THAT WAS A LOT TO DIGEST. TAKE SOME TIME TO PRACTICE FUNCTIONS, STRINGS, AND LISTS.

AS A FINAL EXERCISE, TRY USING SPLIT, JOIN, CHR, AND ORD TO WRITE ENCRYPTION AND DECRYPTION FUNCTIONS FOR A CIPHER LIKE THIS:

```
[1] encrypt("APPLE")
'BQQMF'
[2] encrypt("BQQMF")
'APPLE'
```

I HOPE THIS PRIMER WAS USEFUL. IF YOU'RE FEELING LOST, TRY WORKING SLOWLY THROUGH ALL OF THE EXAMPLES, AND TRY DOING THE EXERCISES.

(AND WE'LL COVER ALL OF THIS IN CLASS)

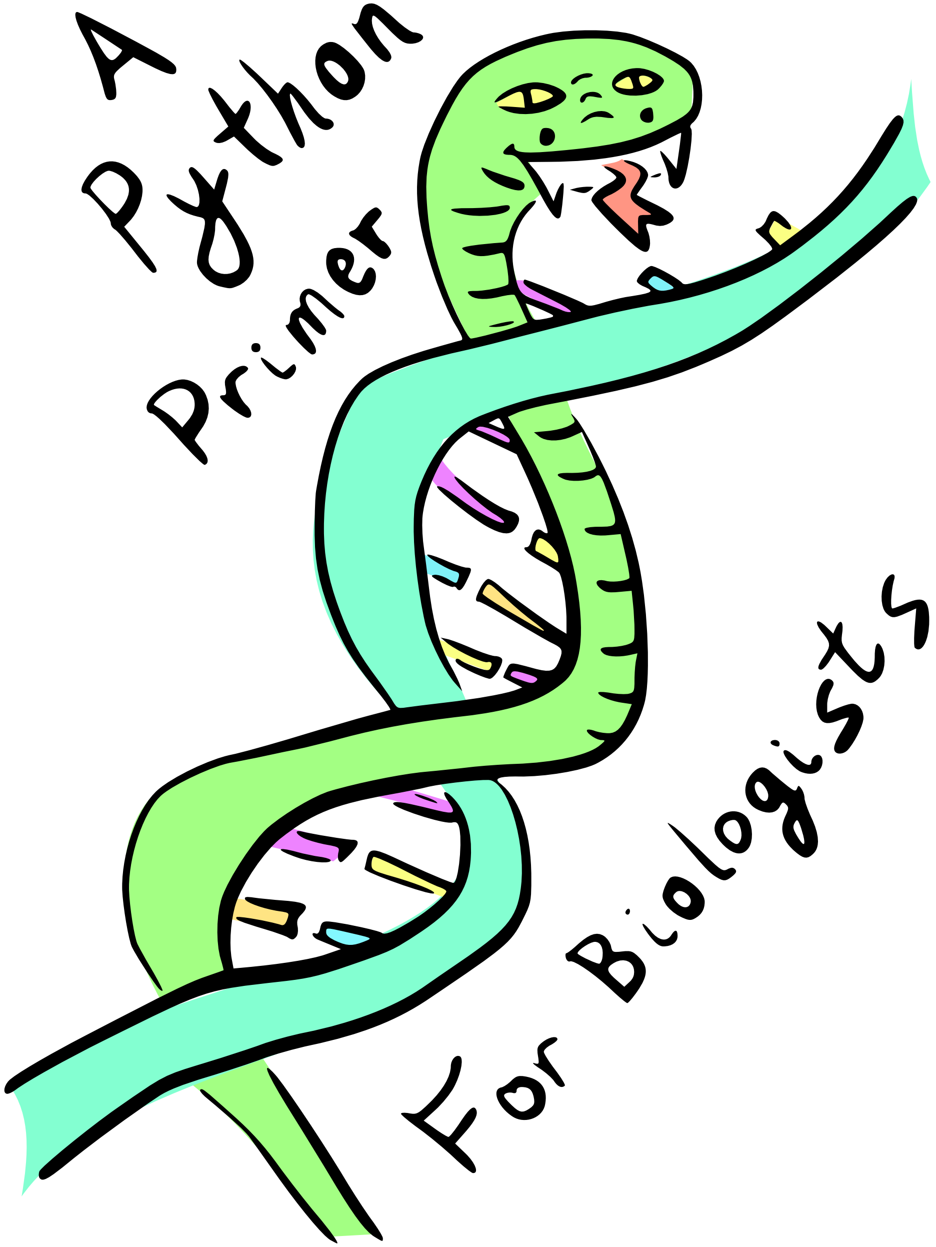
FOR MORE ON GETTING STARTED WITH PYTHON, I HIGHLY RECOMMEND

MARK LUTZ'S "LEARNING PYTHON"
http://search.safaribooksonline.com/9781449355722

AND MARK PILGRIM'S
"DIVE INTO PYTHON 3"
http://histo.ucsf.edu/BMS270/diveintopython3-r802.pdf

SEE YOU IN CLASS!
http://histo.ucsf.edu/BMS270/

A Python Primer For Biologists



Version 0.03
git commit
e2c05f3266

For screen and print pdfs of this primer, see
http://histo.ucsf.edu/BMS270/PythonPrimer.htm

YES WE CAN!

A *LIST* IS A SEQUENCE OF ANYTHING

ENCLOSE LISTS IN SQUARE BRACKETS

SEPARATE LIST ELEMENTS WITH COMMAS

```
[10] l=["Hello","world"]
     l
```

```
'Hello','world'
```

```
"Spam" | 42 | print
```

STRING | INT | FUNCTION

```
"PGI1" | "PFK1" | "FBA1" | "TDH1" | "PGK1"
