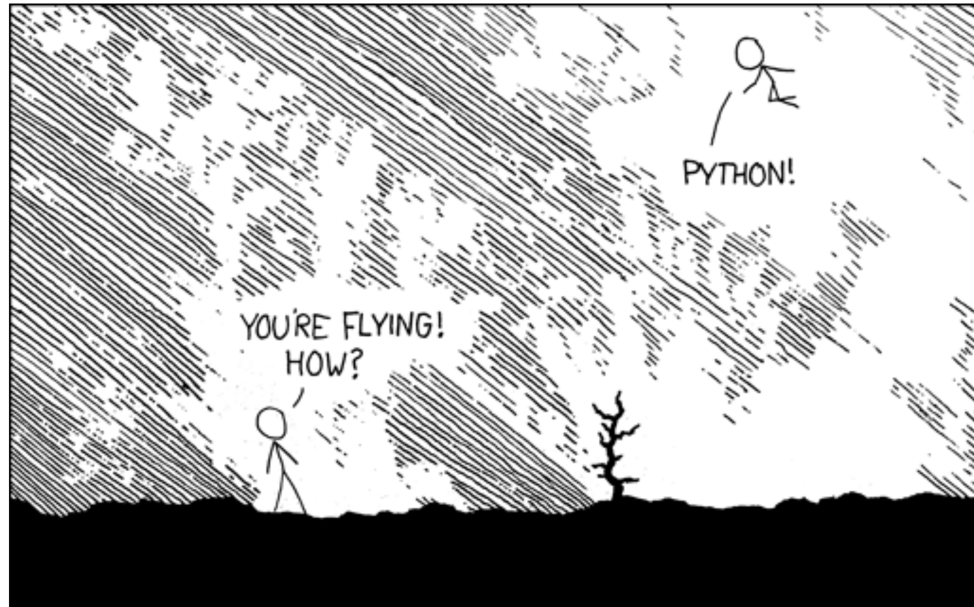
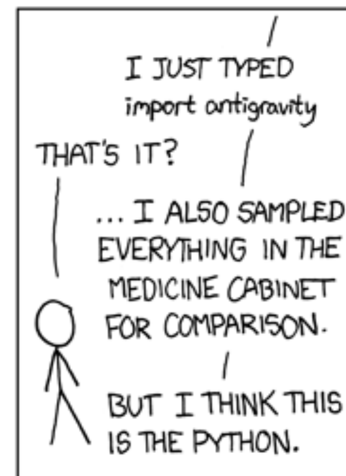
From HMMM to Python



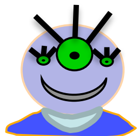


Factorial via Recursion…

Python

```
x = input()
y = fac(x)
print y

def fac(x):
  """ recursive
      factorial! """
  if x == 0:
    return 1
  else:
    REC = fac(x-1)
    return x*REC
```



This is same as `return x*f(x-1)` but done in 2 steps…

Hmmm

```
00 read r1
01 loadn r15 42
02 call r14 5
03 jump 21
04 nop
05 jnez r1 8
06 loadn r13 1
07 jumpi r14
08 storei r1 r15
09 addn r15 1
10 storei r14 r15
11 addn r15 1
12 addn r1 -1
13 call r14 5
14 addn r15 -1
15 loadi r14 r15
16 addn r15 -1
17 loadi r1 r15
18 mul r13 r13 r1
19 jumpi r14
20 nop
21 write r13
22 halt
```

Name(s)________________________________

Quiz

Refer to the factorial code on the previous slide, and answer the following questions…

1. At what memory address does the stack begin? What is the lowest memory address that we could start the stack?

2. Which lines of code make up the whole factorial function? (If you're bored, match every python line with the corresponding assembly code…)

3. Which line(s) of code place(s) factorial's return value in the right place?

4. On line 13, what value gets stored in the register r14?

5. (Bonus—i.e., it'll help to do the bonus quiz to answer this question):
   What is the highest value that the stack pointer (r15) gets if the user's original input is 3?

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Quiz

Refer to the factorial code on the previous slide, and answer the following questions…

1. At what memory address does the stack begin? What is the lowest memory address that we could start the stack?
   A. 50 B. 42 C. 43 D. 51 E. 23

2. Which lines of code make up the whole factorial function? (If you're bored, match every python line with the corresponding assembly code…)

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1. At what memory address does the stack begin? What is the lowest memory address that we could start the stack?
   A. 50 B. 42 C. 43 D. 51 E. 23

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3. Which line(s) of code place(s) factorial's return value in the right place?

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1. At what memory address does the stack begin? What is the lowest memory address that we could start the stack?

