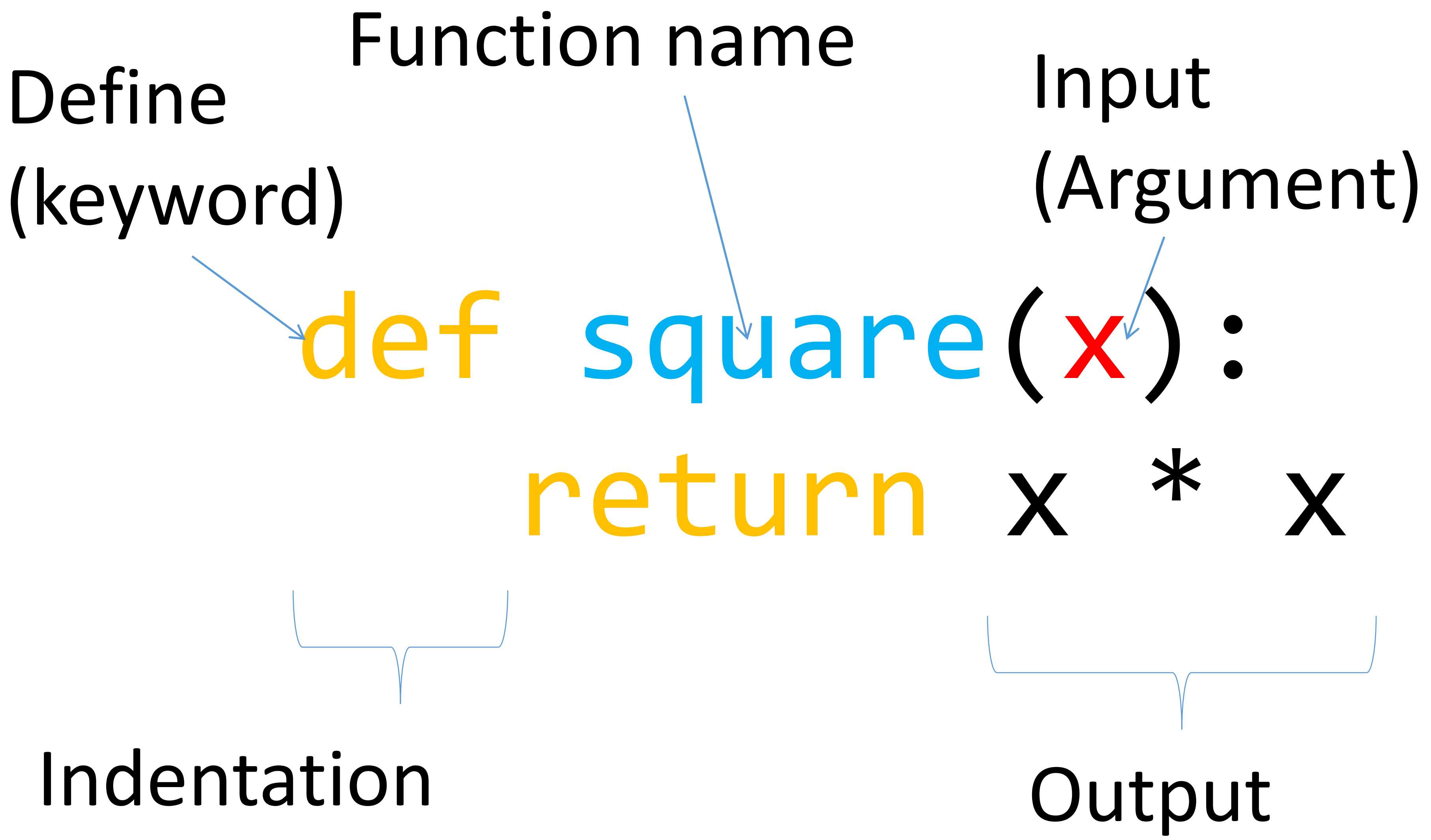
List Versus Tuples

How do we use lists and tuples differently

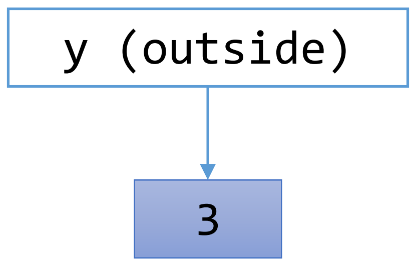
- Before this, let’s revisit “functions”

Let’s Write Our Own Function!



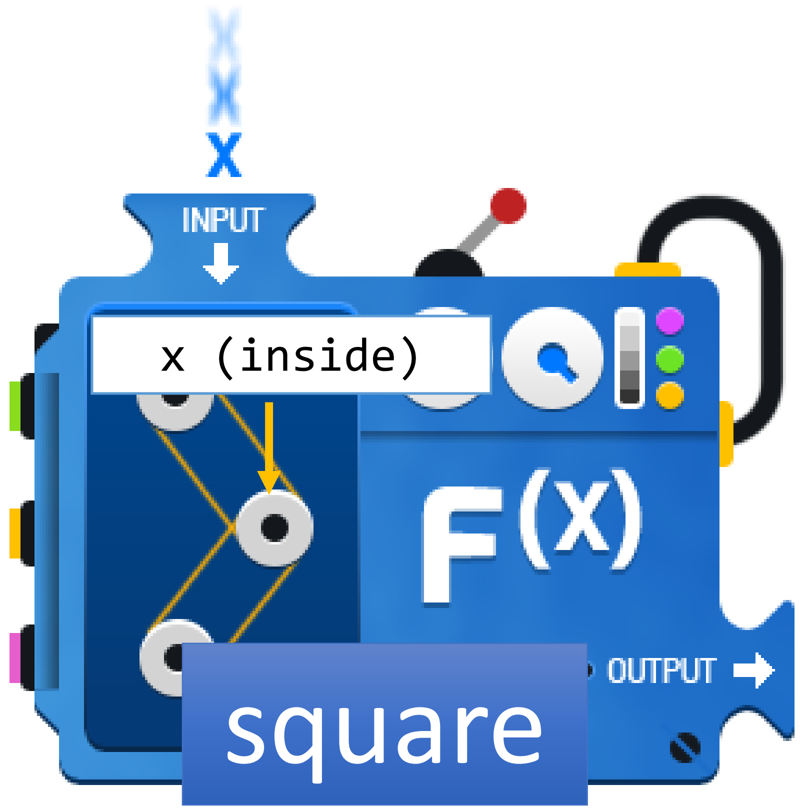
```python
def square(x):
    return x * x
```