```

WE CAN SLICE, SPLICE, AND INDEX A LIST JUST LIKE A STRING

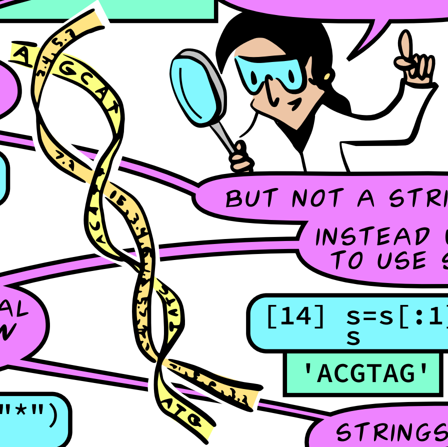
```
[11] data=[1.2,2.5,1.8,1.6,2.4]
     print(data+[3.1])
     print(data[:3])
     print(data[3:])
     print(data[1:4])
     print(data[0])
```

```
[1.2, 2.5, 1.8, 1.6, 2.4, 3.1]
[1.2, 2.5, 1.8]
[1.6, 2.4]
[2.5, 1.8, 1.6]
1.2
```

LIKEWISE, WE CAN ITERATE OVER A LIST IN A FOR LOOP

```
[12] F = [min,max,sum]
     for f in F:
         print(f(data))
```

```
1.2
2.5
9.5
```



STRINGS AND LISTS ARE VERY SIMILAR, BUT THERE ARE A FEW *DIFFERENCES*

WE CAN MODIFY THE INSIDE OF A LIST

```
[13] data[1]="C"
     data
```

```
[1.2,'C',1.8,
 1.6,2.4]
```

BUT NOT A STRING

INSTEAD WE HAVE TO USE SPLICING

```
[14] s=s[:1]+"C"+s[2:]
     s
```

```
'ACGTAG'
```

LISTS HAVE A SPECIAL *MEMBER FUNCTION* FOR *APPENDING*

```
[15] data.append("*")
     data
```

```
[1.2,'C',1.8,
 1.6,2.4,'*']
```

STRINGS USE THE CONCATENATION OPERATOR

```
[16] s+="*"
     s
```

```
'ACGTAG*'
```

AND THERE ARE A FEW METHODS THAT ONY MAKE SENSE FOR STRINGS

```
[17] "Hello,world".split(",")
```

```
['Hello','world']
```

```
[18] "".join(["Hello","world"])
```

```
'Helloworld'
```

SO FAR, WE'VE BEEN PLAYING WITH NUMBERS.