2. Which lines of code make up the whole factorial function? (If you're bored, match every python line with the corresponding assembly code…)
   A. 5-19 B. 0-22 C. 0-4 D. 0-3 E. 5-22

3. Which line(s) of code place(s) factorial's return value in the right place?

4. On line 13, what value gets stored in the register r14?

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3. Which line(s) of code place(s) factorial's return value in the right place?
   A. 18 B. 6 and 18 C. 6, 18 and 21 D. 2 E. 9, 11, 14 and 16

4. On line 13, what value gets stored in the register r14?

5. (Bonus—i.e., it'll help to do the bonus quiz to answer this question):
   What is the highest value that the stack pointer (r15) gets if the user's original input is 3?

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4. On line 13, what value gets stored in the register r14?
   A. 13 B. 5 C. 42 D. 14 E. 12

5. (Bonus—i.e., it'll help to do the bonus quiz to answer this question):
   What is the highest value that the stack pointer (r15) gets if the user's original input is 3?

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Quiz

Refer to the factorial code on the previous slide, and answer the following questions…

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5. (Bonus—i.e., it'll help to do the bonus quiz to answer this question):
   What is the highest value that the stack pointer (r15) gets if the user's original input is 3?
   A. 44 B. 46 C. 47 D. 48 E. Other

Name(s) ______________________________

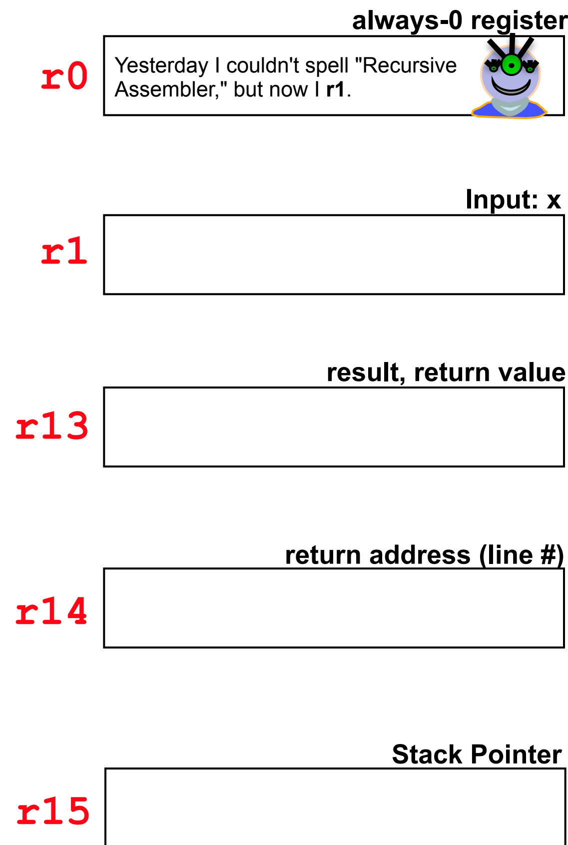
Bonus Quiz!

Write down what happens in the registers and memory (the stack) as this program runs…

Program (low RAM) The input is 3.

```
00 read r1
01 loadn r15 42
02 call r14 5
03 jump 21
04 nop
05 jnez r1 8
06 loadn r13 1
07 jumpi r14
08 storei r1 r15
09 addn r15 1
10 storei r14 r15
11 addn r15 1
12 addn r1 -1
13 call r14 5
14 addn r15 -1
15 loadi r14 r15
16 addn r15 -1
17 loadi r1 r15
18 mul r13 r13 r1
19 jumpi r14
20 nop
21 write r13
22 halt
```

