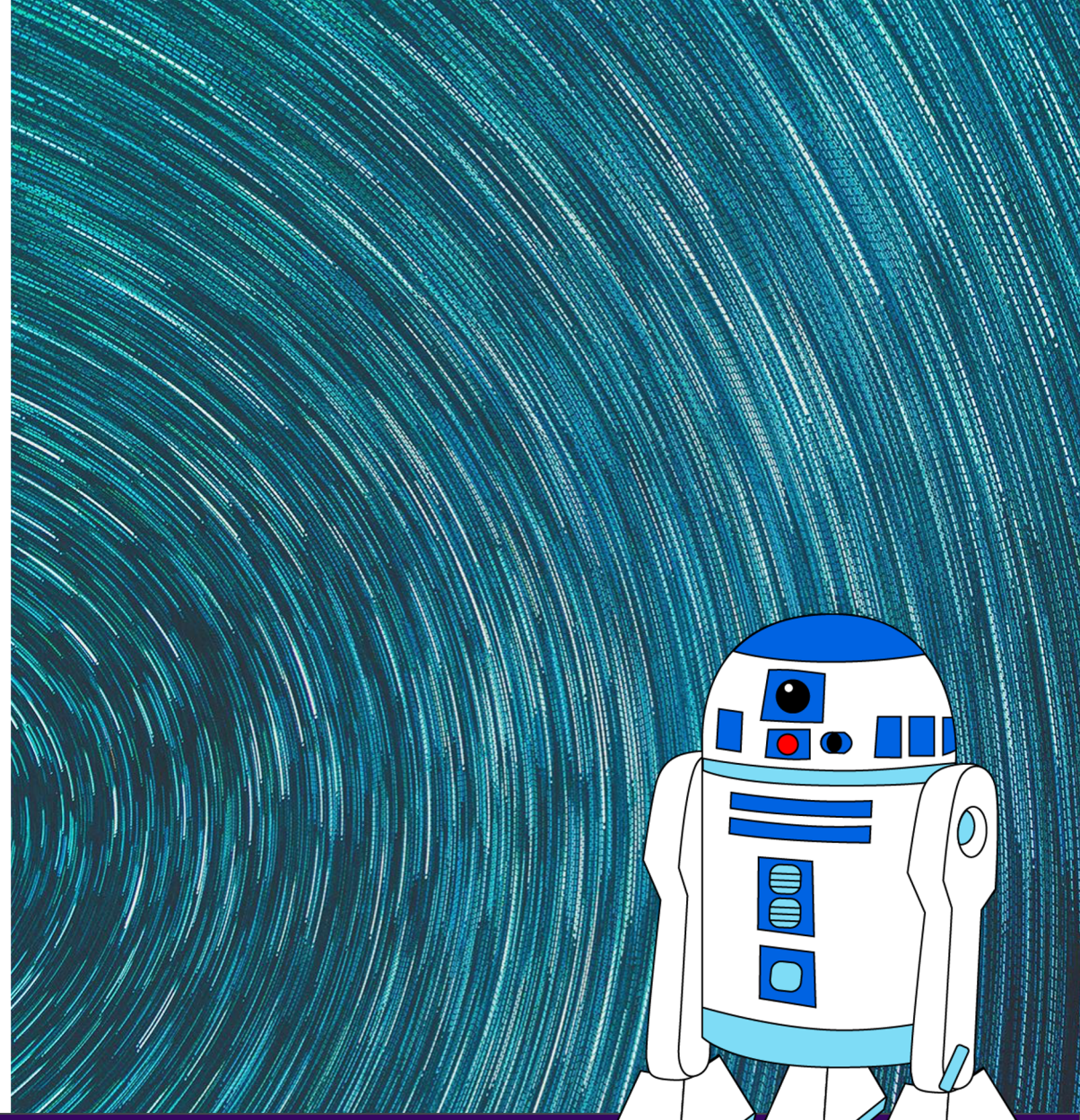
CIS 521:
ARTIFICIAL INTELLIGENCE

Introduction to Python

Professor Chris Callison-Burch



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Last extensive revision:
Jie Gao, Fall 2019

Previous revisions:
Daniel Moroz, Fall 2015

Plan Day 1

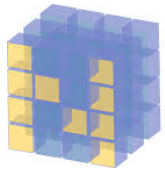
- **Baby steps**
  - History, Python environments, Docs
- **Absolute Fundamentals**
  - Objects, Types
  - Math and Strings basics
  - References and Mutability
- **Data Types**
  - Strings, Tuples, Lists, Dictionaries
- **Looping**
  - Comprehensions
- **Iterators**
  - Generators
- **To Be Continued…**

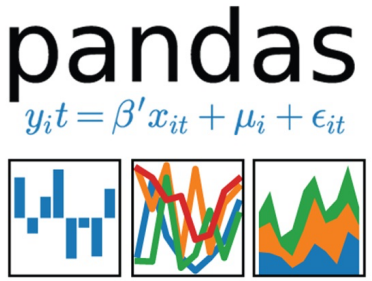
Python

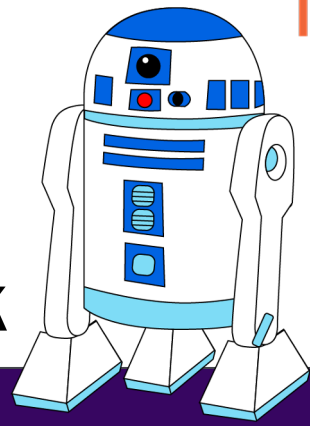
- **Developed by Guido van Rossum in the early 90s**
  - Originally Dutch, in USA since 1995.
  - Benevolent Dictator for Life (now retired)
- **Available on Eniac; download at python.org**
- **Named after the Monty Python comedy group**