For example



- "square" is a function

```
>>> y = 3
>>> square(3)
9
```

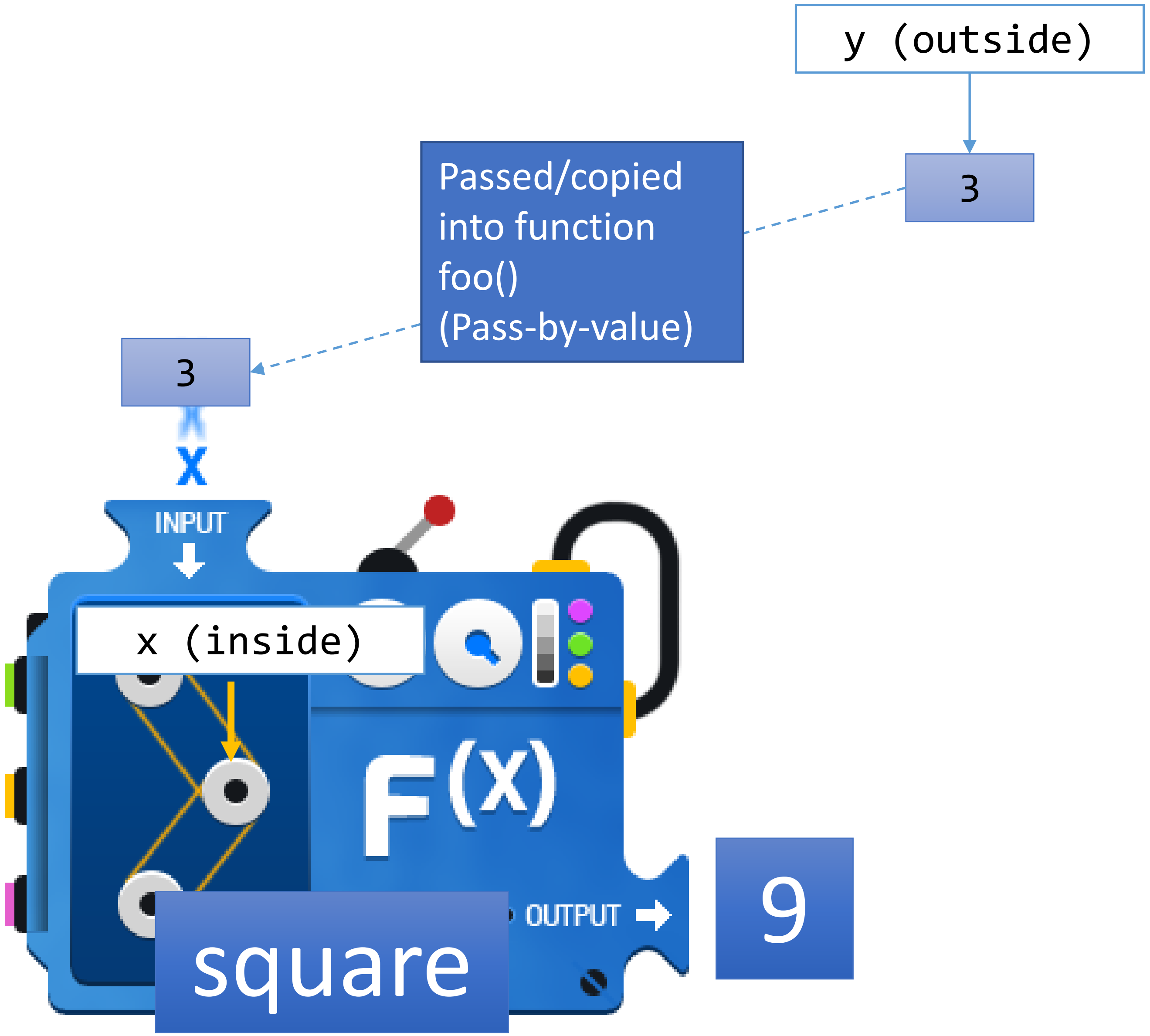


More Precisely

- "square" is a function

```
>>> y = 3
>>> square(3)
9
```

- Because the "3" that enters the function square is a copy of y
  - Meaning, the outside y will **NOT** be changed
  - This is under the assumption of "pass-by-value"



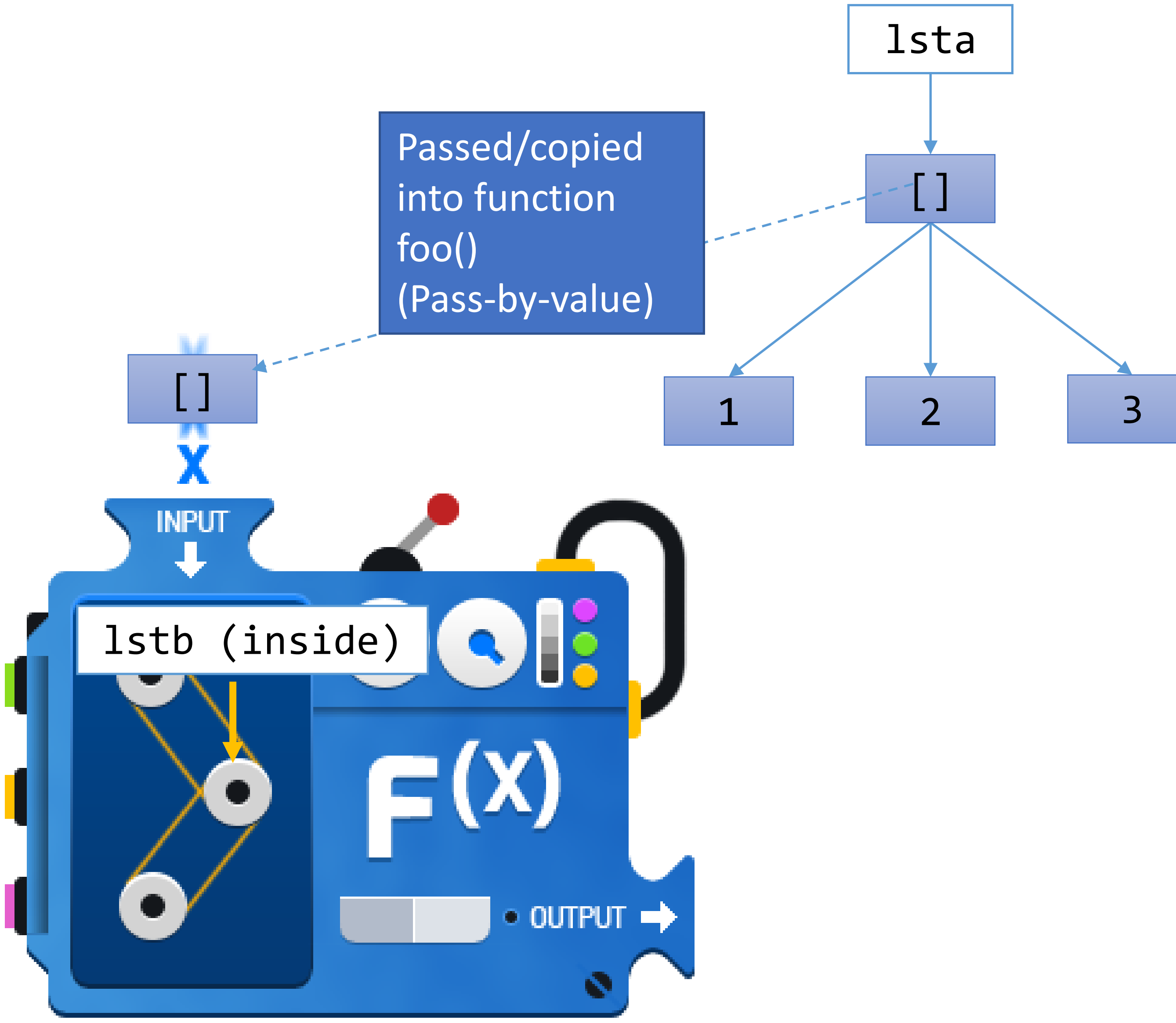
However,

- If we pass a list into a function

```
lsta = [1,2,3]

def f(lstb):
    lstb[0] = 999

f(lsta)
print(lsta)
```



