Python Programming Techniques

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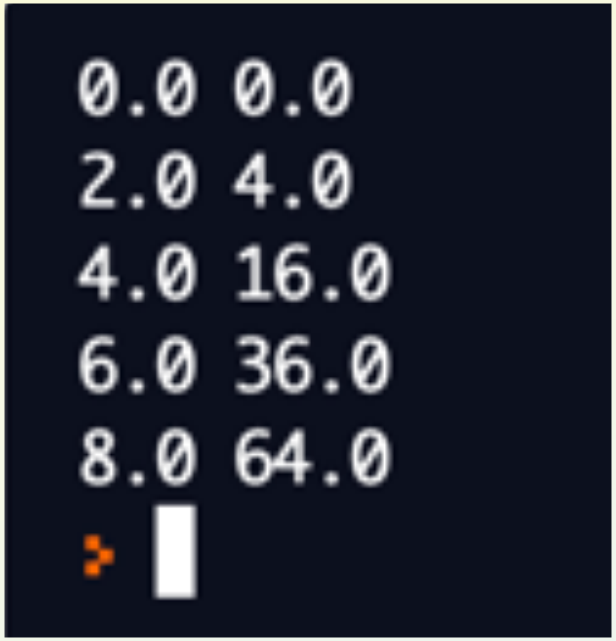
Versatile

Very efficient for user / programmer.

Example 1

```
x = 0.
xmax = 10.
xincr = 2.

while x < xmax:          # Here is a block of code
    y = x * x
    print(x, y)
    x += xincr
```



```
0.0 0.0
2.0 4.0
4.0 16.0
6.0 36.0
8.0 64.0
> 
```

Example 1

No variable declaration.

No memory allocation.

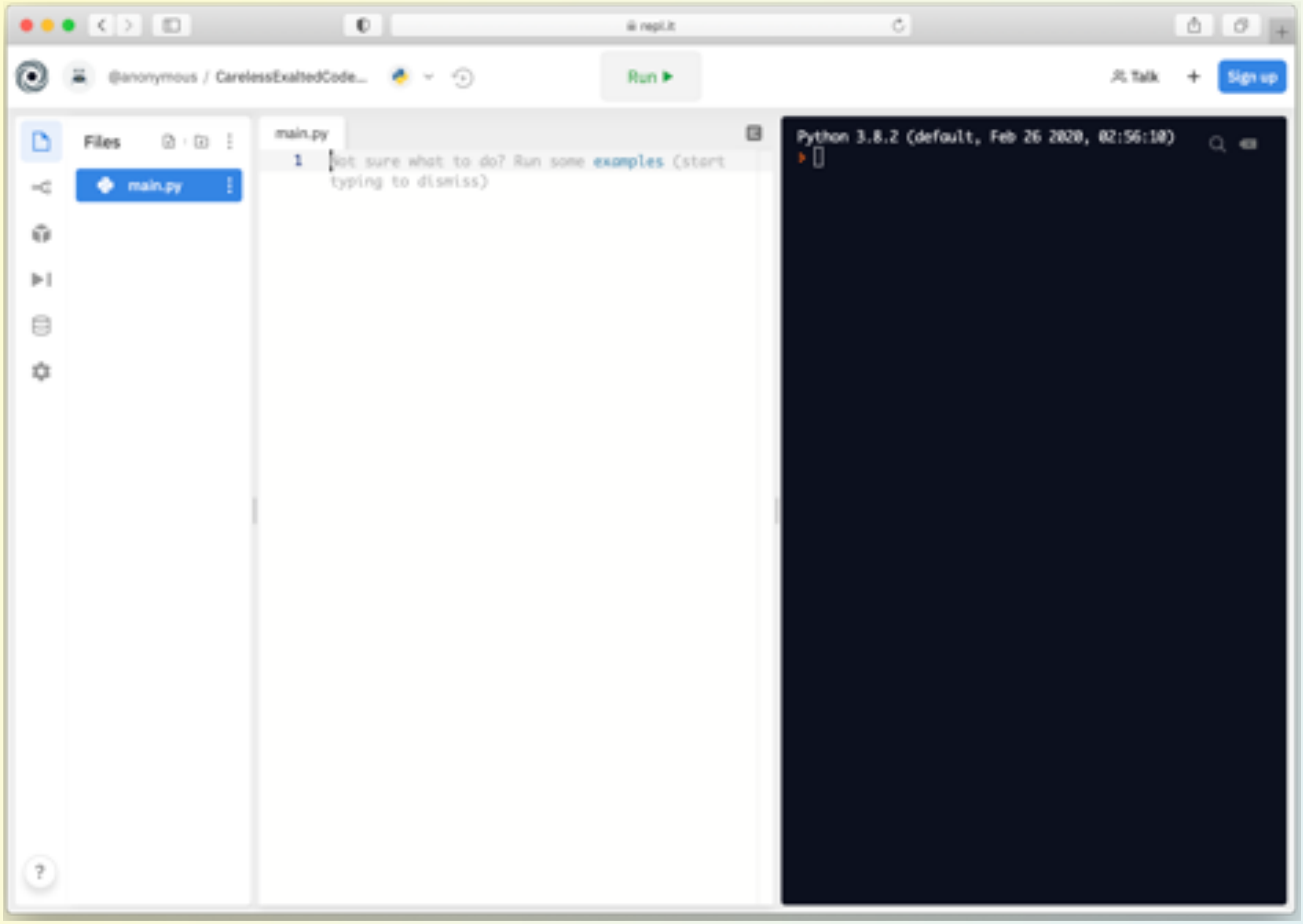
No compiling, no .o or .obj files

No linking.

No kidding - Just run.