A *STRING* LETS US PLAY WITH TEXT BY INTERPRETING NUMBERS AS A SEQUENCE OF EIGHT BIT *CHARACTERS*

```
[1] "Hello, world"
Hello, world
```

ENCLOSE STRINGS IN "QUOTES"

EIGHT BITS=ONE BYTE

0 1 0 0 0 0 0 1

$2^7\ 2^6\ 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$

$2^0+2^6=1+64=65$ } **A**

NORMALLY, PYTHON USES THE ASCII CONVENTION TO MAP EIGHT BIT NUMBERS TO LETTERS, DIGITS, AND SYMBOLS

WE CAN LOOK UP THE NUMBER FOR A SINGLE CHARACTER WITH *ORD*

AND USE *CHR* FOR THE OPPOSITE LOOKUP

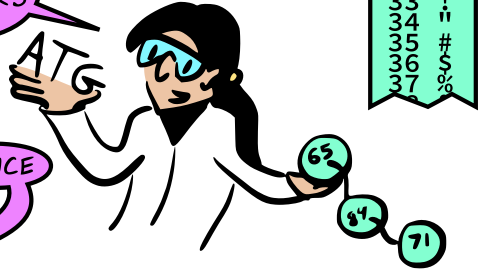
```
[2] ord("A")
65
```

HERE ARE THE MOST COMMON CHARACTERS:

```
[3] for i in range(33,127):
      print(i,chr(i))
33 !
34 "
35 #
36 $
37 %
```

WE CAN USUALLY IGNORE THE FACT THAT CHARACTERS ARE NUMBERS

INSTEAD, THINK OF STRINGS AS SEQUENCES THAT WE CAN



SPLICE

```
[4] s = "ATG"+"TAG"
    s
"ATGTAG"
```

SLICE

```
[5] s[:3]
"ATG"
```

FIRST THREE

```
[6] s[3:]
"TAG"
```

EVERYTHING *AFTER* FIRST THREE

```
[7] s[2:5]
"GTA"
```

AFTER FIRST TWO UNTIL FIFTH

AND INDEX

```
[8] s[0]
"A"
```

NOTE THAT, IN PYTHON, WE COUNT FROM *ZERO*

0	1	2	3	4	5
A	T	G	T	A	G

WE CAN ALSO ITERATE OVER A STRING IN A FOR LOOP:

```
[9] x = ord("a")-ord("A")
    for i in s:
        print(chr(ord(i)+x))
a
t
g
t
a
g
```

BUT WHAT IF WE CARE ABOUT POLYKETIDES OR PLANT LINEAGES? CAN WE INTERPRET NUMBERS AS ARBITRARY SEQUENCES?

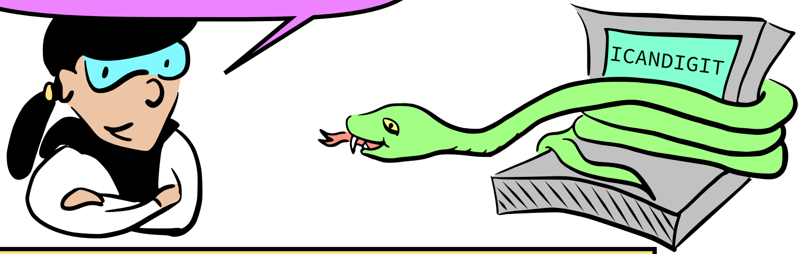
WHAT IS PYTHON?