However,

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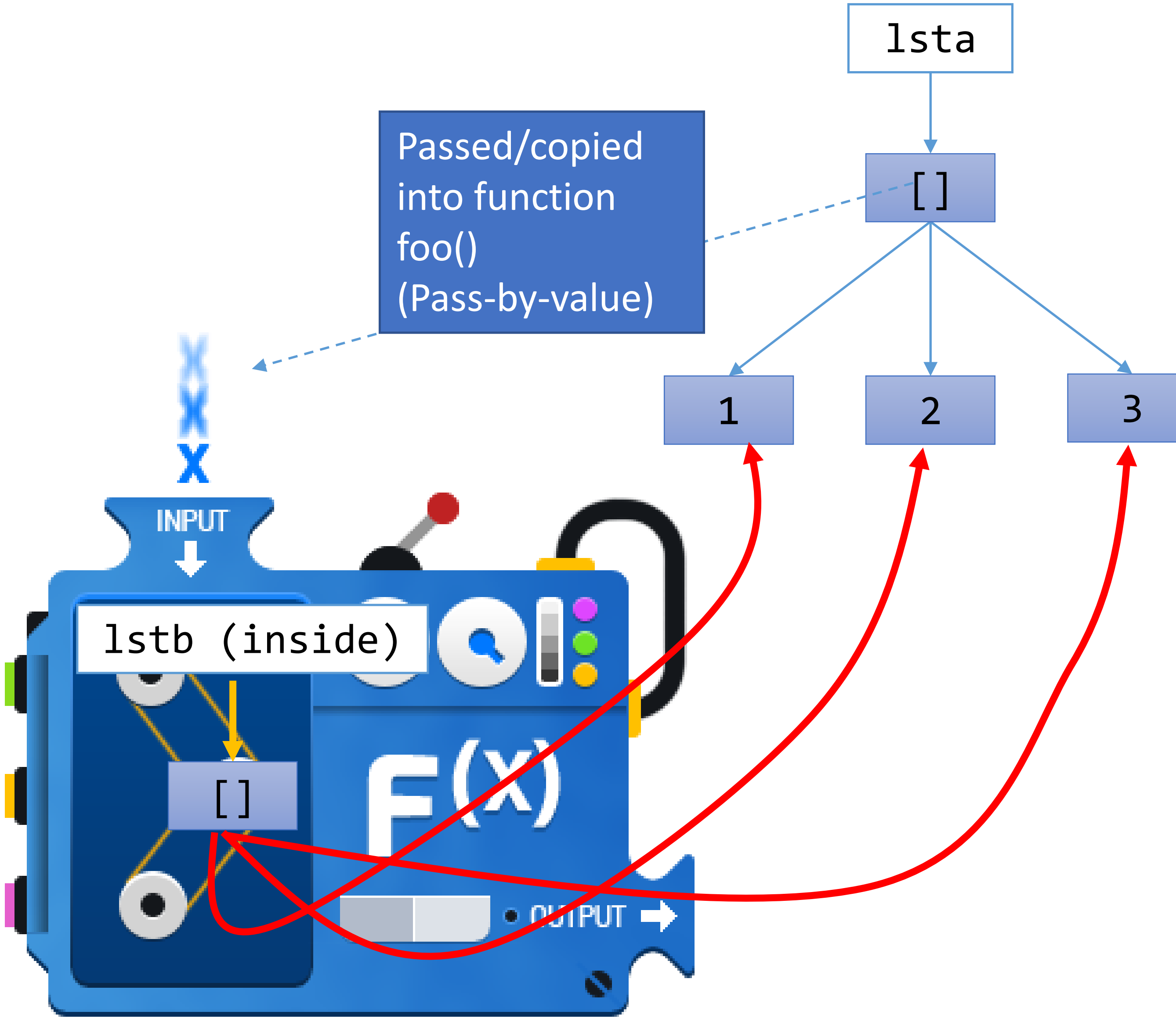