Browser based IDE

https://repl.it/languages/python3



```
Not sure what to do? Run some examples (start
typing to dismiss)
```

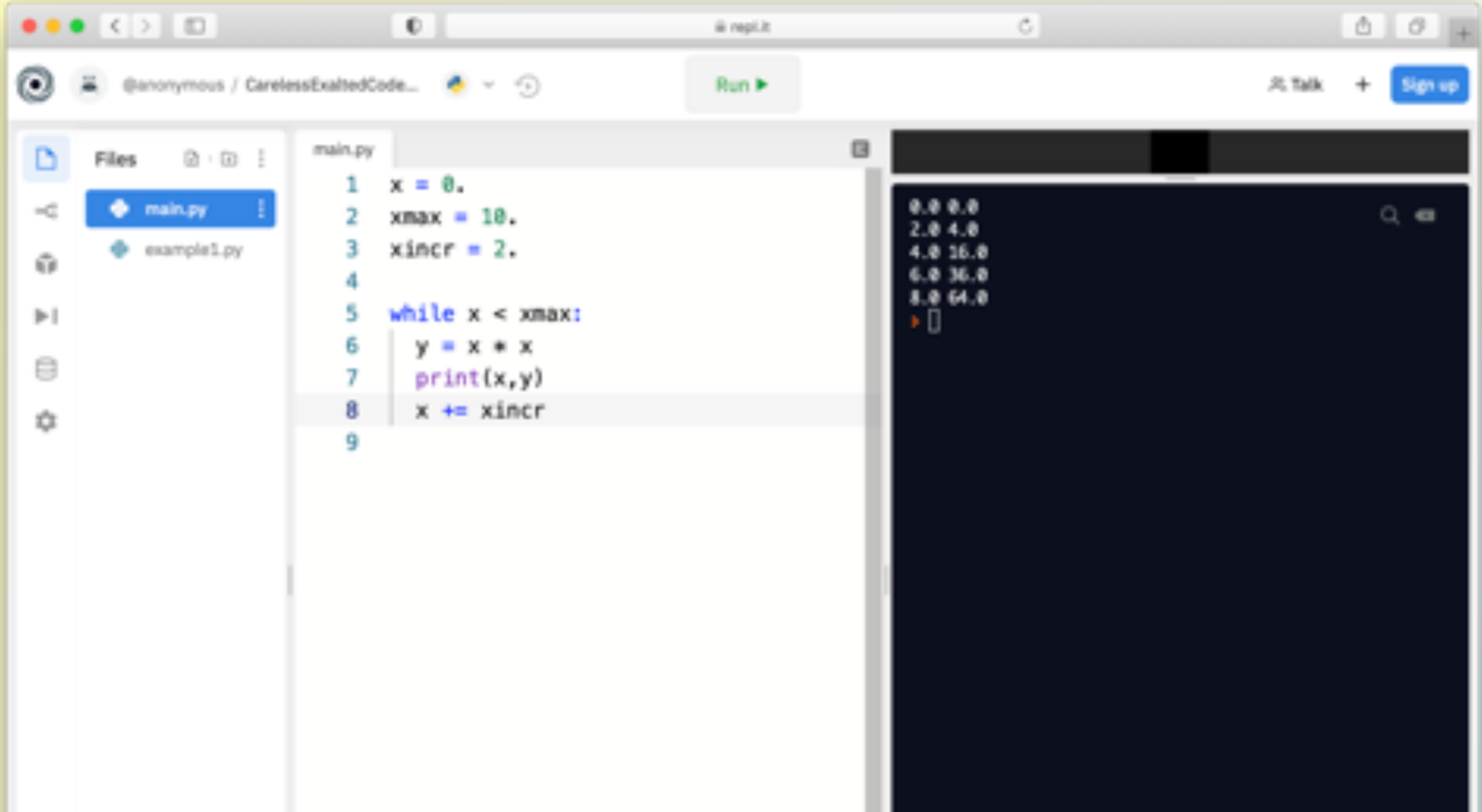
```
Python 3.8.2 (default, Feb 26 2020, 02:56:10)
›
```

Try out the interpreter

```
>>> 2+3
5
>>> a = 5.1
>>> b = 6.2
>>> print (a*b)
31.62
```

Browser based IDE

https://repl.it/languages/python3



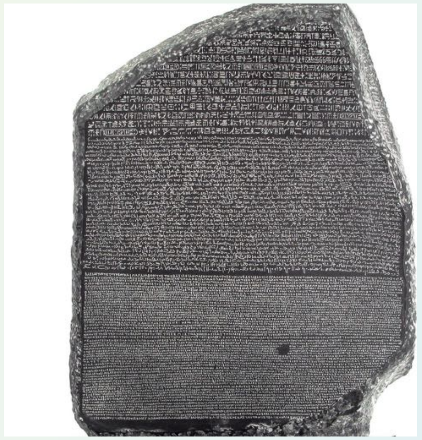
```python
x = 0.
xmax = 10.
xincr = 2.

while x < xmax:
    y = x * x
    print(x,y)
    x += xincr
```

```
0.0 0.0
2.0 4.0
4.0 16.0
6.0 36.0
8.0 64.0
```

help() dir() type()

```
>>> help()           # interpretor
help>  keywords      #  if, else, for …
help>  symbols       #   +  –  =  /  …
help>  modules       # math, os, sys
help>  topics        # USE UPPER CASE
```

Python Rosetta Stone



Variables

Case sensitive

- start is not the same as Start
- count is not the same as Count
- R = 1 / r

Start with a letter, not a number

Long names OK

Types and Operators

```
int                     # scalar variable, holds a single value
float
long
complex     a = (3 + 4j)     # type(a)

+  -  *  /  %  //  **        # Arithmetic operators

+=                      # Assignment operators
-=
*=
/=

<   <=   >   >=   ==   !=   # Comparison operators
+       # has magic overload abilities!
```

Casts

```
int()
long()
float()

hex()        # string representation
oct()        # string representation

str()        # for printing numbers + strings
```

Built-in Constants

`True`	`<type 'bool'>`
`False`	`<type 'bool'>`
`None`	`<type 'NoneType'>`

Indenting Counts!

Indent 4 spaces or a tab -- be consistent

Convention, not a requirement

: at end of line indicates start of code block

requires next line to be indented

Code block ends with an *outdent*

Code runs but not as desired – check your indents

Program

Loops

Conditionals, Control

Functions

Keywords

Control

```
if    else    elif

while    break    continue

and   or   not
```

```
>>>   help()
help >   keywords
```

Programming Exercise

Write a python program that converts degrees to radians for:

0, 10, 20, 30, ... 180 degrees

Write code: `main.py`

Click on Run.

