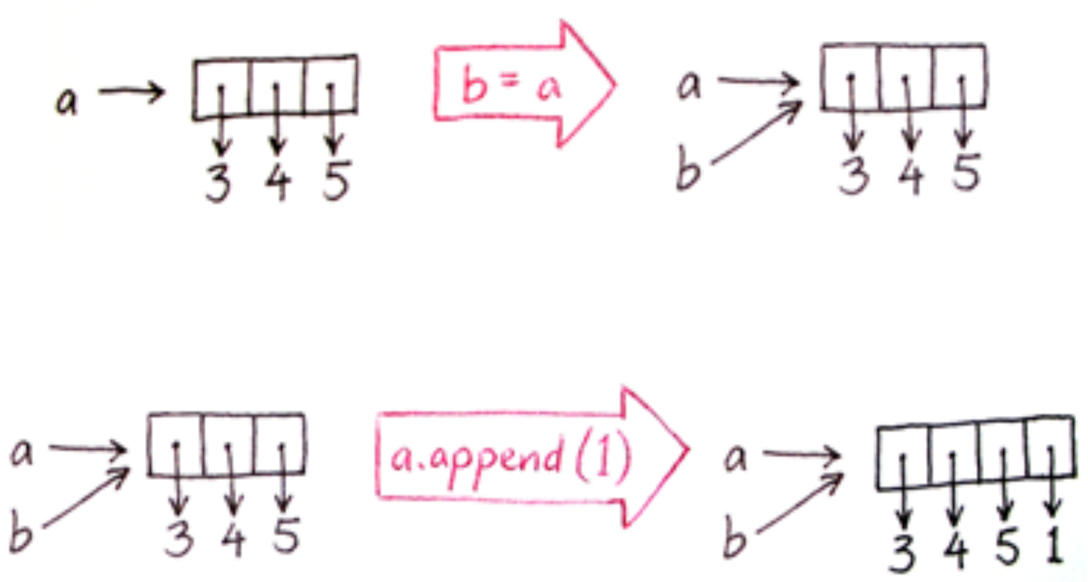
15-112
Fundamentals of Programming

Week 2 - Lecture 3:
Lists



May 25, 2016

Builtin Data Types

Python name	Description	Values
NoneType	absence of value	None
bool (boolean)	Boolean values	True, False
int (integer)	integer values	-2^{63} to $2^{63}-1$
long	large integer values	all integers
float	fractional values	e.g. 3.14
complex	complex values	e.g. 1+5j
str (string)	text	e.g. "Hello World!"
list	a list of values	e.g. [2, "hi", 3.14]

...

String vs List

string	list
s = “hw2-1 was hard”	a = [1, 3.14, “hi”, True]
A sequence (string) of characters.	A sequence of arbitrary objects.
immutable	mutable
~~s[0] = “H”~~	a[0] = 100

Lists: basic usage

```
a = []              # creates an empty list
b = list()          # also creates an empty list
c = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
d = list(range(1, 11))      d = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
e = [1, 3.14, None, True, "Hi", [1, 2, 3]]

for i in range(len(c)):
    print(c[i])

for item in e:
    print(item)

print(e[1:4])
e[2] = 0
print(e[::2])
```

Lists: basic usage

print([1, 2, 3] + [4, 5, 6]) [1, 2, 3, 4, 5, 6]

a = [0] * 5

print(a) [0, 0, 0, 0, 0]

if (1 **in** a):
    print(“1 is in the list a.”)

if (1 **not in** a):
    print(“1 is not in the list a.”)

b = [0, 0, 0, 0, 0]

if (a == b):
    print(“a and b contain the same elements.”)

Lists: built-in functions

```
a = list(range(1, 11))
print(len(a))
print(min(a))
print(max(a))
print(sum(a))
a = [4, 5, 1, 3, 2, 8, 7, 6, 9, 10]
a = sorted(a)
print(a)                    [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
```

Lists: interesting example

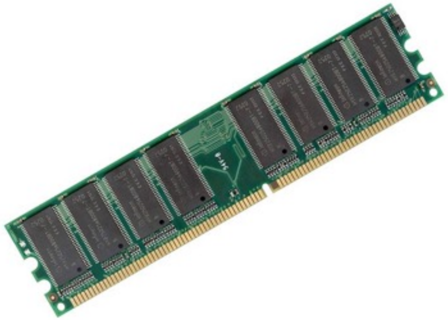
```
x = 1
y = x
x += 1
print(x, y)          2  1
```