Some Positive Features of Python

- **Fast development:**
  - Concise, intuitive syntax
    - Whitespace delimited
  - Garbage collected
- **Portable:**
  - Programs run on major platforms without change
  - cpython: common Python implementation in C.
- **Various built-in types:**
  - lists, dictionaries, sets: useful for AI
- **Large collection of support libraries:**
  - NumPy for Matlab like programming
  - Sklearn for machine learning
  - Pandas for data analysis







Recommended Reading

- **Python Overview**
  - The Official Python Tutorial (https://docs.python.org/3/tutorial/index.html)
  - Slides for CIS192, Spring 2019 (https://www.cis.upenn.edu/~cis192/)
- **PEPs – Python Enhancement Proposals**
  - PEP 8 - Official Style Guide for Python Code (Guido et al)
    - Style is about consistency. 4 space indents, < 80 char lines
    - Naming convention for functions and variables: lower_w_under
    - Use the automatic pep8 checker!
- PEP 20 – The Zen of Python (Tim Peters) (try: *import this*)
  - Beautiful is better than ugly; simple is better than complex
  - There should be one obvious way to do it
  - That way may not be obvious at first unless you're Dutch
  - Readability counts

Python REPL Environment

- **REPL**
  - Read-Evaluate-Print Loop
  - Type “python” at the terminal
  - Convenient for testing
  - If you’d like syntax highlighting in REPL try bpython

You should use Python version 3.7 or version 3.8.

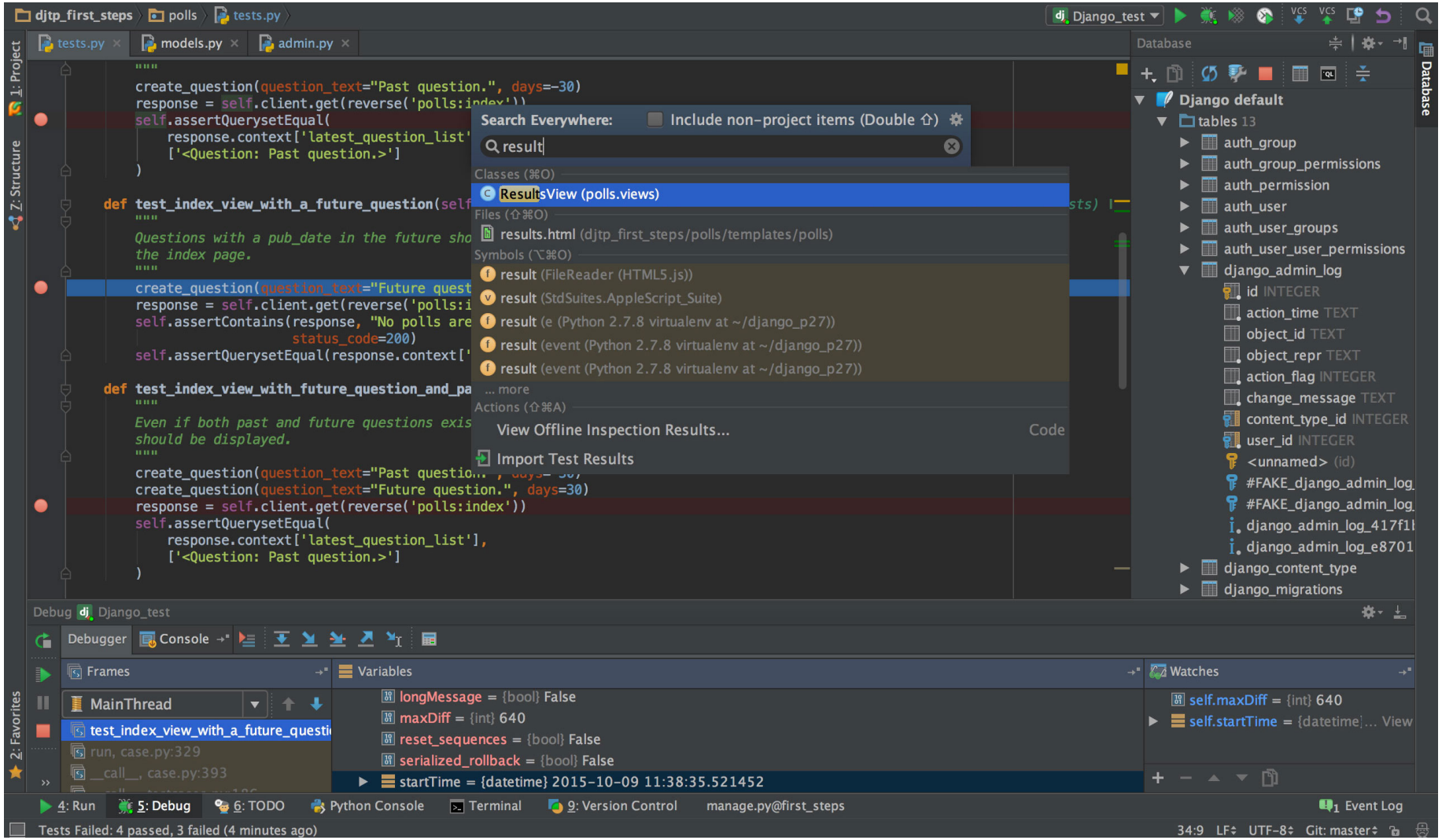
```
cis521x@eniac:~> python3
Python 3.4.6 (default, Mar 22 2017, 12:26:13) [GCC] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> print('Hello World!')
Hello World!
>>> 'Hello World!'
'Hello World!'
>>> [2*i for i in range(10)]
[0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
>>> exit()
cis521x@eniac:~>
```