PYTHON IS AN *INTERPRETED* PROGRAMMING LANGUAGE

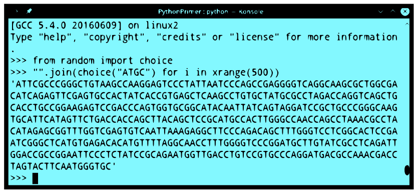
THAT MEANS WE SAY WHAT WE WANT DONE IN A SPECIAL *LANGUAGE*

AND PYTHON* *INTERPRETS* IT AS INSTRUCTIONS THE COMPUTER CAN FOLLOW

TRANSLATE("""ATTTGTGCT AACGATATCGGTATAACT""")

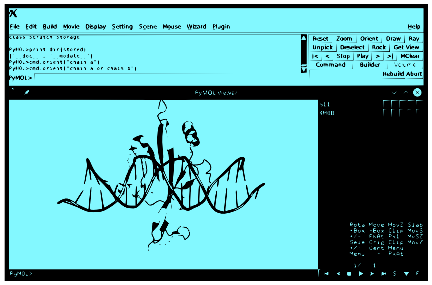


*PROPERLY, *PYTHON* IS THE LANGUAGE, AND A *PYTHON INTERPRETER* IS A PROGRAM THAT DOES THE INTERPRETING. THERE ARE MANY INTEPRETERS AVAILABLE:



```
[GCC 5.4.0 20160609] on linux2
Type "help", "copyright", "credits" or "license" for more information
.
>>> from random import choice
>>> "".join(choice("ATGC") for i in xrange(500))
'ATTCGCCCGGGCTGTAAGCCAAGGAGTCCCTATTAATCCCAGCCGAGGGGTCAGGCAAGCGCTGGCGA
CATCAGAGTTCGAGTGCCACTATCACCGTGAGCTCAAGCCTGTGCTATGCGCCTAGACCAGGTCAGCTG
CACCTGCCGGAAGAGTCCGACCCAGTGGTGCGGCATACAATTATCAGTAGGATCCGCTGCCCGGGCAAG
TGCATTCATAGTTCTGACCACCAGCTTACAGCTCCGCATGCCACTTGGGCCAACCAGCCTAAACGCCTA
CATAGAGCGGTTTGGTCGAGTGTCAATTAAAGAGGCTTCCCAGACAGCTTTGGGTCCTCGGCACTCCGA
ATCGGGCTCATGTGAGACACATGTTTTAGGCAACCTTTGGGGTCCCGGATGCTTGTATCGCCTCAGATT
GGACCGCCGGAATTCCCTCTATCCGCAGAATGGTTGACCTGTCCGTGCCCAGGATGACGCCAAACGACC
TAGTACTTCAATGGGTGC'
>>>
```

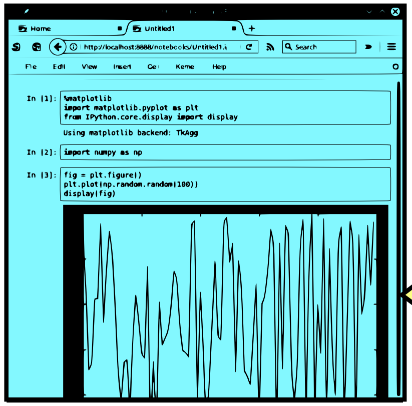
CPYTHON SHELL


File Edit Build Movie Display Setting Scene Mouse Wizard Plugin Help
Reset Zoom Orient Draw Ray
Unpick Deselect Rock Get View
|< < Stop Play > >| MClear
Command Builder Volume
Rebuild Abort
PyMOL Viewer
all
4M8B

```
class scratch_storage

PyMOL>print dir(stored)
['__doc__', '__module__']
PyMOL>cmd.orient("chain a")
PyMOL>cmd.orient("chain a or chain b")
PyMOL>
```

PYMOL EMBEDDED PYTHON INTERPRETER


Home
Untitled1
http://localhost:8888/notebooks/Untitled1.i
Search
File Edit View Insert Cell Kernel Help

```
In [1]: %matplotlib
        import matplotlib.pyplot as plt
        from IPython.core.display import display

        Using matplotlib backend: TkAgg

In [2]: import numpy as np

In [3]: fig = plt.figure()
        plt.plot(np.random.random(100))
        display(fig)
```

