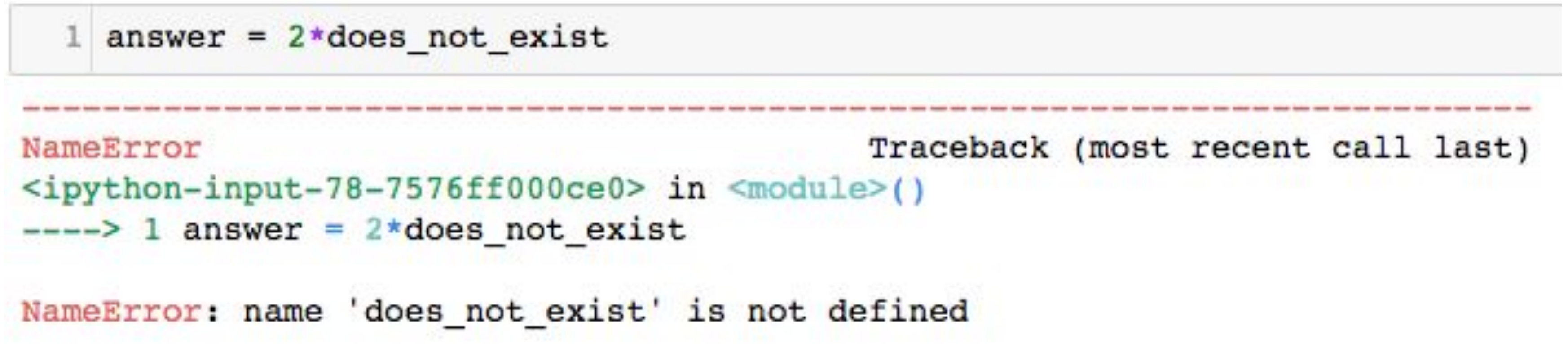
```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
<ipython-input-72-6ee721a55259> in <module>()
----> 1 goat_int = int('goat')

ValueError: invalid literal for int() with base 10: 'goat'
```

`ValueError` signifies that the type of a variable is okay, but its value doesn't make sense for the operation that we are asking for.
https://docs.python.org/3/library/exceptions.html#ValueError

Variables in Python

Variables must be declared (i.e., must have a value) before we evaluate them

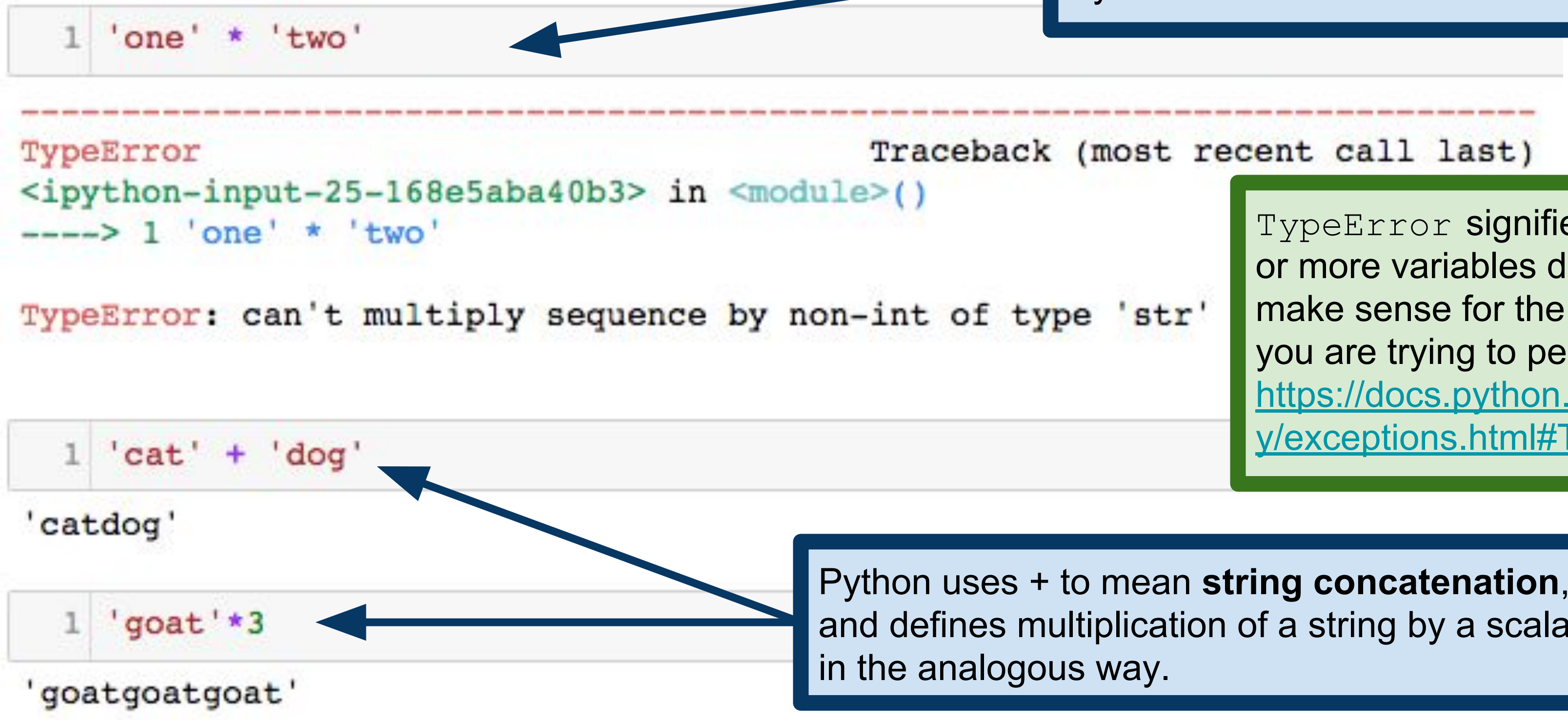

```
answer = 2*does_not_exist
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-78-7576ff000ce0> in <module>()
----> 1 answer = 2*does_not_exist

NameError: name 'does_not_exist' is not defined
```