CPU Registers with labels



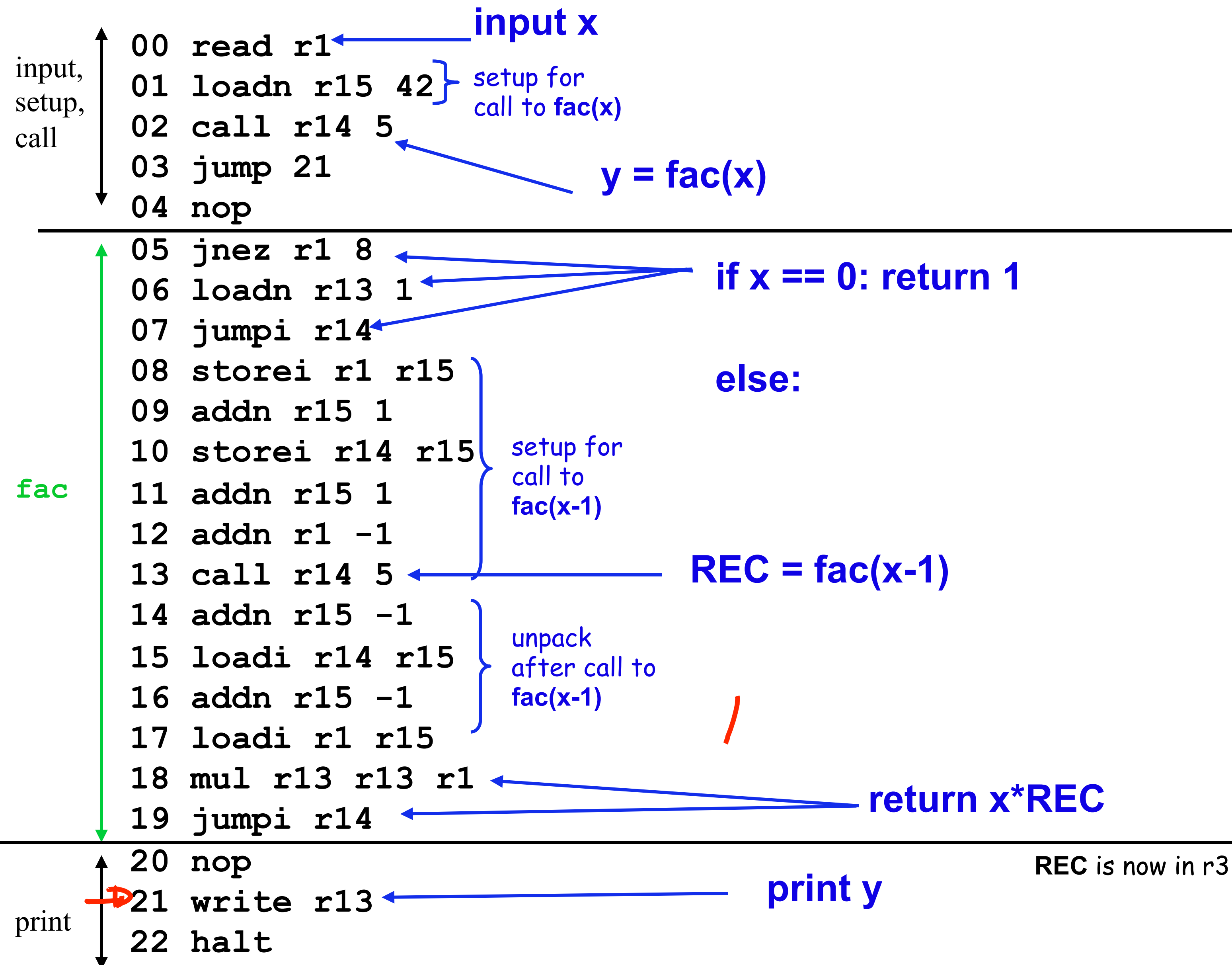
Memory (high RAM) **"the stack"**

Address	Value
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	

Common Pitfalls

- **Problem**: You forgot to store something on the stack and it gets wiped out by accident
- **Solution**: Store EVERYTHING on the stack, even if you think you don't need it!
- **Problem**: Things are coming back from the stack different from when they went on
- **Solution(s):**
  - Make sure that you take things off in the REVERSE order from how you put them on
  - Make sure your stack pointer ends up the same way it started (for every addn r15 1, you have an addn r15 -1)

Recursive Factorial!



Common Pitfalls

- **Problem**: You forgot to store something on the stack and it gets wiped out by accident
- **Solution**: Store EVERYTHING on the stack, even if you think you don't need it!
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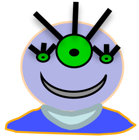


Hmmm, I'm not sure about this game

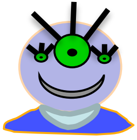
Hmmm Detectives

```
00 read r1            # get an integer from the user
                      # and hold it in register r1
01 load r2 2          # put 2 in r2
02 mul r1 r2 r1       # r1 = r1 * r2
03 loadn r3 42        # put 42 in r3
04 storei r1 r3       # store the value of r1 at memory
                      # location 42
05 load r4 42         # load the value from memory
                      # location 42 into r4
06 write r4           # write out (print) the contents of r4
07 halt               # stop here.
```

Hmmm says:

Invalid load target at pc 1: 2

Halting program execution.



Hmmm, I'm not sure about this game

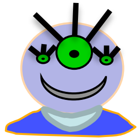
Hmmm Detectives

```
00 read r1              # get an integer from the user
                        # and hold it in register r1
01 loadn r2 2            # put 2 in r2
02 mul r1 r2 r1         # r1 = r1 * r2
03 load r3 42           # put 42 in r3
04 storei r1 r3         # store the value of r1 at
                        # memory location 42
05 load r4 42           # load the value from memory
                        # location 42 into r4
06 write r4             # write out (print) the contents of r4
07 halt                 # stop here.
```

Hmmm says:

Invalid store target at pc 4: 0

Halting program execution.