However,

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```
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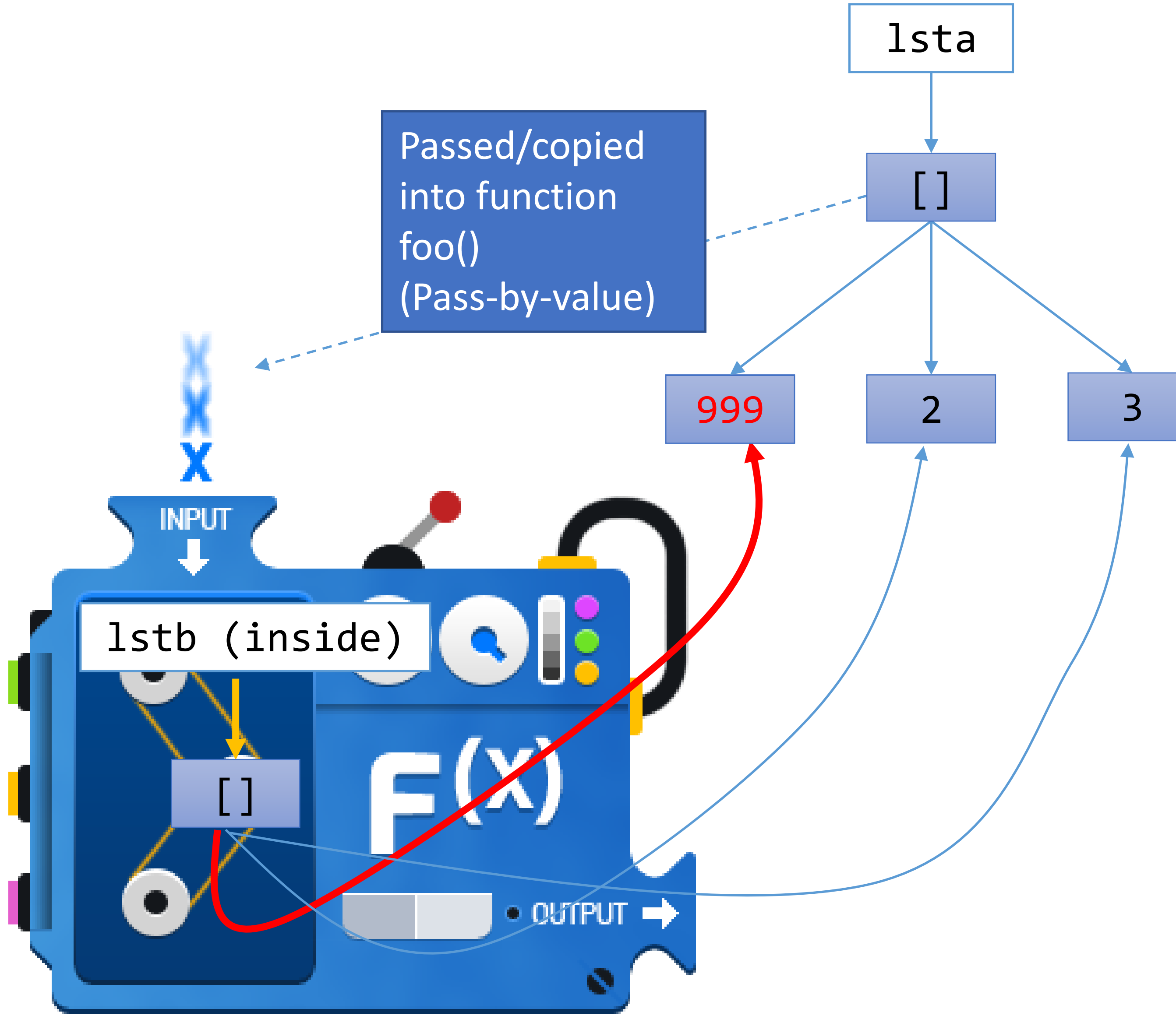
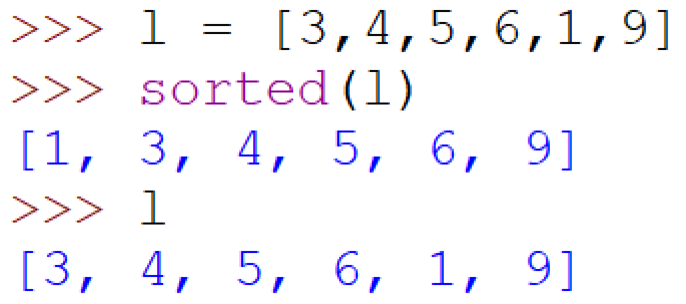


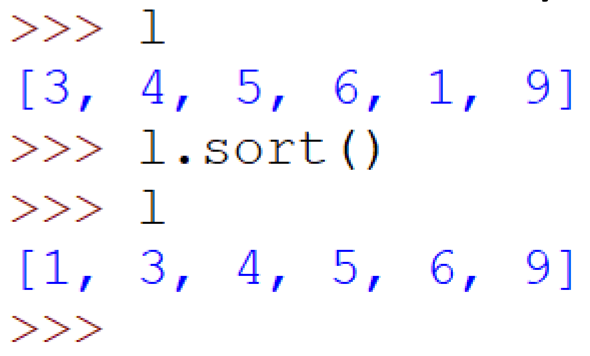
You may say there are TWO types of functions

- Type Pass-by-value:
  - Functions that will NOT modify the inputs (aka arguments or parameters)



```
>>> l = [3,4,5,6,1,9]
>>> sorted(l)
[1, 3, 4, 5, 6, 9]
>>> l
[3, 4, 5, 6, 1, 9]
```

- Type Pass-by-reference (or pass-by-pointers)
  - Functions that WILL modify the inputs (aka arguments or parameters)



```
>>> l
[3, 4, 5, 6, 1, 9]
>>> l.sort()
>>> l
[1, 3, 4, 5, 6, 9]
>>>
```

To Modify a Sequence, which one is better?

- Say, we just simplify want to add one element into a sequence
- Lists:

```
[1,2,3,4,5]     →     [1,2,3,4,5,999]
```

- Tuples

```
(1,2,3,4,5)     →     (1,2,3,4,5,999)
```

- If I want to write a function to achieve these, what is the difference?

Tuples

- Say, `tup = (1,2,3,4,5)`
- I want to pass it into a function `modifyTup()` and produce a longer tuple
- However, I cannot modify the original tuple

You may say there are TWO types of functions

- Type Pass-by-value:
  - Functions that will NOT modify the inputs (aka arguments or parameters)

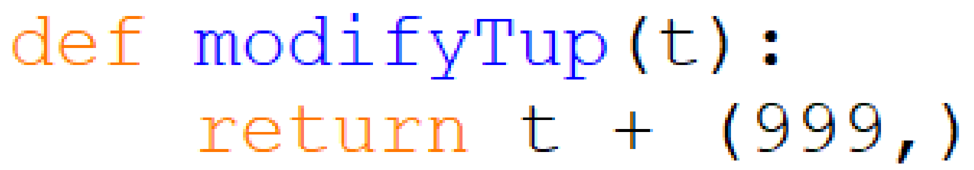
```
>>> l = [3,4,5,6,1,9]
>>> sorted(l)
[1, 3, 4, 5, 6, 9]
>>> l
[3, 4, 5, 6, 1, 9]
```

- ~~Type Pass-by-reference (or pass-by-pointers)~~
  - ~~Functions that WILL modify the inputs (aka arguments or parameters)~~

```
>>> l
[3, 4, 5, 6, 1, 9]
>>> l.sort()
>>> l
[1, 3, 4, 5, 6, 9]
>>>
```

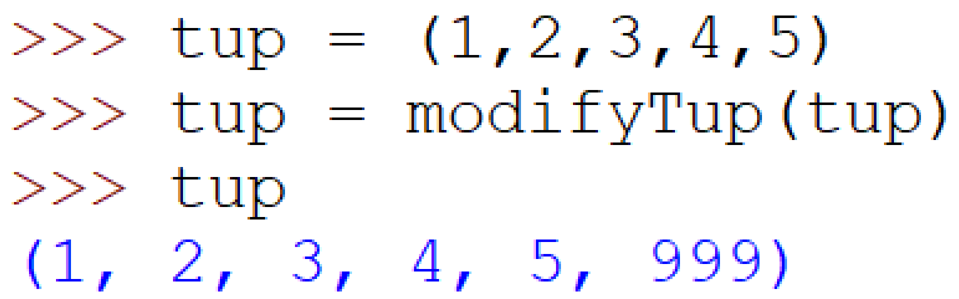
Tuples

- Say, `tup = (1,2,3,4,5)`
- I want to pass it into a function `modifyTup()` and produce a longer tuple
- However, I cannot modify the original tuple
- The only way I can do is to return a longer tuple by `modifyTup()`



```
def modifyTup(t):
    return t + (999,)
```

- And use it like this



```
>>> tup = (1,2,3,4,5)
>>> tup = modifyTup(tup)
>>> tup
(1, 2, 3, 4, 5, 999)
```