Output in console window.

radians = degrees * 3.14 / 180.

print(degrees, radians)

```
x = 0.
xmax = 10.
xincr = 2.

while x < xmax:
    y = x * x
    print(x, y)
    x += xincr
```

Debugging Tip

Interpreter shell retains variables in scope after running program:

```
dir()
```

```
print(degree)
```

Comments

in line text after # is ignored

# can be in any column

Text within triple quotes

```
"""  This is a multi-line
comment that will be
compiled to a string but
will not execute anything.
It is code so it must conform
to indenting """
```

sample2.py

```
s = “shrubbery”
print(s)

len(s)
```

Strings

Sequence of characters such as s = “abcdefg”

Indexed with [ ] starting at [0]

s[0] is a, s[1] is b

s[-1] refers to last character in string.

Negative indexing starts at last character.

Use s[p:q] for string **slicing**.

s[3:] evaluated as “defg”

s[:3] evaluated as “abc” *up to but not 3*

s[1:-2] evaluated as “bcde”

up to but not including -2

String Concatenation

```
first = ‘John’
last = ‘Cleese’

full = first + “  “ + last

sp = “ “
full = first + sp + last
```

+ Operator is Operand “Aware”

```
>>> “water” + “fall”    # concatenate

>>> 3 + 5      # addition
```

```
>>> 3 + “George”    # unsupported type

>>> “George” + 3    # TypeError
```

Printing

```
pi = 3.14159
print ('The answer is ' + str(pi))
        # cast float to string to avoid TypeError
        # when combining string and numbers
```

The Immutable String

Can’t replace characters in a string.

```
s = “abcd”
```

~~`s[1] = “g”`~~ ***Object does not support item assignment***

```
s = “agcd”     # re-assign entire string
```

Automatic Memory Managment

~~malloc()   realloc()   free()~~

~~char name[32]~~

```
name = “as long as you want”

len(name)
```

len() function is part of __builtins__

Conditionals

```
a = 3

if a > 0:
   print (“a is positive”)
elif a < 0:
   print( “a is negative”)
else:
   print (“a = 0”)
```

String Exercise

Degrees to radians:

- **Print column titles**
- **Right align degree values**
- **Limit radians to 7 characters**

Reminder: `len(s)`

str Under the Hood

`str` – **is a Class!** **Not just a memory area of characters**

Object oriented programming

Encapsulated data and methods

Use the dot . to address methods and data

```
a = “hello”
a.upper()           # returns “HELLO”
```

```
type(a)
dir(str)
help(str)
```

```
>>> help()
help> topics
help> STRINGMETHODS
```

hidden methods start with __

Math module

```
import math
dir(math)


math.sqrt(x)
math.sin(x)
math.cos(x)
```

```
from math import *
dir()

sqrt(x)
```

```
from math import pi
dir()

print pi
```

Keywords for Inclusion

```
import     from     as
```

import math Exercise

Degrees to radians and now cosine:

- **Use math.pi for defined constant**
- **Use math.cos(radian) to compute cosine**
- **Print cosine in 3rd column**
  - ***Align cosine to decimal point***
    - ***(Do not truncate the cosine)***

Data Structures

Resemble arrays in other languages

List [ ]	# ordered sequence of stuff
Tuple ( )	# n-tuple, immutable
Dictionary { }	# key – value pairs

Lists [ ]

Indexed from [0]

Last index is [-1]   or length - 1

Class object with its own methods, e.g.

```
    .append()
    .sort()
```

Magic slice operator :

Magic iter() function   actually __iter__()

min()   max()   are builtins

Declare a List

```
x = [59, 50, 42, 34, 23, 14]

x.append(4)   # works in place, no return
```

Identify the sequence? Next item?

```
x.append(“Spring St”)

x[3] = ”Penn Station”
                    # list is mutable, can replace values
```

mutable

```
x = []              # create empty list, then append to it
x = list()
```

List methods

```
append()
extend()
insert()
remove()
sort()        # in place, does not return a new list
reverse()  # in place
index()
count()

cList = aList + bList    # concatenate lists
```

range() Function

```
range(stop) # assumes start=0 and incr=1
range(start, stop) # assumes incr=1
range(start, stop, incr)
```

Returns sequence of integers, up to, but not including stop.

Python 2 returns a list.

Python 3 returns a "range class" to save memory.

Both give you an iterable sequence.

range() is a built-in function: `dir(__builtins__)`

Keywords Looping with range()

```
for   in
```

```
for i in range(10):

for s in dayList:    # dayList = [“Mon”, ”Tue”, “Wed”]
```

List Techniques

```
d = list(range(4))     # [0, 1, 2, 3]
d = [0] * 4            # [0, 0, 0, 0]


d = [ -1  for x in range(4) ]
                       # [-1, -1, -1, -1]
```

List Comprehension

Lists Exercise

Degrees to radians, cosines, and now lists:

Create a list of radians and a list of cosines

Print the lists

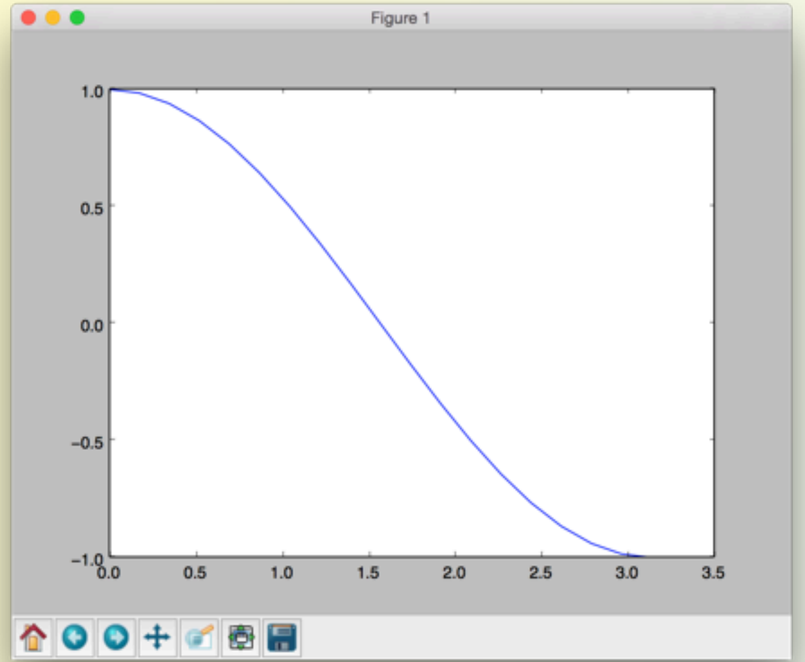
Use a range() loop instead of while

Plot Exercise

Degrees to radians, cosines, lists, now plot:

Plot a curve: x axis: radians, y axis: cosines

```
import matplotlib.pyplot as plt
plt.plot(radiansL, cosinesL)
plt.show()    # displays on screen
```



matplotlib + LaTeX

```
import matplotlib.pyplot as plt

plt.rc("text", usetex=True)
    # set config to draw text with Tex

plt.xlabel( r"\textbf{Time}" )
    # draw x label "Time" in bold font
    # compare to:   plt.xlabel("Time")
s = r"\n" # raw string has \n, not linefeed
```

latex.py example - requires latex installation

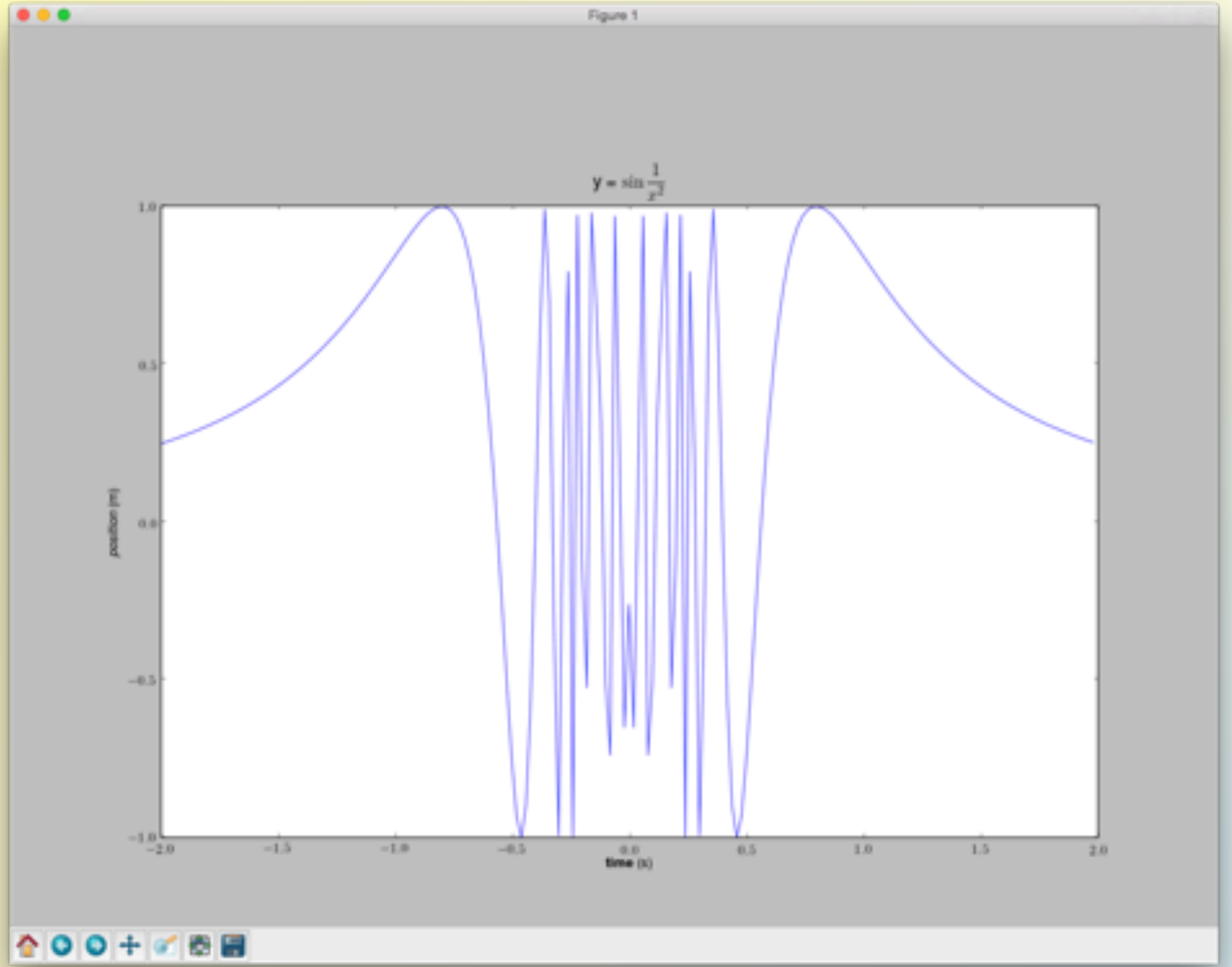


Figure 1
$y = \sin\frac{1}{x^2}$
1.0
0.5
0.0
−0.5
−1.0
position (m)
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
time (s)

del keyword

```
del a[3]    # deletes element at index 3

del a[2:4]  # deletes element 2 and 3
            # list slicing

del a       # deletes entire list.  a is gone.
```

Unpack a list into variables

```
name = [“Abe”, “Lincoln”]

first, last = name
    # multiple variables on left side of =
    # number of variables must be len(name)
```

List of Lists

```
d = [ [0]*4  for y in range(3) ]
```

```
[
    [0, 0, 0, 0],
    [0, 0, 0, 0],
    [0, 0, 0, 0]
]
```

```
d[2][0] = 5
    [
        [0, 0, 0, 0],
        [0, 0, 0, 0],
        [5, 0, 0, 0]
    ]
```

N-dimensional Arrays

`import numpy`

ndarray class – optimized to be very fast.