Hmmm, I'm not sure about this game

Hmmm Detectives

```
00 read r1              # get an integer from the user
                        # and hold it in register r1
01 loadn r2 2            # put 2 in r2
02 mul r1 r2 r1         # r1 = r1 * r2
03 load r3 42           # put 42 in r3
04 store r1 r3         # store the value of r1 at
                              # memory location 42
05 load r4 42           # load the value from memory
                        # location 42 into r4
06 write r4             # write out (print) the contents of r4
07 halt                 # stop here.
```

```
ARGUMENT ERROR:
'r3' IS NOT A VALID NUMBER.

***** ASSEMBLY TERMINATED UNSUCCESSFULLY *****
              ASSEMBLY RESULTS:

0 : 0000 0001 0000 0001          00 read r1          # get an integer from
1 : 0001 0010 0000 0010          01 loadn r2 2       # put 2 in r2
2 : 1000 0001 0010 0001          02 mul r1 r2 r1     # r1 = r1 * r2
3 : 0001 0011 0010 1010          03 loadn r3 42      # put 42 in r3
4 : ***ARGUMENT ERROR HERE***    04 store r1 r3     # store the value of
5 : 0010 0100 0010 1010          05 load r4 42       # load the value from
6 : 0000 0100 0000 0010          06 write r4         # write out (print)
7 : 0000 0000 0000 0000          07 halt             # stop here.
```

Taxonomy of Programming Models

Programming

What mood am I in today?

Declarative Programming

Imperative Programming

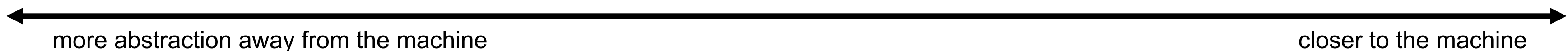
Logic Programming

Functional Programming

Object-Oriented Programming

Low-level Programming

Prolog **Racket** **Python** **Hmmm**



more abstraction away from the machine

closer to the machine

More Powerful Languages…

Functional Languages	Imperative Languages
Simple, elegant syntax	“Large” syntax
“Bootstrapping”	“What’s bootstrapping?”
No “side effects”	Major “side effects”
No: `for, while, =`	Yes: `for, while, =`

More Powerful Languages…

Functional Languages

Simple, elegant syntax
Few or no “side effects”
No: `for, while, =`

ML, Lisp, Scheme,
Haskell, Python

Imperative Languages

“Large” syntax
“Side effects” are how you get things done
Yes: `for, while, =`

Java, C, C++, Pascal,
Fortran, Python

Legal disclaimer:

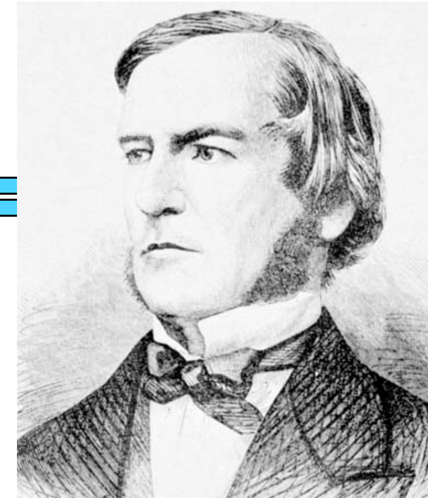
Python can be viewed as “functional” if we restrict our attention to a subset of its syntax. May not be considered functional in some states.

demo!

Beyond Integers…

```
>>> 3/4
0
>>> 3.0/4
0.75
>>> 3+2j
(3+2j)
>>> (3+2j)*(1-j)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
NameError: name 'j' is not defined
>>> (3+2j)*(1-1j)
(5-1j)
>>> S = "spam"
>>> S + "mer"
'spammer'
>>> 3*S
'spamspamspam'
>>> S*3
'spamspamspam'
>>> len(S)
4
```

Booleans



George Boole
1815-1864

```
>>> 3 == 1+2
True
>>> 42 == "spam"
False
>>> True == 1
True
>>> False == 0
True
>>> True + 5
6
```

`str`ing functions

`str`	`str(42)` returns `'42'`	converts input to a string
`len`	`len('42')` returns `2`	returns the string's length
`+`	`'XL' + 'II'` returns `'XLII'`	*concatenates* strings
`*`	`'VI'*7` returns `'VIVIVIVIVIVIVI'`	*repeats* strings

Given these strings

```
s1 = "ha"
s2 = "t"
```

What are

```
s1 + s2

2*s1 + s2 + 2*(s1+s2)
```

String surgery

```
s = 'harvey mudd college'
     0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
```

`s[ ]` *indexes* into the string, returning a one-character string

index

`s[0]` returns `'h'`

Read "s-of-zero" or "s-zero"

`s[6]` returns

`s[ ]` returns `'e'`

Which index returns 'e'?