Compare These Two

- Tuples

```
def modifyTup(t):
    return t + (999,)
```

```
>>> tup = (1,2,3,4,5)
>>> tup = modifyTup(tup)
>>> tup
(1, 2, 3, 4, 5, 999)
```

- Integers

```
def modifyInt(x):
    return x + 1
```

```
>>> x = 4
>>> x = modifyInt(x)
>>> x
5
```

Lists

- Say, `lst = [1,2,3,4,5]`
- I want to pass it into a function `modifyLst()` and produce a longer list
- ~~However, I cannot modify the original list~~

You may say there are TWO types of functions

- Type Pass-by-value:
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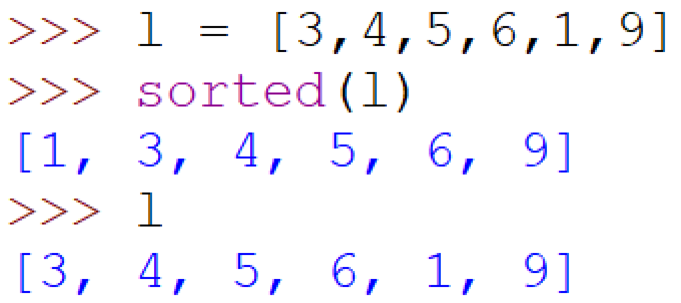
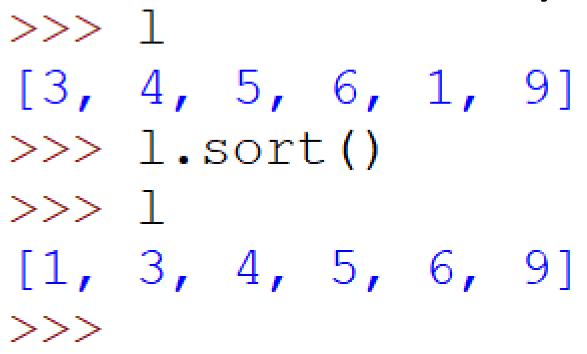


```
>>> l = [3,4,5,6,1,9]
>>> sorted(l)
[1, 3, 4, 5, 6, 9]
>>> l
[3, 4, 5, 6, 1, 9]
```

- Type Pass-by-reference (or pass-by-pointers)
  - Functions that WILL modify the inputs (aka arguments or parameters)



```
>>> l
[3, 4, 5, 6, 1, 9]
>>> l.sort()
>>> l
[1, 3, 4, 5, 6, 9]
>>>
```

Lists

- Say, `lst = [1,2,3,4,5]`
- I want to pass it into a function `modifyLst()` and produce a longer list
- ~~However, I cannot modify the original list~~
- ~~The only way~~ I can do is to return a longer list by `modifyLst()`

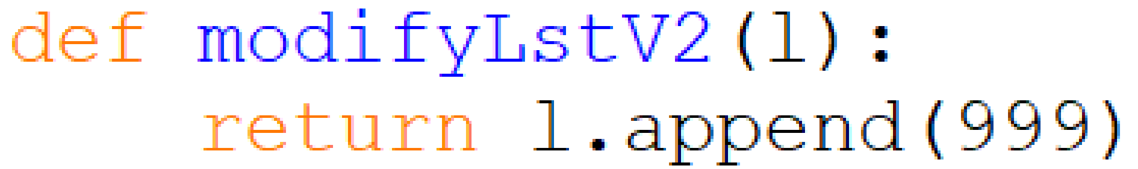
```
def modifyLst(l):
    return l + [999]
```

- And use it like this

```
>>> lst = [1,2,3,4,5]
>>> lst = modifyLst(lst)
>>> lst
[1, 2, 3, 4, 5, 999]
```

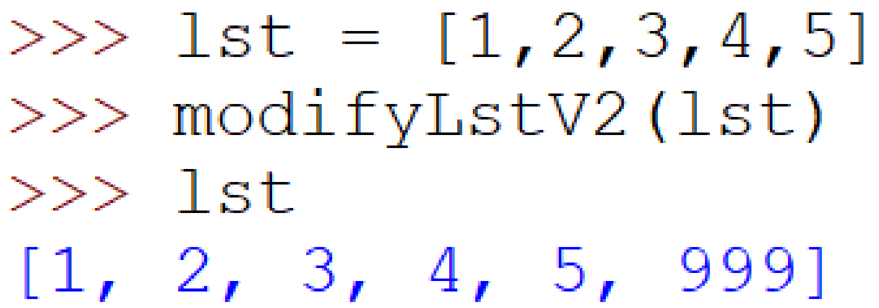
Lists Version 2

- Say, `lst = [1,2,3,4,5]`
- I want to pass it into a function `modifyLst()` and produce a longer list
- However, how about this:



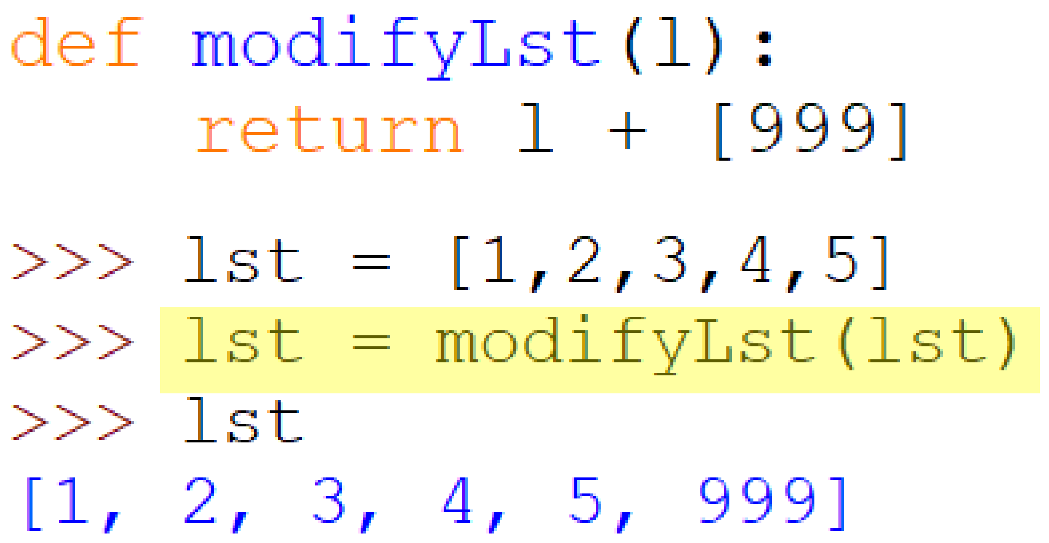
```
def modifyLstV2(l):
    return l.append(999)
```