JUPYTER NOTEBOOK

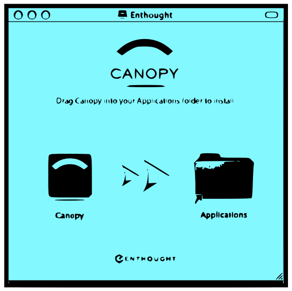
WE WILL USE THE *JUPYTER NOTEBOOK* WHICH WE CAN TALK TO VIA A WEB BROWSER

INSTALLING THE JUPYTER NOTEBOOK WITH ENTHOUGHT CANOPY EXPRESS

1) DOWNLOAD THE CANOPY EXPRESS INSTALLER FOR YOUR PLATFORM FROM:

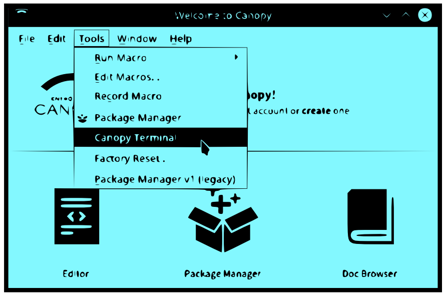
HTTPS://STORE.ENTHOUGHT.COM/DOWNLOADS/#DEFAULT

2) FOLLOW THE PLATFORM SPECIFIC INSTRUCTIONS TO INSTALL CANOPY EXPRESS, CHOOSING THE PYTHON 3.5 INSTALLER



Drag Canopy into your Applications folder to install

3) FROM CANOPY, CHOOSE TOOLS: CANOPY TERMINAL

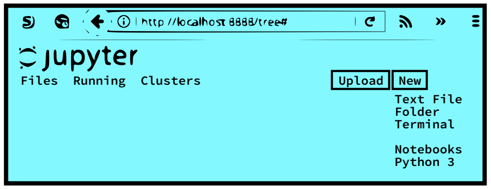


4) IN THE TERMINAL, TYPE:

```
jupyter notebook
```

THIS WILL OPEN THE JUPYTER NOTEBOOK SERVER IN YOUR DEFAULT WEB BROWSER

5) FROM YOUR WEB BROWSER, CHOOSE PYTHON3 FROM THE "NEW" MENU



THIS WILL OPEN A PYTHON NOTEBOOK IN A NEW BROWSER TAB OR WINDOW

6) YOU'RE READY TO CODE! IN YOUR NEW NOTEBOOK CELL TYPE "HELLO, WORLD" AND PRESS SHIFT-RETURN (MAC) OR SHIFT-ENTER (PC)

IN THIS GUIDE, WE WILL SHOW *INPUT CELLS* AS ROUND BOXES

```
[ ] "Hello, world"
```

```
Hello, world
```

AND *OUTPUT* CELLS AS RECTANGLES

WHEN PYTHON EXECUTES YOUR INPUT, IT WILL ADD A NUMBER IN THE BRACKETS NEXT TO THE INPUT CELL

7) NOW MOVE ON TO THE NEXT PAGE AND FOLLOW ALONG IN YOUR NOTEBOOK!

WRITING OUR OWN FUNCTIONS IS NIFTY, BUT WOULDN'T IT BE GREAT IF THEY WERE ALREADY WRITTEN FOR US?

IN FACT, WE'VE SEEN SOME *BUILT-IN* FUNCTIONS ALREADY

```
[1] float(8)
```

```
8.0
```

```
[2] for i in range(0,10,2):
        x += i
```

HELP IS ANOTHER USEFUL BUILT-IN

```
[3] help(float)
```

```
Help on class float in modu

class float(object)
 |  float(x) -> floating p
 |
 |  Convert a string or nu
```