`s[len(s)]` returns

Negative indices…

```
      0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
s = 'harvey mudd college'
    -19 -17 -15 -13 -11 -9 -7 -5 -3 -1
      -18 -16 -14 -12 -10 -8 -6 -4 -2
```

Negative indices count ***backwards*** from the end!

`s[-1]` returns `'e'`

`s[-11]` returns

`s[-0]` returns

Python can suit any mood…

Slicing

what to do if you want a bigger piece of the pie!

```
s = 'harvey mudd college'
     0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
```

`s[ : ]` *slices* the string, returning a substring

What's going on here?

`s[0:6]` returns `'harvey'`

`s[12:18]` returns `'colleg'`

`s[17:]` returns `'ge'`

`s[:]` returns `'harvey mudd college'`

Slicing

what to do if you want a bigger piece of the pie!

```
s = 'harvey mudd college'
     0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
```

`s[ : ]` *slices* the string, returning a substring

the first index is the first character of the slice

the second index is **ONE AFTER** the last character

a missing index means the end of the string

`s[0:6]` returns `'harvey'`

`s[12:18]` returns `'colleg'`

`s[17:]` returns `'ge'`

`s[:]` returns `'harvey mudd college'`

Slicing

what to do if you want a bigger piece of the pie!

```
s = 'harvey mudd college'
     0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
```

`s[ : ]` ***slices*** the string, returning a substring

What are these slices?

```
s[15:-1]

s[:]
```

How would you get

```
'mud'

'e'
```

Lists ~ Strings *of anything*

Commas separate elements.

```
L = [ 3.14, [2,40], 'third', 42 ]
```

Square brackets tell python you want a list.

```
len(L)
```

```
L[0]
```

Indexing: could return a different type

Slicing: always returns the same type

```
L[0:1]
```

How could you extract from `L` `'hi'`

disclaimer: lists are also arrays…

Skip-Slicing

if you don't want your neighbor to get any...

```
s = 'harvey mudd college'
     0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
```

`s[ : : ]` ***skip-slices***, returning a subsequence

the third index is the "stride" length

it defaults to 1

`s[0:8:2]` returns `'hre '`

What skip-slice returns `'doe'`

What does this return? `s[1::6]`

I love this one.

Name(s): ______________________

Raising and razing lists

"Quiz"

```
pi = [3,1,4,1,5,9]          Q = [ 'pi', "isn't", [4,2] ]

message = 'You need parentheses for chemistry !'
```

I ♥ ( )

Part 1

What are `len(pi)`, `len(Q)`, `len(Q[1])`

What slice of **pi** is `[3,1,4]`

What slice of **pi** is `[3,4,5]`

What are

`pi[0] * (pi[1] + pi[2])`

and

`pi[0] * (pi[1:2] + pi[2:3])`

Part 2

What are `Q[0]`, `Q[0:1]`, `Q[0][1]`, `Q[1][0]`

What is `message[9:15]`

What is `message[::5]`

Extra! Mind Muddlers

What is `pi[pi[2]]`?

How many nested **pi**'s before `pi[...pi[0]...]` produces an error?

Name(s): ______________________

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```
pi = [3,1,4,1,5,9]          Q = [ 'pi', "isn't", [4,2] ]

message = 'You need parentheses for chemistry !'
```

I ♥ ( )

Part 1

What are `len(pi)`, `len(Q)`, `len(Q[1])`

A. 6, 3, 1
B. 5, 2, 2
C. 6, 4, 2
D. 6, 3, 5
E. 5, 3, 4

What slice of **pi** is `[3,1,4]`

What slice of **pi** is `[3,4,5]`

What are

`pi[0] * (pi[1] + pi[2])`

and

`pi[0] * (pi[1:2] + pi[2:3])`

Extra! Mind Muddlers

What is `pi[pi[2]]`?

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Name(s): ____________________

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```

I ♥ ( )

Part 1

What are
```
len(pi)
len(Q)
len(Q[1])
```

What slice of **pi** is **[3,1,4]**

What slice of **pi** is **[3,4,5]**

```
A. pi[0:2], pi[0:3:2]
B. pi[1:3], pi[1:5:2]
C. pi[0:3], pi[0:5:2]
D. pi[0:3:2], pi[1:6:2]
E. pi[1:5:2], pi[0:5:1]
```

What are