- And use the function like this



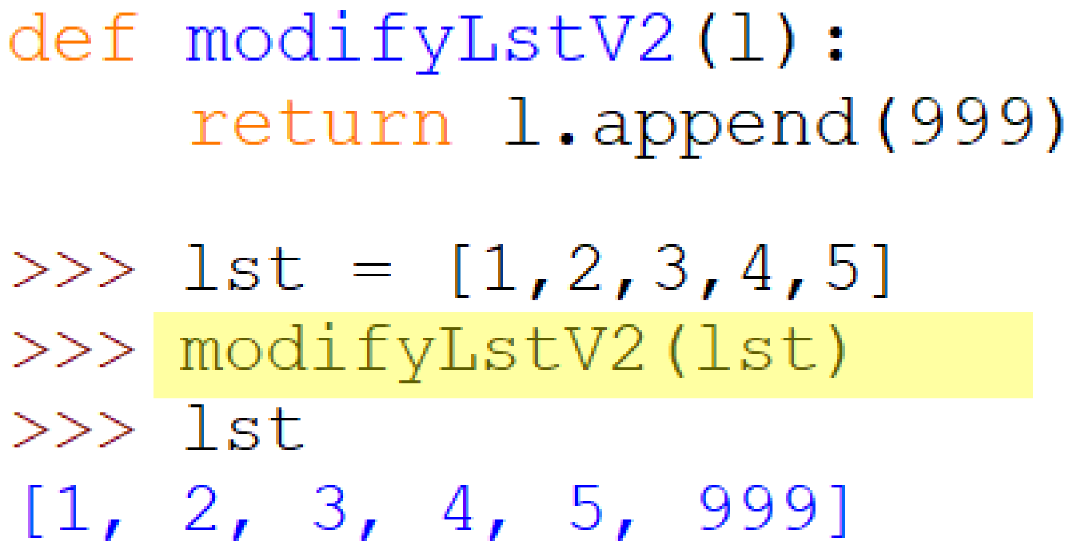
```
>>> lst = [1,2,3,4,5]
>>> modifyLstV2(lst)
>>> lst
[1, 2, 3, 4, 5, 999]
```

What is the difference between the two versions?



```
def modifyLst(l):
    return l + [999]

>>> lst = [1,2,3,4,5]
>>> lst = modifyLst(lst)
>>> lst
[1, 2, 3, 4, 5, 999]
```



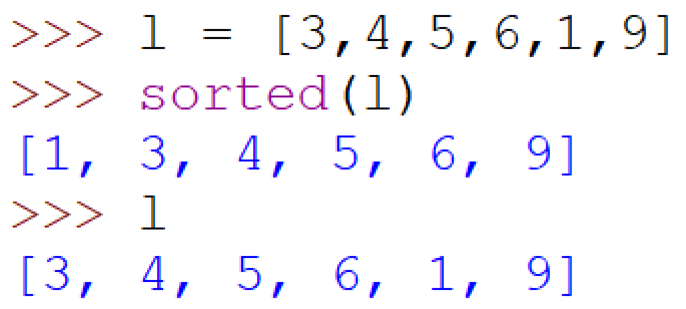
```
def modifyLstV2(l):
    return l.append(999)

>>> lst = [1,2,3,4,5]
>>> modifyLstV2(lst)
>>> lst
[1, 2, 3, 4, 5, 999]
```

- This **return** the value to copy to “`lst`”
- This **modify the original** input “`lst`”

Two Types of Functions

- Type Pass-by-value:
  - Functions that will NOT modify the inputs (aka arguments or parameters)



```
>>> l = [3,4,5,6,1,9]
>>> sorted(l)
[1, 3, 4, 5, 6, 9]
>>> l
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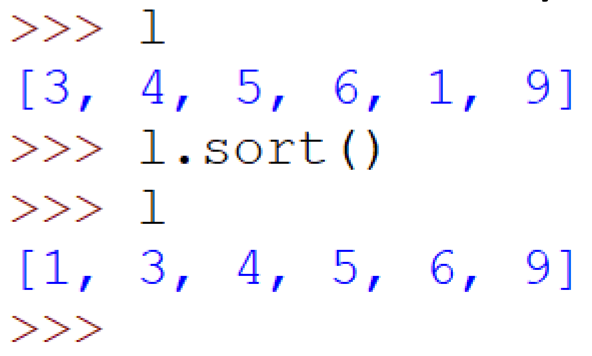
```

- Type Pass-by-reference (or pass-by-pointers)
  - Functions that WILL modify the inputs (aka arguments or parameters)



```
>>> l
[3, 4, 5, 6, 1, 9]
>>> l.sort()
>>> l
[1, 3, 4, 5, 6, 9]
>>>
```

What is the difference between the Three Versions?

- Let’s simply try to apply the “modify” function 100000 times to see how fast they run?
- `time()` is from the package “time”
  - It will return the number of seconds passed since “epoch” time
    - 1st Jan 1970 00:00:00

```
print(f'Running {N} times')
start_time = time()
lst = []
for _ in range(N):
    modifyLstV2(lst)
print(f'modifyLstV2(l): {round(time()-start_time,3)}s')

start_time = time()
lst = []
for _ in range(N):
    lst = modifyLst(lst)
print(f'modifyLst(l)  : {round(time()-start_time,3)}s')

start_time = time()
tup = ()
for _ in range(N):
    tup = modifyTup(tup)
print(f'modifyTup(t)  : {round(time()-start_time,3)}s')
```

What is the difference between the Three Versions?

- Let’s simply try to apply the “modify” function 100000 times to see how fast they run?
- Result:

```
Running 10000 times
modifyLstV2(l): 0.002s
modifyLst(l)  : 0.226s
modifyTup(t)  : 0.216s
```

- 20000 times:

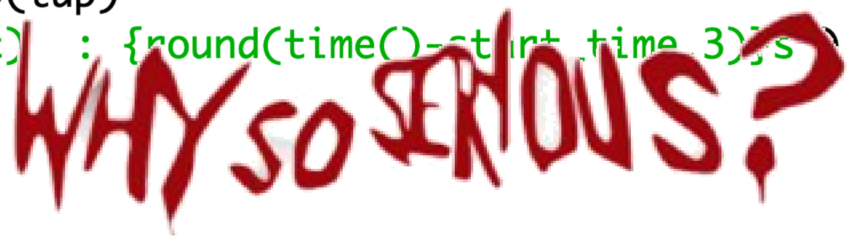
```
Running 20000 times
modifyLstV2(l): 0.005s
modifyLst(l)  : 0.886s
modifyTup(t)  : 0.873s
```

More than double

```
print(f'Running {N} times')
start_time = time()
lst = []
for _ in range(N):
    modifyLstV2(lst)
print(f'modifyLstV2(l): {round(time()-start_time,3)}s')

start_time = time()
lst = []
for _ in range(N):
    lst = modifyLst(ls
print(f'modifyLst(l)  :                     e,3)}s')

start_time = time()
tup = ()
for _ in range(N):
    tup = modifyTup(tup)
print(f'modifyTup(t)  : {round(time()-start_time,3)}s')
```