Integrated with matplotlib for graphing.

[princeton.edu/~efeibush]()

[Python Programming mini-course]()

[numpy]()

numpy2016.pdf

numpy.arange()

Note: arange can use floats for interval & step

```
import numpy
radA = numpy.arange(1.5, 2.5, .1)
       # Returns numpy array of evenly spaced floats
                         # min,   max,   step
for x in radA:  # can iterate on numpy array
```

numpy.linspace()

Note: linspace can use floats for interval

integer for number of steps

```
import numpy
a = numpy.linspace(1.5, 2.5, 11)
        # Returns numpy array of evenly spaced floats
        # min, max, number of steps
a = list(a)      # cast array to list

for x in a:
```

numpy.random

Random number generator

```
>>>help(numpy.random)
    # examples for each function
```

python Runs Your Program
Command Line version

```
python sample1.py
```

sample1.py source code is run directly instead of compile, link, run.

No .obj nor .o files of compiled code.

No .exe nor a.out of executable code.

```
python  -i  exdeg.py
```

Command Line Arguments

```
import sys
print (sys.argv)
```

sys.argv is a list

sys.argv[0] has the name of the python file.
  Subsequent locations have command line args.
  Does not apply in interpreter.

>>> help(sys)

Shell Scripting

```
import os

fileL = []        # set up a list

for f in os.listdir("."):
        if f.endswith(".py"):
                print( f )
                fileL.append(f)

fileL.sort()                    # list function, sort in place

print (fileL)
```

```
#!/bin/csh

foreach file (*.py)
    echo $file
    end
```

# much better text handling than csh or bash;   shell independent

```
import subprocess                         # Advanced
   # then use the Popen class for running programs
```

Defining a Function

Block of code separate from main.

Define function before calling it.

```
def myAdd(a, b):        # define before calling
        return a + b

p = 25                  # main section of code
q = 30

r = myAdd(p, q)         # case sensitive
```

Keywords

Functions (methods, *subroutines*)

```
def
return
```

Define a Function Exercise

Degrees to radians, cosines, lists, now function:

Format the radians using a function call

import

```
import math              # knows where to find it


import sys
sys.path.append(“/Users/efeibush/spline”)
import  cubic.py   # import your own code
```

reload – debugging your own module from the interpreter

n-Tuple ( )

Immutable List

- Saves some memory
- Cannot be modified when passed to function

```
aTuple = tuple(aList)      # Create from a list
        # No append, no assignment;  OK to extract slice
cTuple = aTuple + bTuple      # OK to concatenate

print aTuple[0]        # index using brackets
```

Dictionary { }

Key : Value

Look up table

Index by key -- Any hashable (immutable) type

`print d[key]` # prints value for specified key

Order of key:value pairs is not guaranteed.

Good for command line arguments

name list files, nicknames, etc.

`d[key] = value` # to add a key-value pair

such as `d["New Jersey"] = "Trenton"`

Dictionary methods

```
d = { }
d = dict()

eDict.update(gDict)    # combine dictionaries

del eDict[key]

if key in eDict:
  print (eDict[key])

d.keys()     # returns set of all keys
d.items()    # returns set of all  key:value  pairs as tuples
```

Read a Text File

```
gFile = open("myfile.txt”,  “r”)    # built-in function

for j in gFile:      # python magic:  text file iterates on lines
        print j      # print each line

gFile.close()
```

see readsplit.py   str.split()

.split() method parses a line of text into list of words

Write a Text File

```
f = open("myfile.txt", "w")
```

# open is a built-in function

```
a = 1
b = 2

f.write("Here is line " + str(a) + "\n");
f.write("Next is line " + str(b) + "\n");

f.close()
```

# .write() and .close() are *file object* methods

1. Read, Parse, Store, Write

```
import sys

inF = open(sys.argv[1], "r")     # open the file specified on the command line
linesL = inF.readlines()         # read all lines of text into a list of Strings
inF.close()                      # no longer needed

from collections import OrderedDict
kvD = OrderedDict()              #kvD = {}         # preserves order

for lineS in linesL:             # iterate through each line of text in the list
   wL = lineS.split()            # parse the line into words
   keyS = wL[0]                  # first word is the key
   valueS = wL[2]                # third word is the value, assume w[1] is =
   kvD[keyS] = valueS            # add key-value pair to dictionary; items are strings
   print keyS, valueS

print " "
print kvD.keys()
print kvD.values()

print " "
print kvD.viewitems()
```

2. Read, Parse, Store, **Write**

```
import datetime

outF = open("log", "w")         # open new file; will replace existing file

for k in kvD:                   # iterate through each key in dictionary
   v = kvD[k]                   # get the value for the key; it's a string

   logTime = datetime.datetime.now()              # generate a date-time object
                                                  # cast to str for printing
   s =  str(logTime) + ":  " + k + " " + v + "\n"

   outF.write(s)                                  # write entire line to file

outF.close()
```

Keywords for Exception Handling

```
try
except
finally
```

Summary – Elements of Python

Scalar variables, operators

Strings - Class with methods

List [ ]   tuple ( )   dictionary { }

Control

Comments, indenting

def your own functions

import modules – use functions

Plotting

Text File I/O

Built-in Classes

```
str, list, tuple, dict, file

dir(str)
help(str)
```

hidden methods start with __

Built-in Functions

```
len()
range()
type()
input()                 # read from standard input
                        # Python 2:  raw_input()

print()
open()          # file I/O
help()          # interpreter

abs()      round()     complex()
min()      max()    sum()      pow()
```

```
dir()        dir(__builtins__)
 e.g.      help(input)
```

Interpreter help()

```
>>> help()                    # go into help mode
help>
     keywords
     symbols
     topics
     modules
                          # enter topic UPPER CASE
    q
>>>
```