```
pi[0] * (pi[1] + pi[2])
```

and

```
pi[0] * (pi[1:2] + pi[2:3])
```

Extra! Mind Muddlers

What is **pi[pi[2]]**?

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Raising and razing lists

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```

I ♥ ()

Part 1

What are

- `len(pi)`
- `len(Q)`
- `len(Q[1])`

What slice of **pi** is `[3,1,4]`

What slice of **pi** is `[3,4,5]`

A. 15, "141414"
B. "141414", 15
C. 15, 15
D. 15, [1, 4, 1, 4, 1, 4]
E. 12, "141414"

What are

`pi[0] * (pi[1] + pi[2])`

and

`pi[0] * (pi[1:2] + pi[2:3])`

Extra! Mind Muddlers

What is `pi[pi[2]]`?

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Raising and razing lists

"Quiz"

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I ♥ ( )

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What is `message[9:15]`

What is `message[::5]`

Extra! Mind Muddlers

What is `pi[pi[2]]`?

How many nested `pi`'s before `pi[...pi[0]...]` produces an error?

Static vs. Dynamic Typing

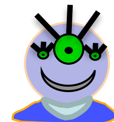
type determined at run time

Python is dynamically typed
Java is statically typed

type determined at compile time

```
>>> x = 5
>>> x = "hello"
>>> x = 3.5

>>> x = 4
>>> y = "2"
>>> x + y
Traceback (most recent call last):
  File "<pyshell#2>", line 1, in <module>
    x + y
TypeError: unsupported operand type(s) for +: 'int' and 'str'

>>> str(x) + y
"42"
>>> x + int(y)
6
```

type casting



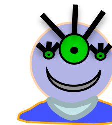
I hate being type cast!

The `in` thing

```
>>> 3*'i' in 'alien'
False
```

python is badly confused here...

```
>>> 'i' in 'team'
False
```



but otherwise it seems pretty perceptive!

```
>>> 'cs' in 'physics'
True

>>> 'sleep' not in 'CS 42'
True

>>> 42 in [41,42,43]
True
```

a little bit different for lists...

```
>>> 42 in [ [42], '42' ]
False
```

*Function*ing in Python

Some basic, built-in functions:

`abs` absolute value

`max`
`min` } of lists
`sum`

`range` creates lists

`round` only as accurately as it can!

these change data from one type to another {
`bool`
`float`
`int`
`long`
`list`
`str`

These are the most important: **`help`** **`dir`**

You call *that* a language?!

*Function*ing in Python

Far more are available in separate files, or *modules*:

```
import math
math.sqrt( 1764 )
dir(math)
```

accesses **math.py**'s functions

lists all of **math.py**'s functions

```
from math import *
pi
sin( pi/2 )
```

same, but without typing **math.** all of the time…

help()
help modules

*Function*ing in Python

```
# my own function!
def dbl( x ):
    """ returns double its input, x """
    return 2*x
```

Functioning in Python

```
# my own function!
def dbl( x ):
    """ returns double its input, x """
    return 2*x
```

keywords

def starts the function
return stops it immediately
and sends back the return value

Comments

They begin with #

Some of Python's *baggage*…

Docstrings

They become part of python's built-in help system!
With each function be sure to include one that

(1) describes overall what the function does, and
(2) explains what the inputs mean/are

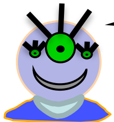
*Function*ing in Python

```
def undo(s):
    """ this "undoes" its string input, s """
    return 'de' + s
```

```
>>> undo('caf')

>>> undo(undo('caf'))
```

if, elif, else…

```
def foo(x):
    """This function demonstrates the use
    of if, elif, and else"""
    if x > 0 and x < 42:
        return “Small”
    elif x >= 42 and x < 100:
        return “Nice!”
    elif 100 <= x < 200:    # <- Funky!
        return “Big”
    else:
        print "That was one nasty number!"
        return “Yuck!”
```



Notice how lines with the same level of indentation are in the same code block!

Mutable vs. Immutable data

Changeable types:

`dictionary`

`list`

Unchangeable types:

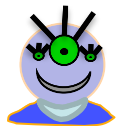
`tuple`

`string`

`int`

`float`

`bool`



What's a dictionary?

I guess I'll have to look it up!

Functions and (immutable) Variables

```
def fact(a):
   result = 1
   while a > 0:
      result *= a
      a -= 1
   return result

>>> x = 5
>>> y = fact(x)
>>> x
??
```

Functions and (immutable) Variables

The fine print: This is not the “truth”… but it’s close enough