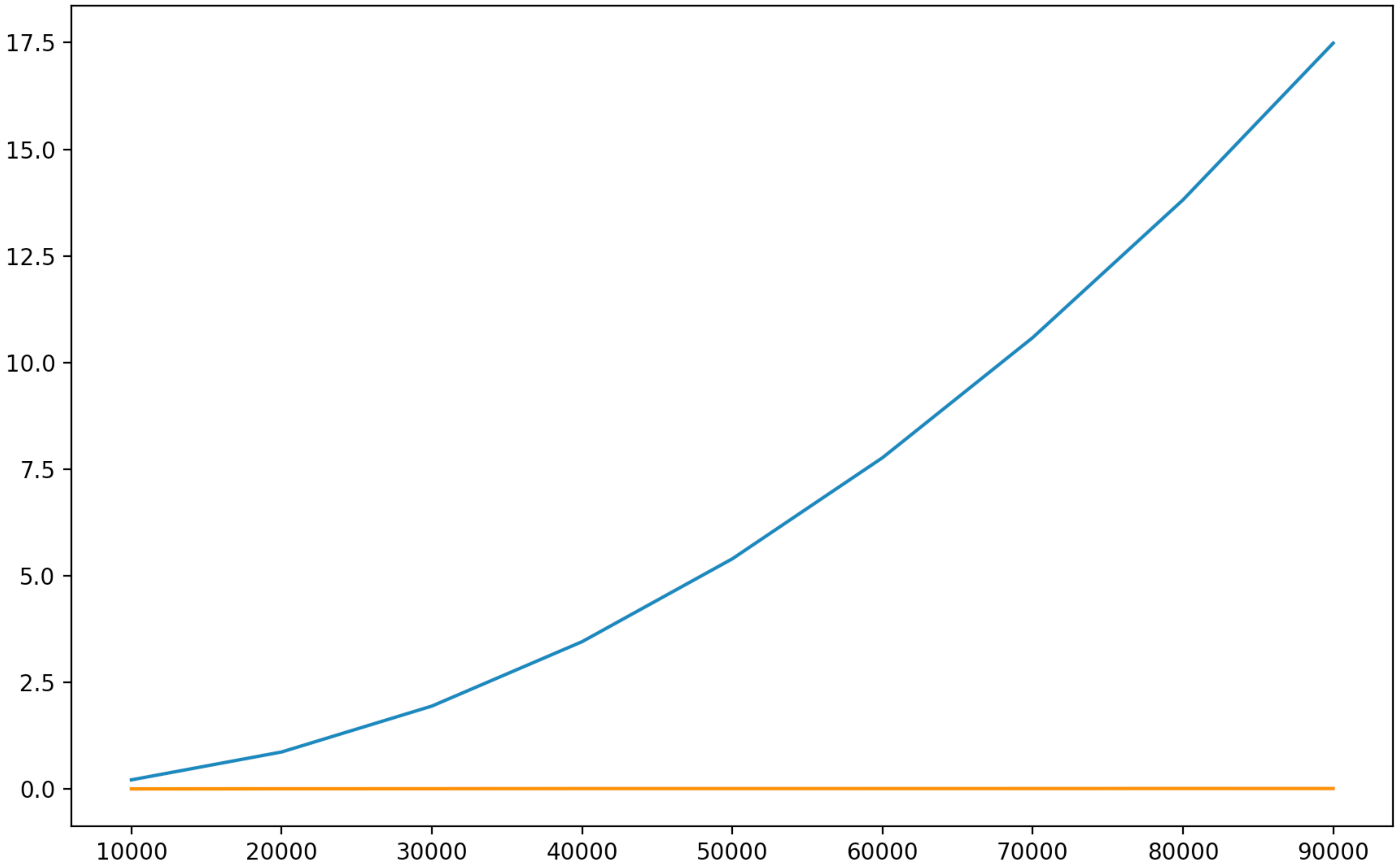
```
Running 10000 times
modifyLstV2(l): 0.002s
modifyLst(l)  : 0.226s
modifyTup(t)  : 0.216s

Running 20000 times
modifyLstV2(l): 0.005s
modifyLst(l)  : 0.886s
modifyTup(t)  : 0.873s

Running 30000 times
modifyLstV2(l): 0.006s
modifyLst(l)  : 1.968s
modifyTup(t)  : 1.945s
```

```
Running 100000 times
modifyLstV2(l): 0.019s
modifyLst(l)  : 21.666s
modifyTup(t)  : 21.71s

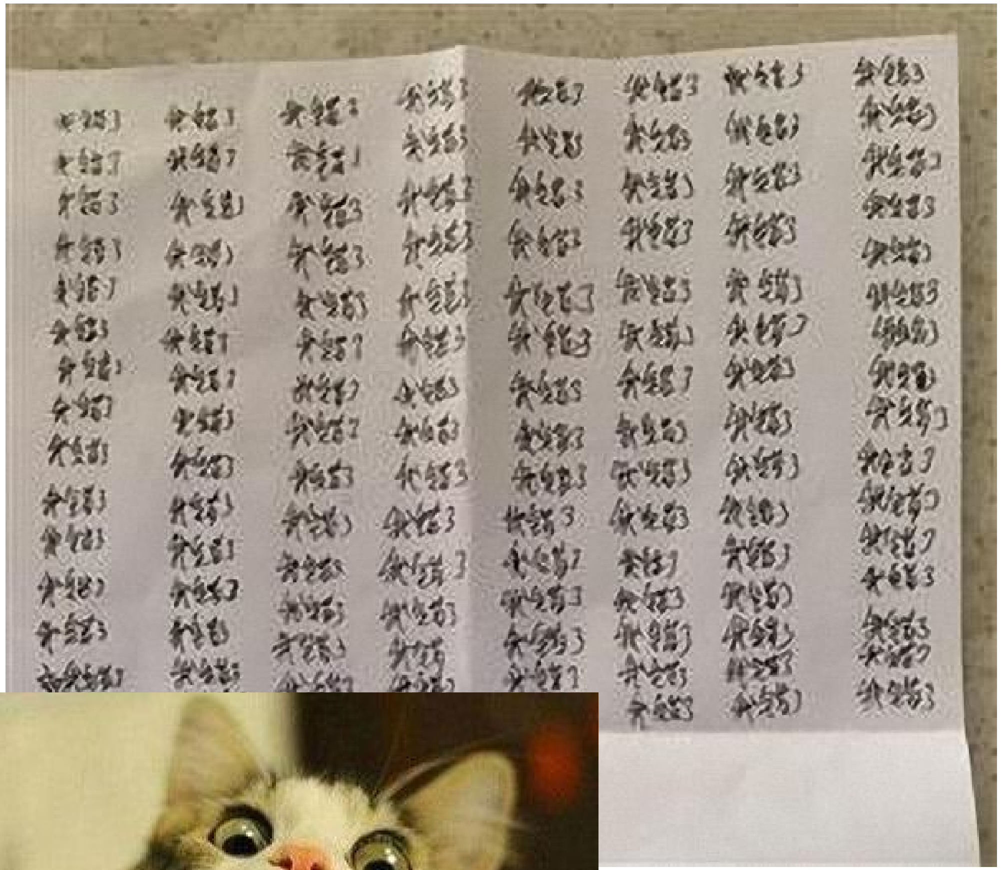
Running 200000 times
modifyLstV2(l): 0.035s
modifyLst(l)  : 86.523s
modifyTup(t)  : 86.256s
```



17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
10000
20000
30000
40000
50000
60000
70000
80000
90000

Why is the Tuple Version so Slow?