Python at princeton.edu

```
ssh nobel.princeton.edu

%  which python

/usr/bin/python
```

version 2.7.5

```
/usr/bin/python3
```

version 3.6.8

nobel
della
perseus
tiger
tigressdata

```
module load anaconda3/2020.7
```

python 3.8.3   Spyder IDE, debugger

More Info & Resources

`python.org`

`docs.python.org`

`princeton.edu/~efeibush/python`

notes3 folder has exercises

pythontools folder has presentation, examples

Resources

University library: O'Reilly books on-line

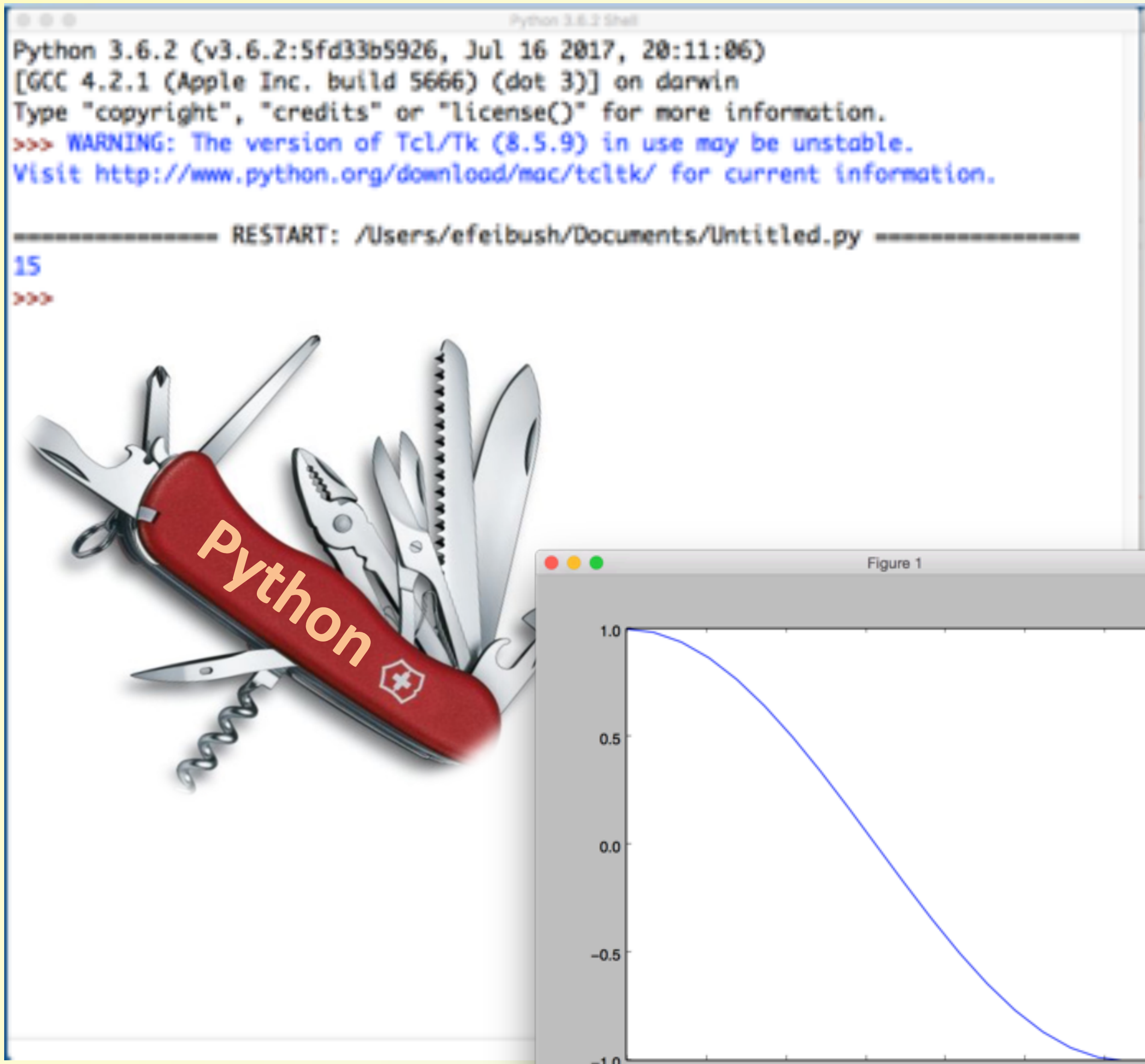
Python in a Nutshell

https://learning.oreilly.com/library/view/python-in-a/9781491913833/

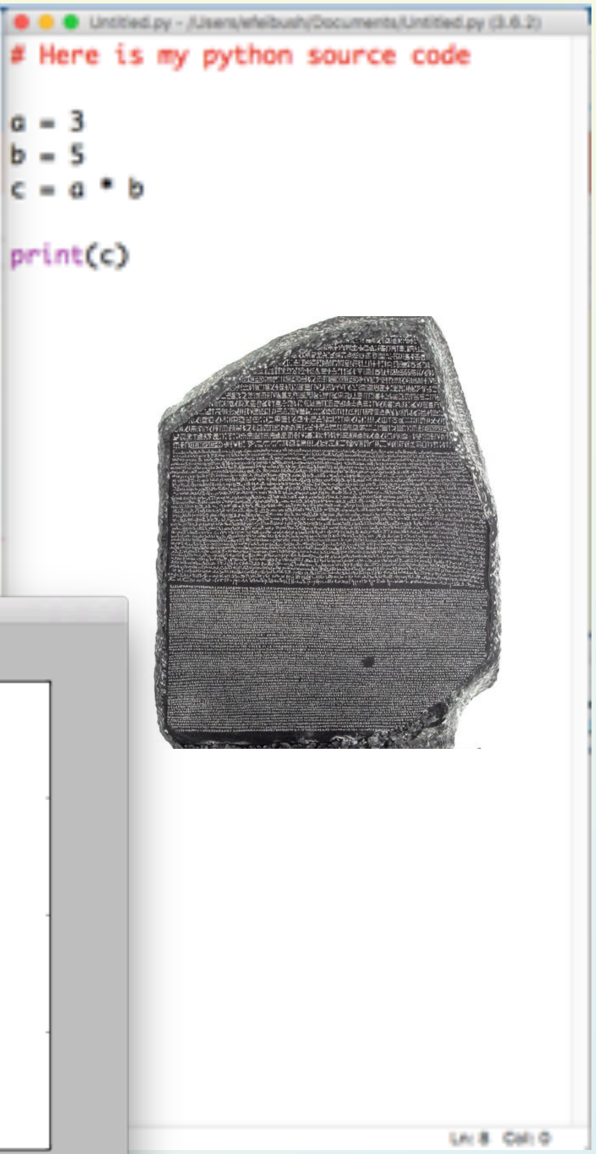
Where to?