`NameError` signifies that Python can’t find anything (variable, function, etc) matching a given name. https://docs.python.org/3/library/exceptions.html#NameError

String Operations



```
'one' * 'two'
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-25-168e5aba40b3> in <module>()
----> 1 'one' * 'two'

TypeError: can't multiply sequence by non-int of type 'str'
```

```
'cat' + 'dog'
```

```
'catdog'
```

```
'goat'*3
```

```
'goatgoatgoat'
```

Try to multiply two strings and Python throws an error.

`TypeError` signifies that one or more variables doesn't make sense for the operation you are trying to perform. https://docs.python.org/3/library/exceptions.html#TypeError

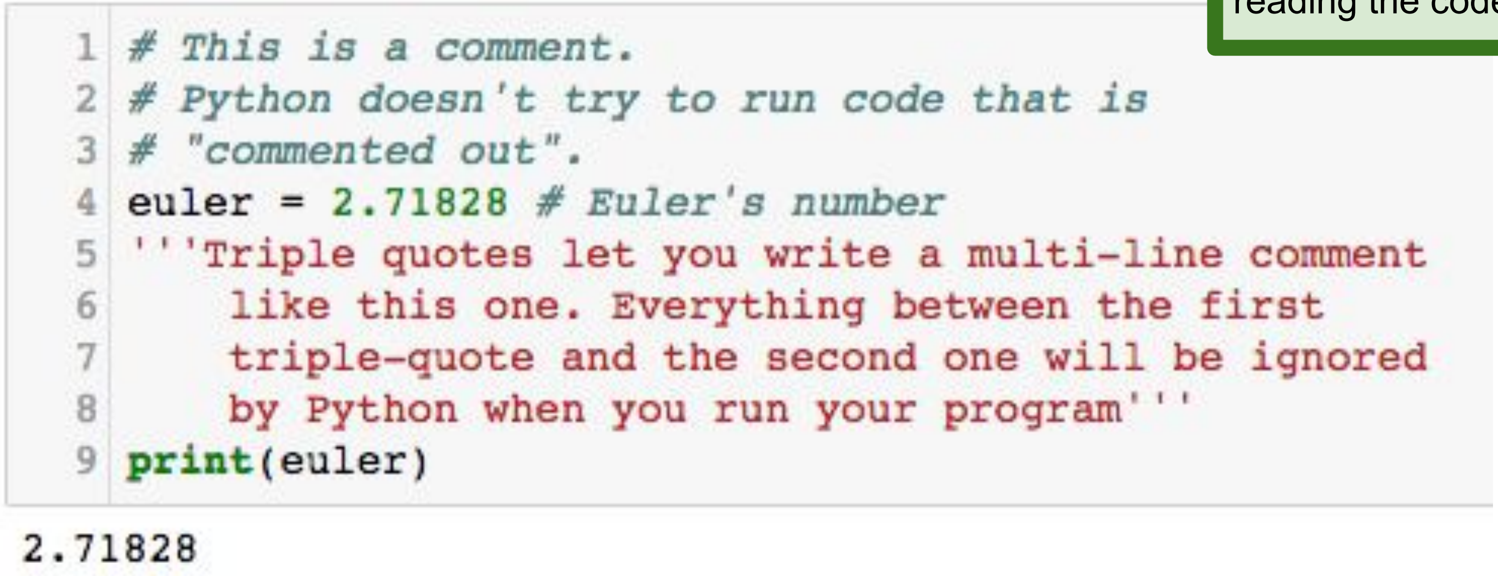
Python uses + to mean **string concatenation**, and defines multiplication of a string by a scalar in the analogous way.

Comments in Python

Comments provide a way to document your code

- Good for when other people have to read your code
- But *also* good for you!

Comments explain to a reader (whether you or someone else) what your code is *meant* to do, which is not always obvious from reading the code itself!



```python
# This is a comment.
# Python doesn't try to run code that is
# "commented out".
euler = 2.71828 # Euler's number
'''Triple quotes let you write a multi-line comment
    like this one. Everything between the first
    triple-quote and the second one will be ignored
    by Python when you run your program'''
print(euler)
```

```
2.71828
```

A parting note for the day...

Homework:

Start your homework early!

If you run into technical issues, you’ll want to have time to come get help!

A note on pace and difficulty

I aim to teach Python from scratch in this course, but…

...time spent on Python is time not spent on the stuff you’re really here for

So, I expect that you are willing to work hard to keep up

If I am moving too fast, or you don’t understand something, come speak to me promptly!