- When I was young
- When I was naughty in school, teachers punished me with "copying"
  - A punishment of copying some phrase (in Chinese) many times
- One time, when I submitted my copying of 50 times
  - Teacher said it should be 100 times
- Should I…
  - Copy 100 times from scratch? Or
  - Copy 50 times and add my existing ones?



To Copy or Not to Copy?

- Copy 100 times all over from scratch? Or
- Copy 50 times and add my existing ones?

- What is the difference if my evil teacher keeps increasing 50 times whenever I submit?
    - Copy all over, or
    - Add to existing one?

Why is the Tuple Version so Slow?

- This line copy the ***whole*** tuples to tup **again**
- So if you want to do it 100000 times
  - The first time copy 6 items
  - The second copy time 7 items
  - 8,9,10,….. 1000005
- Number of times the sum of all

```
tup = ()
for i in range(100000):
    tup = modifyTup(tup)
print(f'Tuple Version:  {round(time()-ts,3)}s')
```

```
def modifyTup(t):
    return t + (999,)
```

```
>>> tup = (1,2,3,4,5)
>>> tup = modifyTup(tup)
>>> tup
(1, 2, 3, 4, 5, 999)
```

Comparing

- Tuples:
  - 6+7+8+…..+100005
  - = 5,000,550,000

Why is the Tuple Version so Slow?

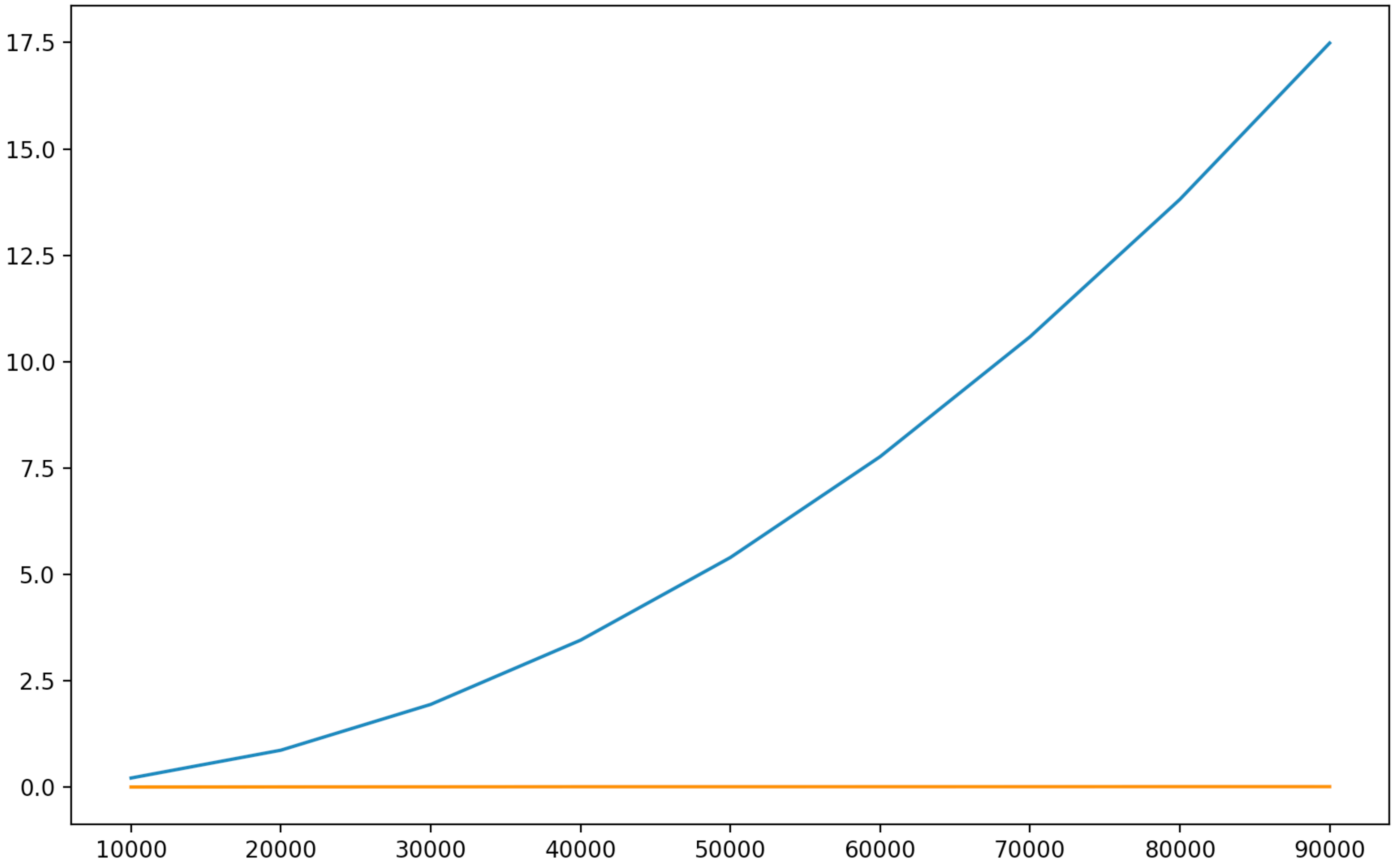
- However, for list, you just add one item to the end
  - No re-copying of the previous existing items in the list
- Therefore
  - The first time 1
  - The second time 1
  - 1,1,1,1,…….1
- In totally only 100000 times

```
def modifyLstV2(l):
    return l.append(999)


lst = []
for i in range(100000):
    tup = modifyLstV2(lst)
```

Comparing

- Tuples:
  - 6+7+8+…..+100005
  - = 5,000,550,000
- Lists:
  - 1+1+1+1+1+1………………….+1+1
  - = 100000
- Lists win!


17.5
15.0
12.5
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7.5
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2.5
0.0
10000
20000
30000
40000
50000
60000
70000
80000
90000

To Copy or Not to Copy?

- Copy 100 times all over from scratch? Or
- Copy 50 times and add my existing ones?

- What is the difference if my evil teacher keeps increasing 50 times whenever I submit?
  - ~~Copy all over, or~~
  - Add to existing one!

Conclusion

Tuple Version

Preserve input

Must return result

Slower

List Version

May or may not preserve input

- May modify input

May or may not need to return result

Faster