Anaconda distribution of python

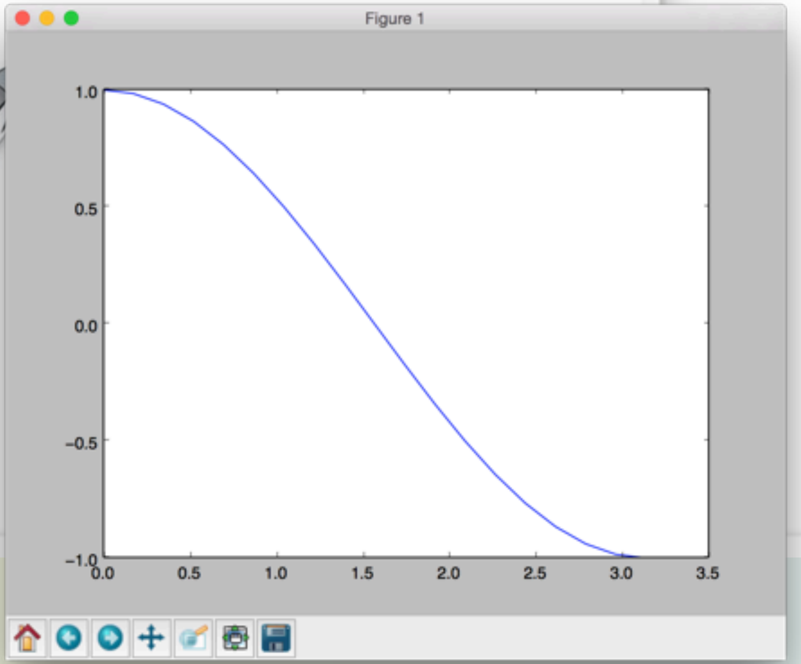
matplotlib – draw graphs
numpy – arrays & math functions
scipy – algorithms & math tools
PIL - Image Processing
Multiprocessing
Pycuda → GPU, CUDA
GUI – Tkinter, pyqt, wxpython
Visualization toolkit – python scripting



```
Python 3.6.2 (v3.6.2:5fd33b5926, Jul 16 2017, 20:11:06)
[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)] on darwin
Type "copyright", "credits" or "license()" for more information.
>>> WARNING: The version of Tcl/Tk (8.5.9) in use may be unstable.
Visit http://www.python.org/download/mac/tcltk/ for current information.

============== RESTART: /Users/efeibush/Documents/Untitled.py ==============
15
>>>
```



```
# Here is my python source code

a = 3
b = 5
c = a * b

print(c)
```



Art Contest

Write a pgm (world’s simplest) image file:

Replace my line for a gradient with your code to make an image.

Change maxIntensity to your scale.

Display your picture:

```
python pgmdisplay.py
```

Reading a netCDF File

Structured, scientific data file format

    Can read from URL

scipy – netcdf_file class for read/write

numpy – multi-dimensional data arrays

Mac

Magnifying glass: idle *(idle.app)*

Python 3.6
IDLE (Python GUI)

Command line from terminal also possible.

Windows

Start Menu

Python
IDLE
(Python GUI)

Interpreter

Integrated Development Environment -- idle

Everything that a program can have:

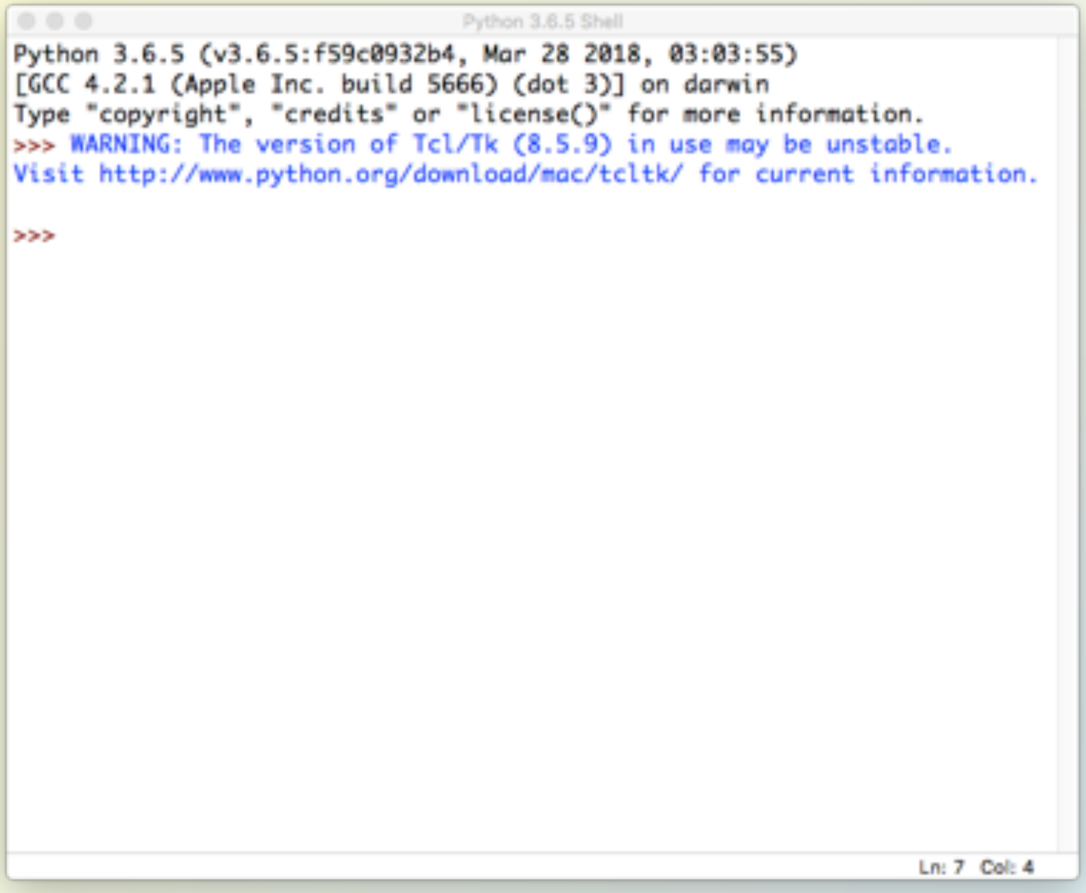
Variables

Strings

Lists

Expressions

Import modules



```
Python 3.6.5 (v3.6.5:f59c0932b4, Mar 28 2018, 03:03:55)
[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)] on darwin
Type "copyright", "credits" or "license()" for more information.
>>> WARNING: The version of Tcl/Tk (8.5.9) in use may be unstable.
Visit http://www.python.org/download/mac/tcltk/ for current information.

>>>
```

Great for learning & trying new lines of code

idle

IDE – Integrated Development Environment

- Color-coded syntax
- Statement completion
- Interpreter retains "scope" after program ends

Written in Python with tkinter GUI module.

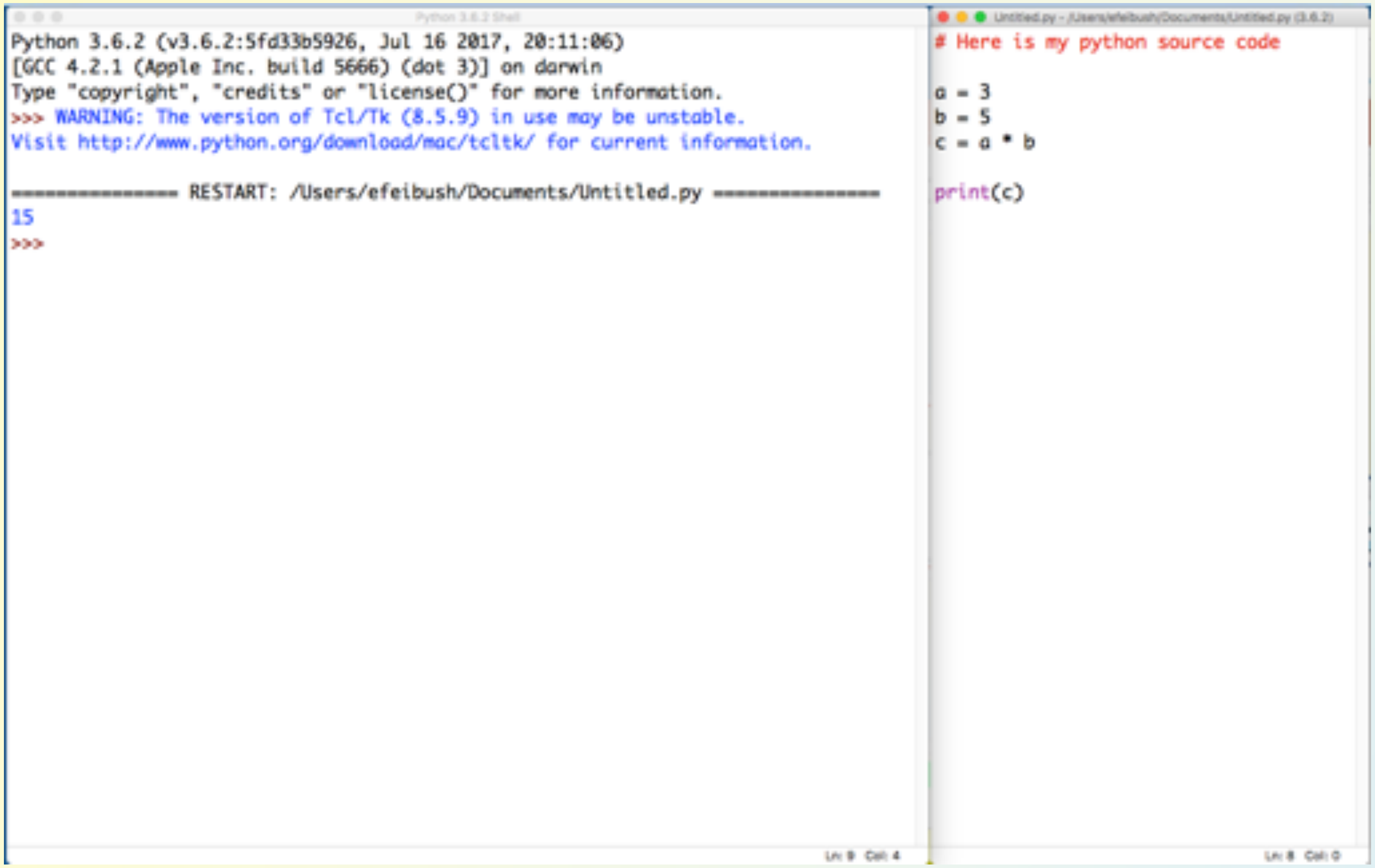
IDLE → Preferences

- Font, Keys
    - History-previous: up-arrow
    - History-next: down-arrow

idle: File → New File

Save command-s

Run → Run Module F5 key



```
Python 3.6.2 (v3.6.2:5fd33b5926, Jul 16 2017, 20:11:06)
[GCC 4.2.1 (Apple Inc. build 5666) (dot 3)] on darwin
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=============== RESTART: /Users/efeibush/Documents/Untitled.py ===============
15
>>>
```

```
# Here is my python source code

a = 3
b = 5
c = a * b

print(c)
```