Python Scripts

- **Scripts**
  - Create a file with your favorite text editor (like Sublime)
  - Type “python3 script_name.py” at the terminal to run
  - Not REPL, so you need to explicitly print
  - Homework submitted as scripts

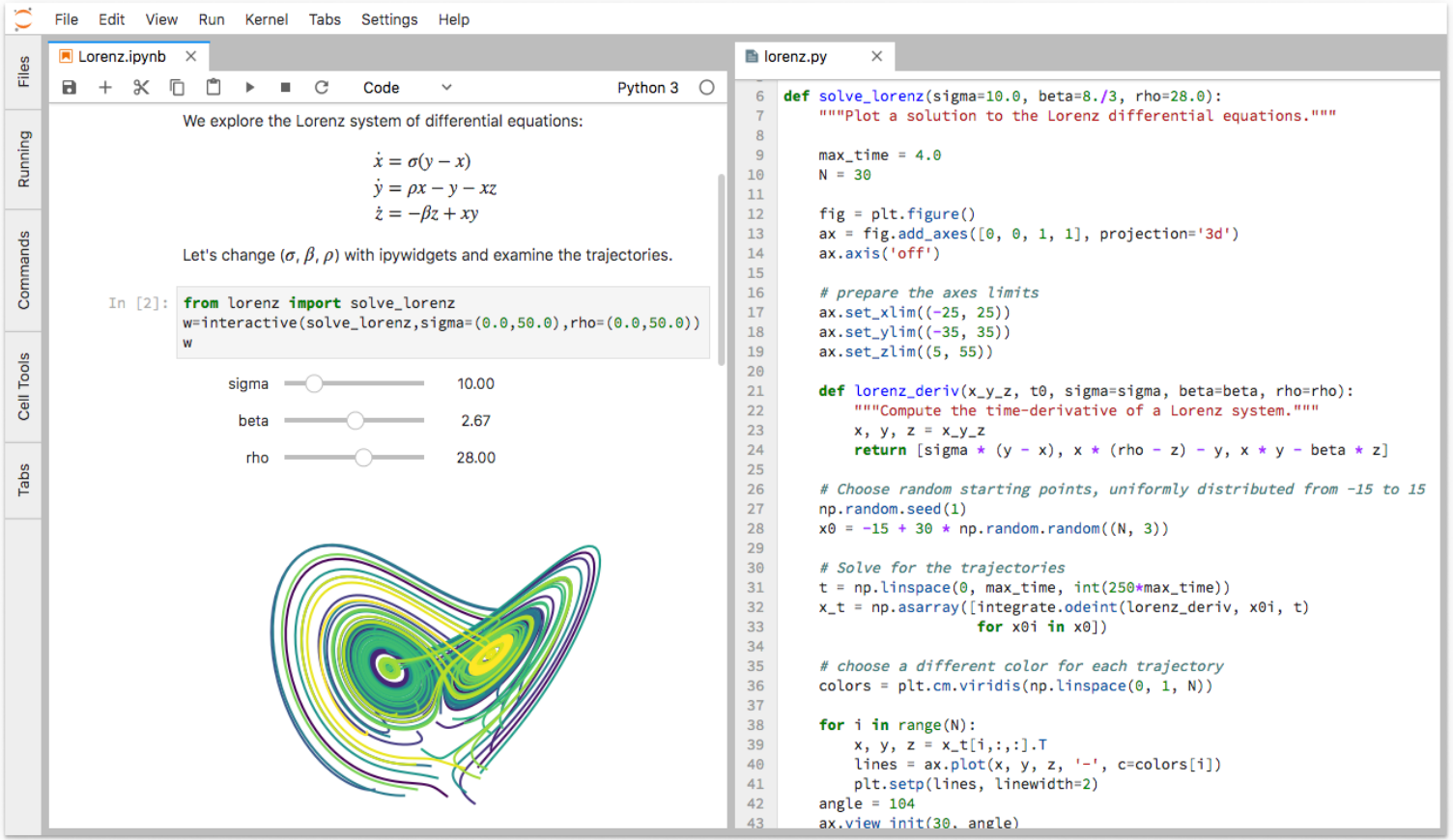
```
cis521x@eniac:~> cat foo.py
import random
def rand_fn():
    """outputs list of 10 random floats between [0.0, 1.0)"""
    return ["%.2f" % random.random() for i in range(10)]

print('1/2 = ', 1/2)
if __name__ == '__main__':
    rand_fn()
    print(rand_fn())

cis521x@eniac:~> python3 foo.py
1/2 =  0.5
['0.08', '0.10', '0.84', '0.01', '0.00', '0.59', '0.67', '0.88', '0.58', '0.81']
cis521x@eniac:~>
```