WONDER HOW MANY BUILT-INS THERE ARE?

```
[4] help(__builtins__)
```

```
class float(object)
 |  float(x) -> floating
 |
 |  Convert a string or n
 |
 |  Methods defined here:
 |
 |  __abs__(...)
 |      x.__abs__() <==> a

print(...)
    print(value, ..., sep

    Prints the values to
    Optional keyword argu
    file: a file-like ob
    sep:  string inserte
    end:  string appende

range(...)
    range(stop) -> list c
    range(start, stop[, s

    Return a list contai
    range(i, j) returns
    When step is given,
    For example, range(4
    These are exactly th

sum(...)
    sum(sequence[, start

    Return the sum of a
    of parameter 'start'
    empty, return start.

max(...)
    max(iterable[, key=f
    max(a, b, c, ...[, k

    With a single iterab
    With two or more arg

ord(...)
    ord(c) ->

    Return th
```

A PLETHORA OF PYTHON PARAPHERNALIA!

PRINT IS AN ESPECIALLY USEFUL FUNCTION

IT CONVERTS ITS PARAMETERS TO *STRINGS* AND *PRINTS* THOSE STRINGS TO THE STANDARD OUTPUT

```
[5] print(42)
```

```
42
```

```
[6] print("forty two")
```

```
forty two
```

```
[7] print("six"*7)
```

```
sixsixsixsixsixsixsix
```

BUT WHAT IS A *STRING?*

READ ON TO FIND OUT!

YOUR FIRST NOTEBOOK: PYTHON AS A CALCULATOR

```
[1]  1+1
```
```
2
```

PRESS SHIFT+ENTER TO EXECUTE CELL

SOME MORE BASIC MATH:

```
[2]  3-2
```
```
1
```
SUBTRACTION

```
[3]  2*3
```
```
6
```
MULTIPLICATION

DIVISION
```
[4]  6/4
```
```
1.5
```

EXPONENTIATION
```
[5]  2**3
```
```
8
```

MODULAR DIVISION (REMAINDER)
```
[6]  6%4
```
```
2
```

```
[7]  x=2+3
```

ASSIGNMENT HIDES OUR OUTPUT

```
[8]  x
```
```
5
```

BUT WE CAN GET IT BACK LIKE SO

SOME TRICKS WE CAN DO WITH ASSIGNMENT

EVALUATING FORMULAE

```
[9]  A=2000
     T=3000
     G=1000
     C=1200
```
```
[10]((G+C)/
      (A+T+G+C))
```
```
0.30555
```
```
[11]Tm=64.9+(41*
   (G+C-16.4)/
   (A+T+G+C))
```

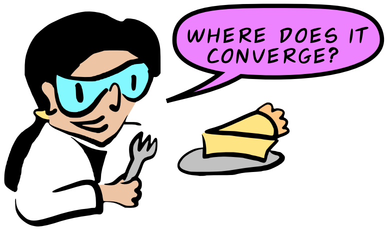
FEEDBACK

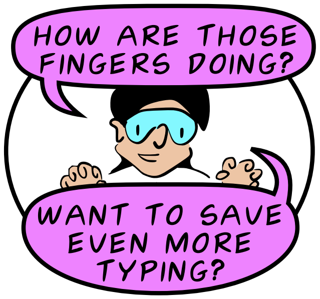
```
[12]  n=0
```
```
[13]n=n+2
    n
```
```
2
```
```
[14]n=n+2
    n
```
```
4
```
```
[15]n=n+2
    n
```
```
6
```
```
[16]n=n+2
    n
```
```
8
```

PRESS CTRL-ENTER TO REPEATEDLY EVALUATE A CELL

HERE'S ANOTHER FUN FEEDBACK TRICK

```
[17]  x=1
      n=3
```
```
[18]x=x-1/n+1/(n+2)
    n=n+4
    x*4
```
```
3.4666666666666667
```
```
[19]x=x-1/n+1/(n+2)
    n=n+4
    x*4
```
```
3.3396825396825403
```





JUST AS WE CAN SAVE *DATA* IN A VARIABLE WE CAN SAVE CODE IN A *FUNCTION*

DEFINE A FUNCTION NAMED PI WITH ONE PARAMETER (N)