```
def swap(a, b):
    temp = a
    a = b
    b = temp

>>> x = 5
>>> y = 10
>>> swap(x, y)
>>> print x, y
??
```

x

y

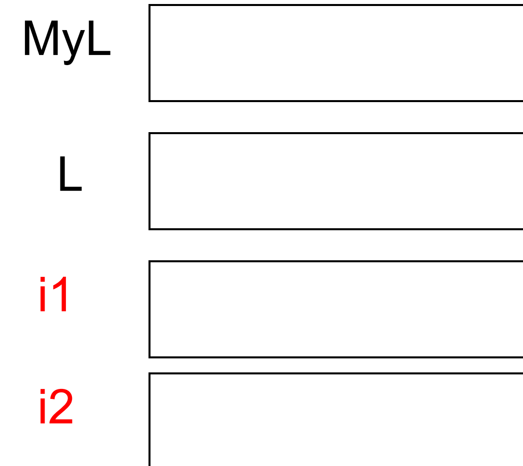
a

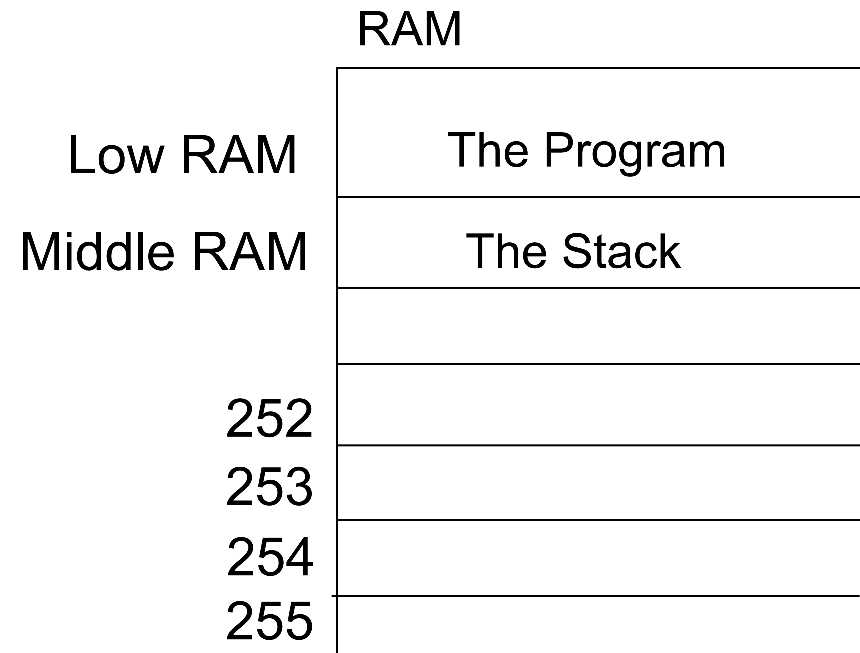
b

temp

Functions and Mutable Types

```
def swap(L, i1, i2):
   temp = L[i1]
   L[i1] = L[i2]
   L[i2] = temp

>>> MyL = [2, 3, 4, 1]
>>> swap(myL, 0, 3)
>>> print myL
??
```





Reference vs. Value

Mutable types:

`dictionary`

`list`

Unmutable types:

`tuple`

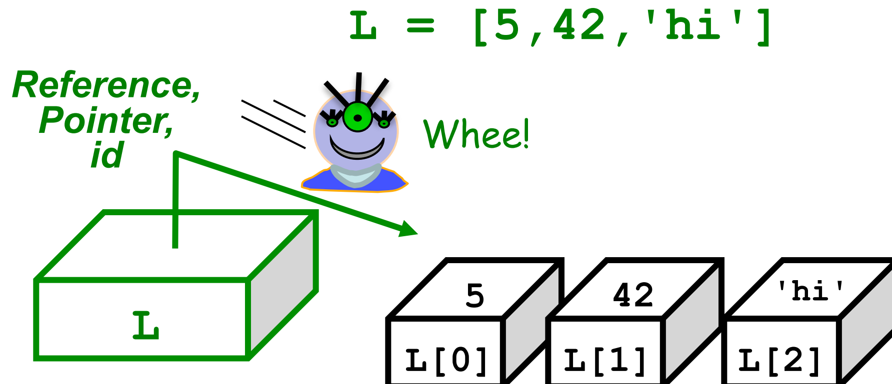
`string`

`int`

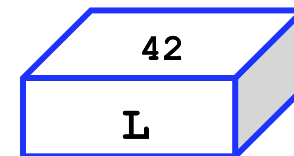
`float`

`bool`

`L = [5,42,'hi']`

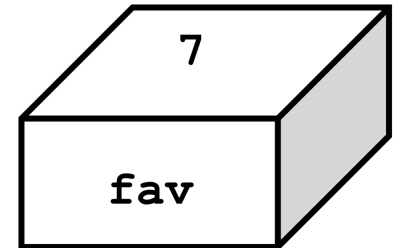


`L = 42`

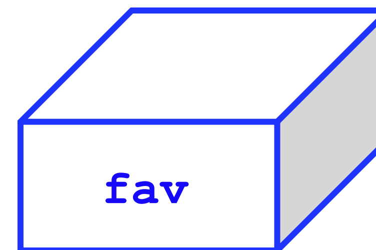


"Pass By Value"