PyCharm IDE


djtp_first_steps
polls
tests.py
Django_test
tests.py
models.py
admin.py
Search Everywhere:
Include non-project items (Double ⇧)
result
Classes (⌘O)
ResultsView (polls.views)
Files (⇧⌘O)
results.html (djtp_first_steps/polls/templates/polls)
Symbols (⌥⌘O)
result (FileReader (HTML5.js))
result (StdSuites.AppleScript_Suite)
result (e (Python 2.7.8 virtualenv at ~/django_p27))
result (event (Python 2.7.8 virtualenv at ~/django_p27))
result (event (Python 2.7.8 virtualenv at ~/django_p27))
... more
Actions (⇧⌘A)
View Offline Inspection Results...
Code
Import Test Results
Database
Django default
tables 13
auth_group
auth_group_permissions
auth_permission
auth_user
auth_user_groups
auth_user_user_permissions
django_admin_log
id INTEGER
action_time TEXT
object_id TEXT
object_repr TEXT
action_flag INTEGER
change_message TEXT
content_type_id INTEGER
user_id INTEGER
<unnamed> (id)
django_content_type
django_migrations
Debug Django_test
Debugger
Console
Frames
Variables
Watches
MainThread
longMessage = {bool} False
maxDiff = {int} 640
reset_sequences = {bool} False
serialized_rollback = {bool} False
startTime = {datetime} 2015-10-09 11:38:35.521452
self.maxDiff = {int} 640
4: Run
5: Debug
6: TODO
Python Console
Terminal
9: Version Control
manage.py@first_steps
Event Log
Tests Failed: 4 passed, 3 failed (4 minutes ago)
34:9
LF
UTF-8
Git: master

Python Notebooks

- **Jupyter Notebooks allow you to interactively run Python code in your web browser and share it with others in places like Google Colab**
- **They are popular for tutorials since you can include inline text and images**



Structure of Python File

- **Whitespace is meaningful in Python**
- **Use a newline to end a line of code.**
  - Use \ when must go to next line prematurely.
- **Block structure is indicated by indentation**
  - The first line with less indentation is outside of the block.
  - The first line with more indentation starts a nested block.
  - Often a colon appears at the end of the line of a start of a new block. (E.g. for function and class definitions.)

A Simple Code Sample

```
x = 34 - 23                    # A comment.
y = 'Hello'                    # Another one.
z = 3.45
if z == 3.45 or y == 'Hello':
    x = x + 1
    y = y + ' World'           # String concat.
print(x)
print(y)
```

Objects and Types

- **All data treated as objects**
  - An object is deleted (by garbage collection) once unreachable.
- **Strong Typing**
  - Every object has a fixed type, interpreter doesn't allow things incompatible with that type (eg. "foo" + 2)
  - type(object)
  - isinstance(object, type)
- **Examples of Types:**
  - int, float
  - str, tuple, dict, list
  - bool: True, False
  - None, generator, function

Static vs Dynamic Typing

- **Java: *static* typing**
  - Variables can only refer to objects of a declared type
  - Methods use type signatures to enforce contracts
- **Python: *dynamic* typing**
  - Variables come into existence when first assigned.

```
>>> x = "foo"
>>> x = 2
```

  - `type(var)` automatically determined
  - If assigned again, `type(var)` is updated
  - *Functions have no type signatures*
  - Drawback: type errors are only caught at runtime

Math Basics

- **Literals**
  - Integers: 1, 2
  - Floats: 1.0, 2e10
  - Boolean: True, False
- **Operations**
  - Arithmetic: + - * /
  - Power: **
  - Modulus: %
  - Comparison: , <=, >=, ==, !=
  - Logic: (and, or, not) *not symbols*
- **Assignment Operators**
  - += *= /= &= ...
  - No ++ or --

Strings

- **Creation**
  - Can use either single or double quotes
  - Triple quote for multiline string and docstring
- **Concatenating strings**
  - By separating string literals with whitespace
  - Special use of ‘+’
- **Prefixing with r means raw.**
  - No need to escape special characters: r’\n’
- **String formatting**
  - Special use of ‘%’ (as in printf in C)
  - print("%s can speak %d languages" % ("C3PO", 6000000))
- **Immutable**