WE USE THE *PARAMETER* (N) TO SET THE NUMBER OF TERMS THAT WE CALCULATE

AS IN A FOR LOOP THE *BODY* OF THE FUNCTION GOES IN AN *INDENTED BLOCK*

```
[1]  def pi(N):
       x=1
       for n in range(3,3+4*N,4):
         x+=-1/n+1/(n+2)
       return x*4
```

WHEN WE *CALL* A FUNCTION WE INCLUDE PARAMETER VALUES IN *PARENTHESIS*

THE *RETURN* STATEMENT IS RESPONSIBLE FOR RETURNING THE RESULT OF THE FUNCTION

```
[2]  pi(10)
```
```
3.1891847822776
```
```
[3]  pi(1000000)
```
```
3.1415931535896
```

FUNCTIONS CAN TAKE MORE THAN ONE PARAMETER

```
[4]  def add(x,y):
       return x+y
```
```
[5]  add(3,5)
```
```
8
```

NO PARAMETERS

```
[6]  def fortytwo():
       return 42
```
```
[7]  fortytwo()
```
```
42
```

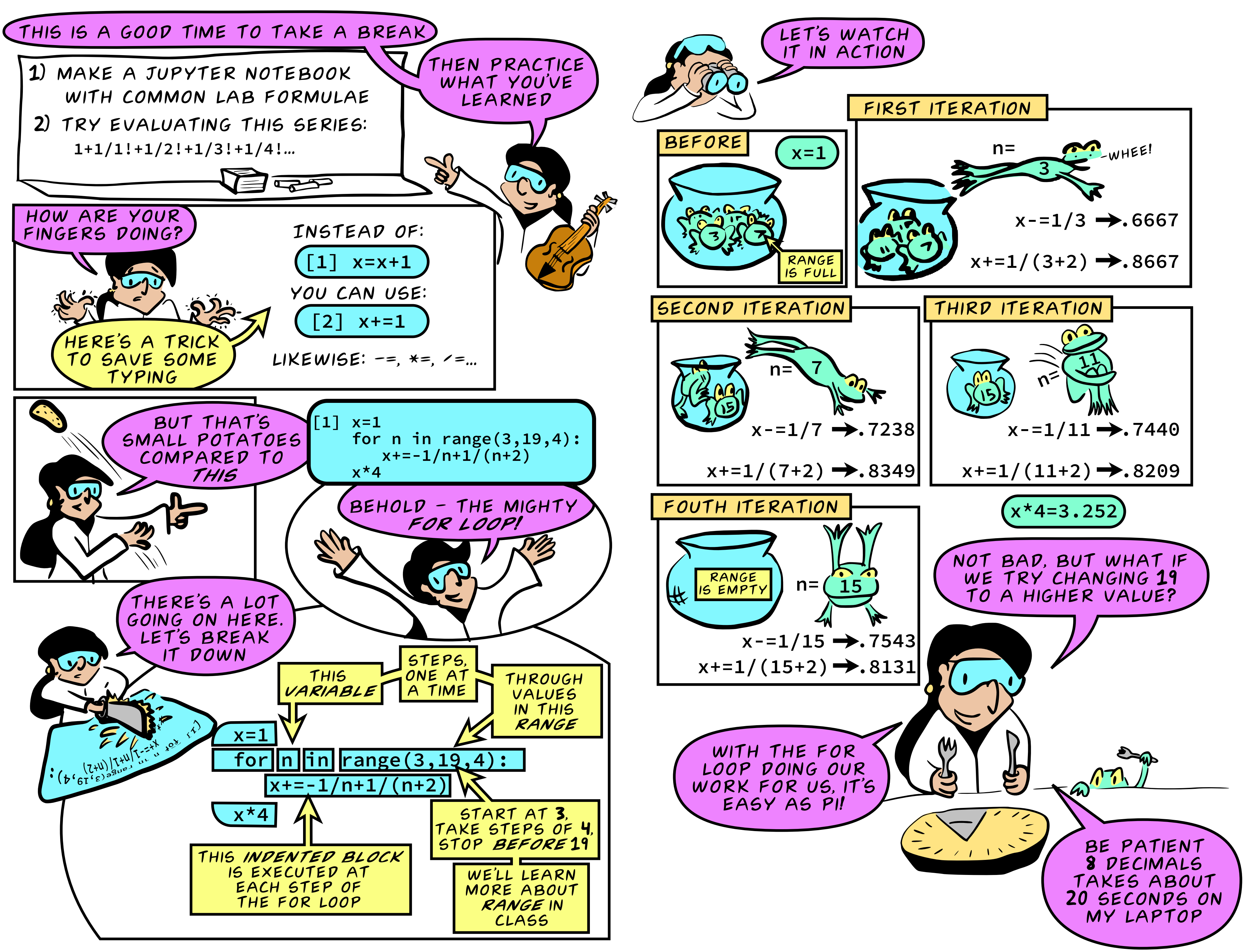
OR *OPTIONAL* PARAMETERS

```
[8]  def f(x=3,y=5):
       return x-y
```