```
def main()
    """ calls conform """
    print " Welcome to Conformity, Inc. "

    fav = 7
    conform(fav)

    print " My favorite number is", fav
```

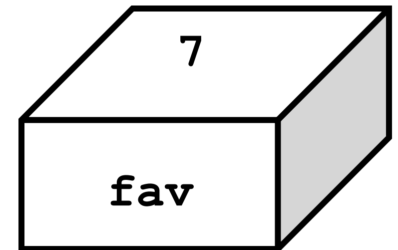


```
def conform(fav)
    """ sets input to 42 """
    fav = 42
    return fav
```



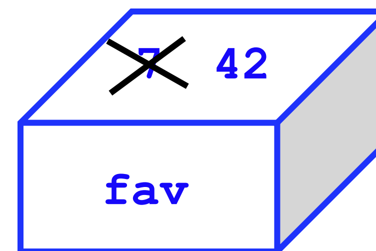
“Pass By Value”

```
def main()
    """ calls conform """
    print " Welcome to Conformity, Inc. "

    fav = 7
    conform(fav)

    print " My favorite number is", fav
```



PASS BY VALUE

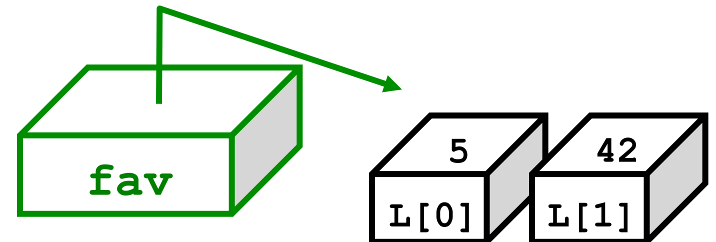
```
def conform(fav)
    """ sets input to 42 """
    fav = 42
    return fav
```



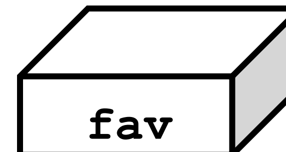
“Pass by value” means that data is **copied** when sent to a method

Passing ***lists*** by value…

```
def main()
    """ calls conform2 """
    print " Welcome to Conformity, Inc. "
    fav = [ 7, 11 ]
    conform2(fav)
    print " My favorite numbers are", fav
```



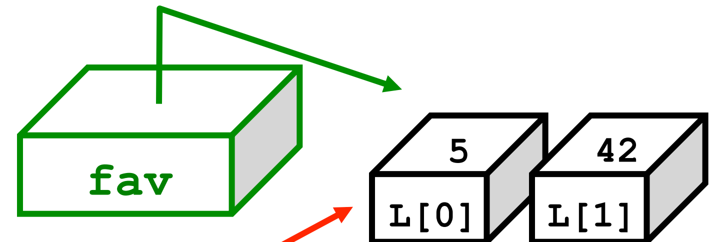

```
def conform2(fav)
    """ sets all of fav to 42 """
    fav[0] = 42
    fav[1] = 42
```



What gets passed by value here?

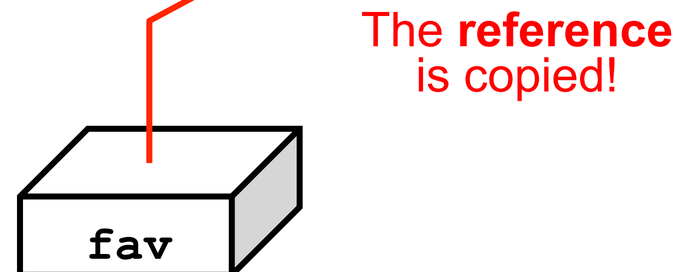
Passing *lists* by value…

```
def main()
    """ calls conform2 """
    print " Welcome to Conformity, Inc. "
    fav = [ 7, 11 ]
    conform2(fav)
    print " My favorite numbers are", fav
```



The **reference** is copied!

```
def conform2(fav)
    """ sets all of fav to 42 """
    fav[0] = 42
    fav[1] = 42
```



can change data elsewhere!

The conclusion

You can change **the contents of lists** in functions that take those lists as input. (actually, lists or any mutable objects)

Those changes will be visible **everywhere.** (immutable objects are safe, however)