References and Mutability

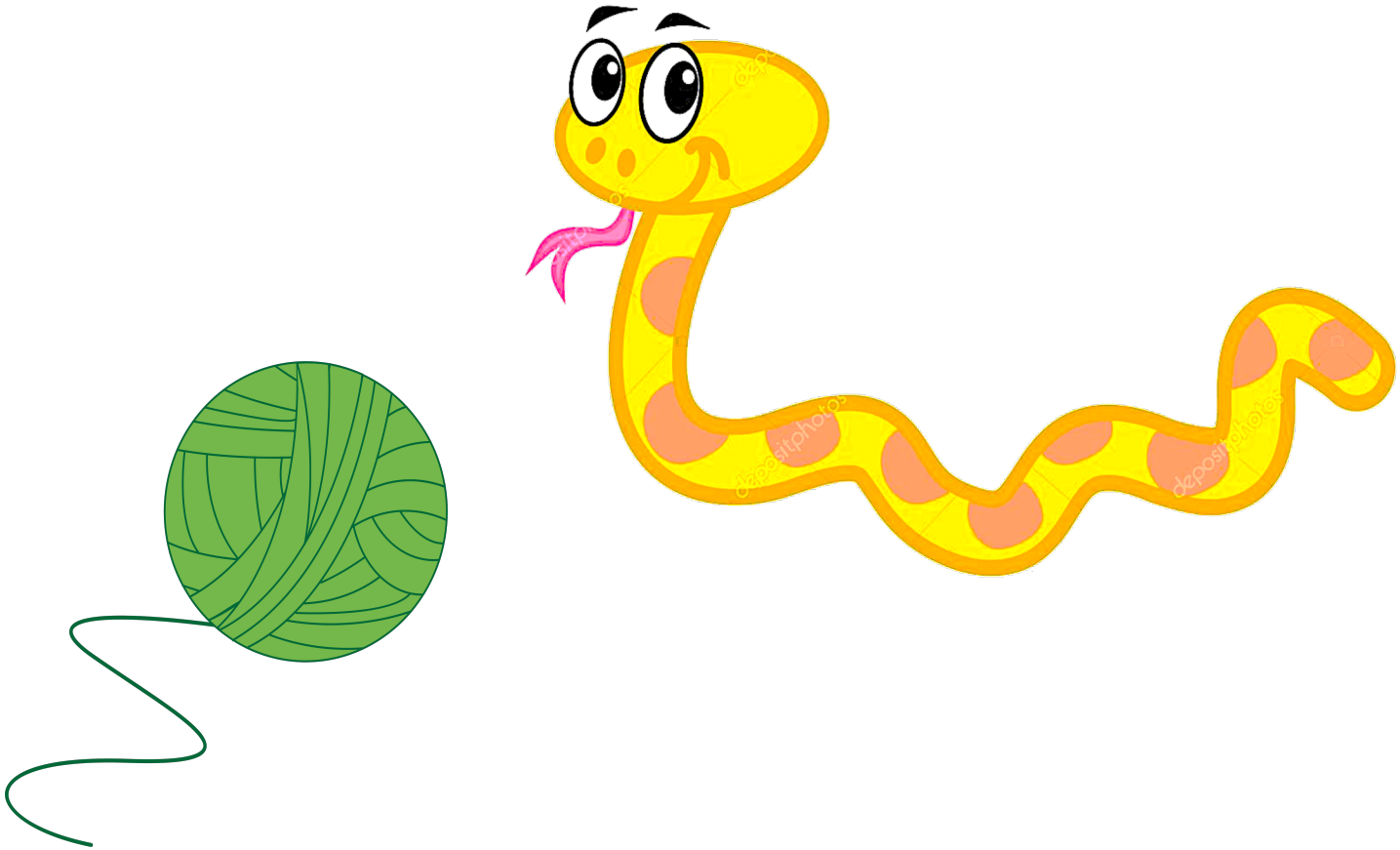
```
>>> x = 'foo  '
>>> y = x
>>> x = x.strip() # new obj
>>> x
'foo'
>>> y
'foo  '
```

- strings are immutable
- `==` checks whether variables point to objects of the same value
- `is` checks whether variables point to the same object

```
>>> x = [1, 2, 3, 4]
>>> y = x
>>> x.append(5) #same obj
>>> y
[1, 2, 3, 4, 5]
>>> x
[1, 2, 3, 4, 5]
```

- lists are mutable
- use `y = x[:]` to get a (shallow) copy of any sequence, ie. a new object of the same value

Sequence types: Tuples, Lists, and Strings



Sequence Types

- **Tuple**
  - A simple *immutable* ordered sequence of items
  - *Immutable*: a tuple cannot be modified once created
  - Items can be of mixed types, including collection types
- **Strings**
  - *Immutable*
  - Very much like a tuple with different syntax
  - Regular strings are Unicode and use 2-byte characters (Regular strings in Python 2 use 8-bit characters)
- **List**
  - *Mutable* ordered sequence of items of mixed types

Sequence Types

- **The three sequence types share much of the same syntax and functionality.**

```
>>> tu = (23, 'abc', 4.56, (2,3), 'def') # tuple

>>> li = ['abc', 34, 4.34, 23] # list

>>> st = "Hello World"; st = 'Hello World' # strings

>>> tu[1]  # Accessing second item in the tuple.
'abc'

>>> tu[-3]  #negative lookup from right, from -1
4.56
```

Slicing: Return Copy of a Subsequence

```
>>> t = (23, 'abc', 4.56, (2,3), 'def')

>>> t[1:4] #slicing ends before last index
('abc', 4.56, (2,3))

>>> t[1:-1] #using negative index
('abc', 4.56, (2,3))

>>> t[1:-1:2] # selection of every nth item.
('abc', (2,3))

>>> t[:2] # copy from beginning of sequence
(23, 'abc')

>>> t[2:] # copy to the very end of the sequence
(4.56, (2,3), 'def')
```

Operations on Lists

```
>>> li = [1, 11, 3, 4, 5]
>>> li.append('a')  # Note the method syntax
>>> li
[1, 11, 3, 4, 5, 'a']
>>> li.insert(2, 'i')
>>> li
[1, 11, 'i', 3, 4, 5, 'a']
>>> li = ['a', 'b', 'c', 'b']
>>> li.index('b')     # index of first occurrence
1
>>> li.count('b')     # number of occurrences
2
>>> li.remove('b')    # remove first occurrence
>>> li
['a', 'c', 'b']
```