BY DEFAULT, PARAMETERS GET PLUGGED IN LEFT TO RIGHT

YOU CAN OVERRIDE THE DEFAULT BY *NAMING* A PARAMETER

```
[9]  f()
```
```
-2
```
```
[10]  f(11)
```
```
6
```
```
[11]  f(y=1)
```
```
2
```
```
[12]  f(8,7)
```
```
1
```


THIS IS A GOOD TIME TO TAKE A BREAK
1) MAKE A JUPYTER NOTEBOOK WITH COMMON LAB FORMULAE
2) TRY EVALUATING THIS SERIES:
1+1/1!+1/2!+1/3!+1/4!...
THEN PRACTICE WHAT YOU'VE LEARNED
HOW ARE YOUR FINGERS DOING?
HERE'S A TRICK TO SAVE SOME TYPING
INSTEAD OF:
YOU CAN USE:
LIKEWISE: -=, *=, /=...
BUT THAT'S SMALL POTATOES COMPARED TO *THIS*
BEHOLD - THE MIGHTY *FOR LOOP!*
THERE'S A LOT GOING ON HERE. LET'S BREAK IT DOWN
THIS *VARIABLE*
STEPS, ONE AT A TIME
THROUGH VALUES IN THIS *RANGE*
THIS *INDENTED BLOCK* IS EXECUTED AT EACH STEP OF THE FOR LOOP
START AT 3, TAKE STEPS OF 4, STOP *BEFORE* 19
WE'LL LEARN MORE ABOUT *RANGE* IN CLASS
LET'S WATCH IT IN ACTION
BEFORE
x=1
RANGE IS FULL
FIRST ITERATION
n=
3
WHEE!
SECOND ITERATION
n=
7
15
THIRD ITERATION
n=
11
15
FOUTH ITERATION
RANGE IS EMPTY
n=
15
x*4=3.252
NOT BAD, BUT WHAT IF WE TRY CHANGING 19 TO A HIGHER VALUE?
WITH THE FOR LOOP DOING OUR WORK FOR US, IT'S EASY AS PI!
BE PATIENT 8 DECIMALS TAKES ABOUT 20 SECONDS ON MY LAPTOP

```
[1] x=x+1
```

```
[2] x+=1
```

```
[1] x=1
    for n in range(3,19,4):
        x+=-1/n+1/(n+2)
    x*4
```

```
x=1
for n in range(3,19,4):
    x+=-1/n+1/(n+2)
x*4
```

First iteration:

```
x-=1/3 →.6667
x+=1/(3+2) →.8667
```

Second iteration:

```
x-=1/7 →.7238
x+=1/(7+2) →.8349
```

Third iteration:

```
x-=1/11 →.7440
x+=1/(11+2) →.8209
```

Fouth iteration:

```
x-=1/15 →.7543
x+=1/(15+2) →.8131
```