Operations on Lists 2

```
>>> li = [5, 2, 6, 8]
>>> li.reverse()    # reverse the list *in place* (modify)
>>> li
[8, 6, 2, 5]

>>> li.sort()       # sort the list *in place*
>>> li
[2, 5, 6, 8]

>>> li.sort(some_function)
# sort in place using user-defined comparison

>>> sorted(li)  #return a *copy* sorted
```

Operations on Strings

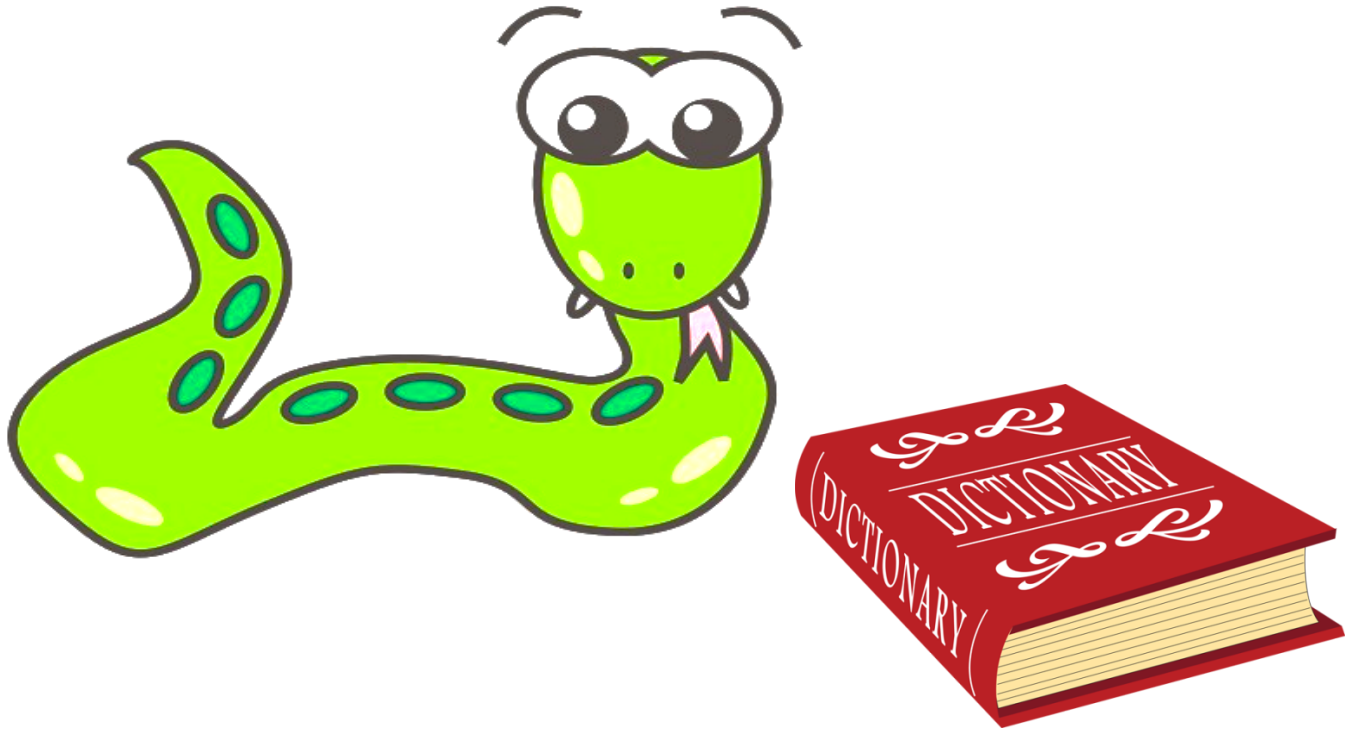
```
>>> s = "Pretend this sentence makes sense."
>>> words = s.split(" ")
>>> words
['Pretend', 'this', 'sentence', 'makes', 'sense.']
>>> "_".join(words) #join method of obj "_"
'Pretend_this_sentence_makes_sense.'

>>> s = 'dog'
>>> s.capitalize()
'Dog'
>>> s.upper()
'DOG'
>>> ' hi --'.strip(' -')
'hi'
```

https://docs.python.org/3.7/library/string.html

Tuples

```
>>> a = ["apple", "orange", "banana"]
>>> for (index, fruit) in enumerate(a):
...     print(str(index) + ": " + fruit)
...
0: apple
1: orange
2: banana

>>> a = [1, 2, 3]
>>> b = ['a', 'b', 'c', 'd']
>>> list(zip(a, b))
[(1, 'a'), (2, 'b'), (3, 'c')]

>>> list(zip("foo", "bar"))
[('f', 'b'), ('o', 'a'), ('o', 'r')]

>>> x, y, z = 'a', 'b', 'c'
```

Dictionaries: a *mapping* collection type



Dict: Create, Access, Update

- Dictionaries are unordered & work by hashing, so keys must be immutable
- Constant average time add, lookup, update

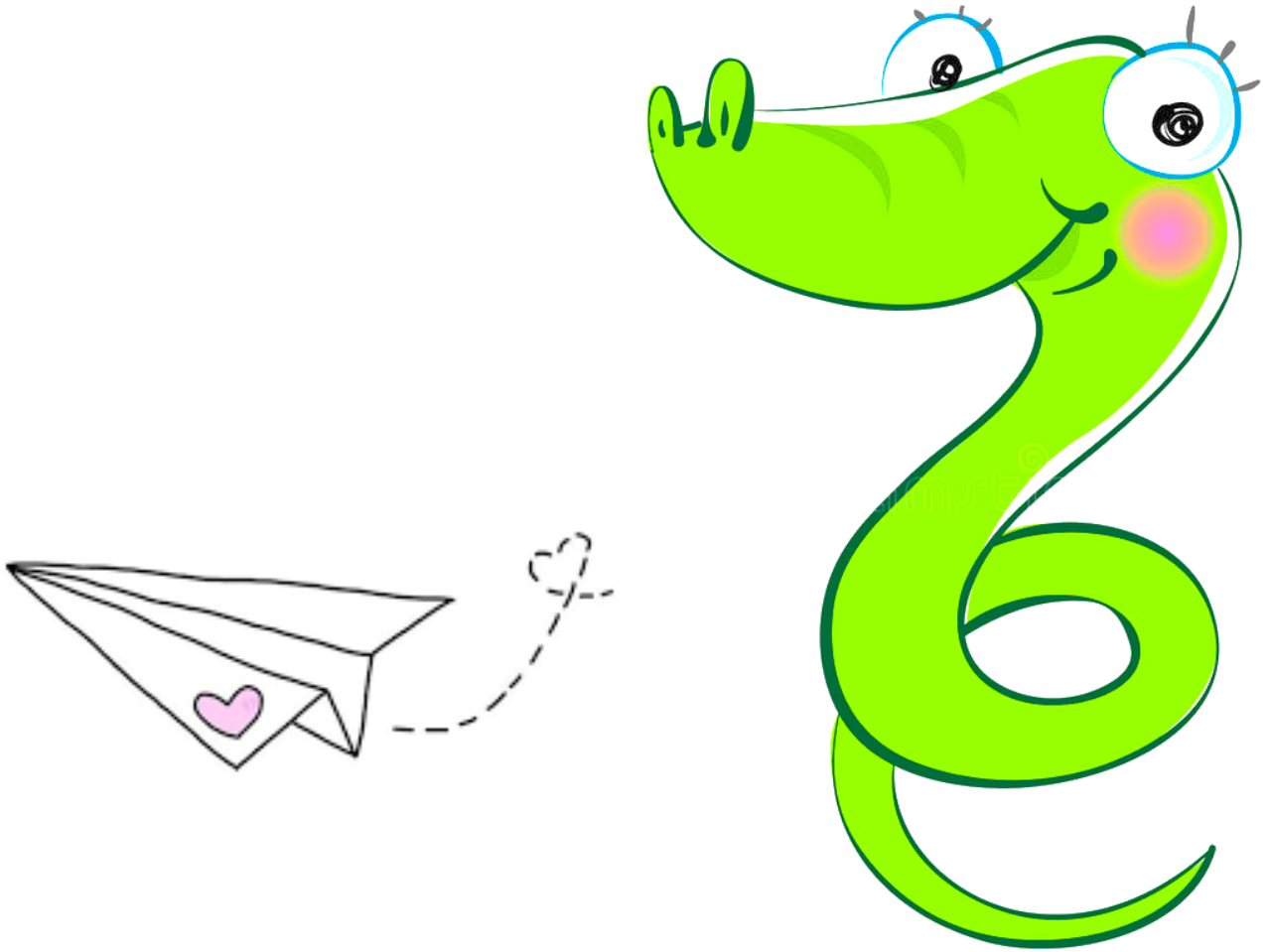
```
>>> d = {'user' : 'bozo', 'pswd':  1234}

>>> d['user']
'bozo'

>>> d['bozo']
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'bozo'

>>> d['user'] = 'clown'  # Assigning to an existing key   replaces its value.

>>> d
{'user': 'clown', 'pswd': 1234}
```

Dict: Useful Methods

```
>>> d = {'user':'bozo', 'p':1234, 'i':34}
>>> d.keys()                  # List of current keys
dict_keys(['user', 'p', 'i'])
>>> d.values()                # List of current values.
dict_values(['bozo', 1234, 34])
>>> d.items()          # List of item tuples.
dict_items([('user', 'bozo'), ('p', 1234), ('i', 34)])

>>> from collections import defaultdict
>>> d = defaultdict(int)
>>> d['a']
0
```

- `defaultdict` **automatically initializes nonexistent dictionary values**

For Loops



For Loops

- **for <item> in <collection>:**
  <statements>

- If you've got an existing list, this iterates each item in it.
- You can generate a list with **Range:**
  - `list(range(5))` **returns [0,1,2,3,4]**
  - So we can say:

```
for x in range(5):
  print(x)
```

- **<item> can be more complex than a single variable name.**
  - `for (x, y) in [('a',1), ('b',2), ('c',3), ('d',4)]:`
  - `  print(x)`

[expression for name in list]

List Comprehensions replace loops!

```
nums = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
#  I want 'n*n' for each 'n' in nums
squares = []
for n in nums:
  for n in nums:
    squares.append(x*x)
print(squares)
```

```
squares = [x*x for x in nums]
print(squares)
```

[expression for name in list]

List Comprehensions replace loops!

```
>>> li = [3, 6, 2, 7]
>>> [elem * 2 for elem in li]
[6, 12, 4, 14]
```

```
>>> li = [('a', 1), ('b', 2), ('c', 7)]
>>> [n * 3 for (x, n) in li]
[3, 6, 21]
```

[expression for name in list if filter]

Filtered List Comprehensions

```
>>> li = [3, 6, 2, 7, 1, 9]
>>> [elem * 2 for elem in li if elem > 4]
[12, 14, 18]
```

- Only 6, 7, and 9 satisfy the filter condition.
- So, only 12, 14, and 18 are produced.

Dictionary, Set Comprehensions

```
lst1 = [('a', 1), ('b', 2), ('c', 'hi')]
lst2 = ['x', 'a', 6]

d = {k: v for k,v in lst1}
s = {x for x in lst2}

d = dict() # translation
for k, v in lst1:
    d[k] = v
s = set() # translation
for x in lst:
    s.add(x)

# Both value of d: {'a': 1, 'b': 2, 'c': 'hi'}
# Both value of d: {'x', 'a', 6}
```

Iterators

Iterator Objects

- **Iterable objects can be used in a `for` loop because they have an `__iter__` magic method, which converts them to iterator objects:**

```
>>> k = [1,2,3]

>>> k.__iter__()
<list_iterator object at 0x104f8ca50>

>>> iter(k)
<list_iterator object at 0x104f8ca10>
```

Iterators

- Iterators are objects with a `__next__()` method:

```
>>> i = iter(k)
>>> next(i)
1
>>> i.__next__()
2
>>> i.next()
3
>>> i.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

- Python iterators do not have a `hasnext()` method!
- Just catch the `StopIteration` exception

Iterators: The truth about for… in…

- `for <item> in <iterable>:`
  `<statements>`

- **First line is just syntactic sugar for:**
  - 1. Initialize: Call `<iterable>.__iter__()` to create an *iterator*
- Each iteration:
  - 2. Call `iterator.__next__()` and bind `<item>`
  - 2a. Catch `StopIteration` exceptions

- **To be iterable: has `__iter__` method**
  - which returns an iterator obj
- **To be iterator: has `__next__` method**
  - which throws `StopIteration` when done

An Iterator Class

```
class Reverse:
    "Iterator for looping over a sequence backwards"
    def __init__(self, data):
        self.data = data
        self.index = len(data)
    def __next__(self):
        if self.index == 0:
            raise StopIteration
        self.index = self.index - 1
        return self.data[self.index]

    def __iter__(self):
        return self

>>> for char in Reverse('spam'):
        print(char)
```

```
m
a
p
s
```

Iterators use memory efficiently

```
Eg: File Objects
>>> for line in open("script.py"):   # returns iterator
...     print(line.upper())
...
IMPORT SYS
PRINT(SYS.PATH)
X = 2
PRINT(2 ** 3)

instead of
>>> for line in open("script.py").readlines(): #returns list
...     print(line.upper())
...
```

Generators

Generators: using yield

- **Generators are iterators (with `__next()__` method)**
- **Creating Generators: `yield`**
  - Functions that contain the **`yield`** keyword ***automatically*** return a generator when called

```
>>> def f(n):
...     yield n
...     yield n+1
...
>>>
>>> type(f)
<class 'function'>
>>> type(f(5))
<class 'generator'>
>>> [i for i in f(6)]
[6, 7]
```

Generators: What does yield do?

- Each time we call the `__next__` method of the generator, the method runs until it encounters a yield statement, and then it stops and returns the value that was yielded. Next time, it resumes where it left off.

```
>>> gen = f(5) # no need to say f(5).__iter__()
>>> gen
<generator object f at 0x1008cc9b0>
>>> gen.__next__()
5
>>> next(gen)
6
>>> gen.__next__()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

Generators

- **`xrange(n)` vs `range(n)` in Python 2**
  - **`xrange`** acts like a generator
  - **`range(n)`** keeps all n values in memory before starting a loop *even if n is huge*: **`for k in range(n)`**
  - **`sum(xrange(n))`** much faster than **`sum(range(n))`** for large **`n`**

- **In Python 3**
  - **`xrange(n)`** is removed
  - **`range(n)`** acts similar to the old **`xrange(n)`**
  - Can use list() to get similar behavior as in Python 2
  - Python 3's range is more powerful than Python 2's xrange

Generators

- **Benefits of using generators**
  - Less code than writing a standard iterator
  - Maintains local state automatically
  - Values are computed one at a time, as they're needed
  - Avoids storing the entire sequence in memory
  - Good for aggregating (summing, counting) items. One pass.
  - Crucial for infinite sequences
  - Bad if you need to inspect the individual values

Using generators: merging sequences

- **Problem: merge two sorted lists, using the output as a stream (i.e. not storing it).**

```
def merge(l, r):
    llen, rlen, i, j = len(l), len(r), 0, 0
    while i < llen or j < rlen:
        if j == rlen or (i < llen and l[i] < r[j]):
            yield l[i]
            i += 1
        else:
            yield r[j]
            j += 1
```

Using generators

```
>>> g = merge([2,4], [1, 3, 5]) #g is an iterator
>>> while True:
...     print(g.__next__())
...
1
2
3
4
5
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
StopIteration
>>> [x for x in merge([1,3,5],[2,4])]
[1, 2, 3, 4, 5]
```

Generators and exceptions

```
>>> g = merge([2,4], [1, 3, 5])
>>> while True:
…     try:
…         print(g.__next__())
…     except StopIteration:
…         print('Done')
…         break
…
1
2
3
4
5
Done
```

Plan for next time

- **Import**
- **Functions**
  - Args, kwargs
- **Classes**
  - “magic” methods (objects behave like built-in types)
- **Profiling**
  - timeit
  - cProfile