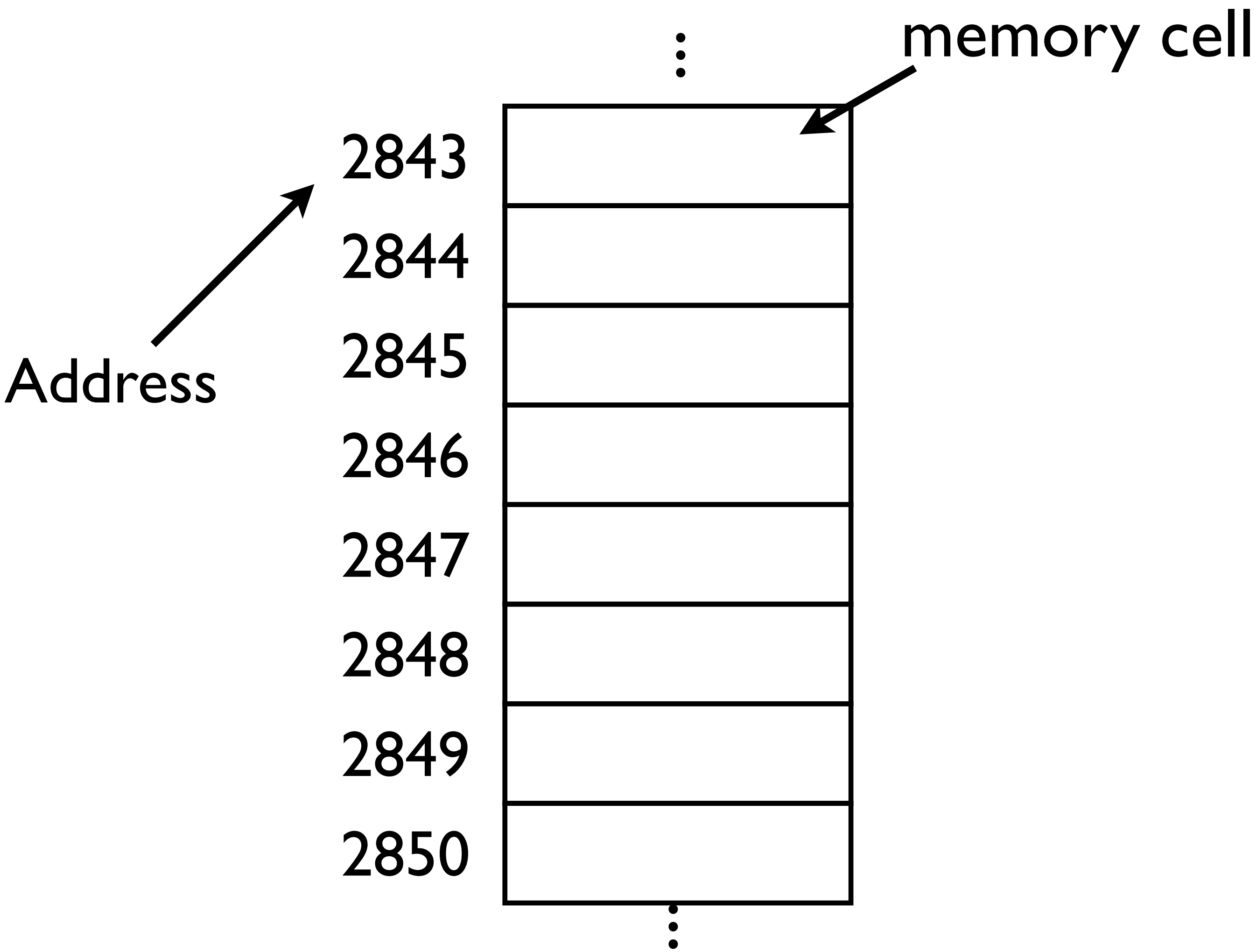
```
x = [1, 2, 3]
y = x
x[0] = 4
print(x, y)          [4, 2, 3]  [4, 2, 3]
```

immutable vs mutable

Memory (Storage)

Closer look at RAM (Main memory)





immutable vs mutable

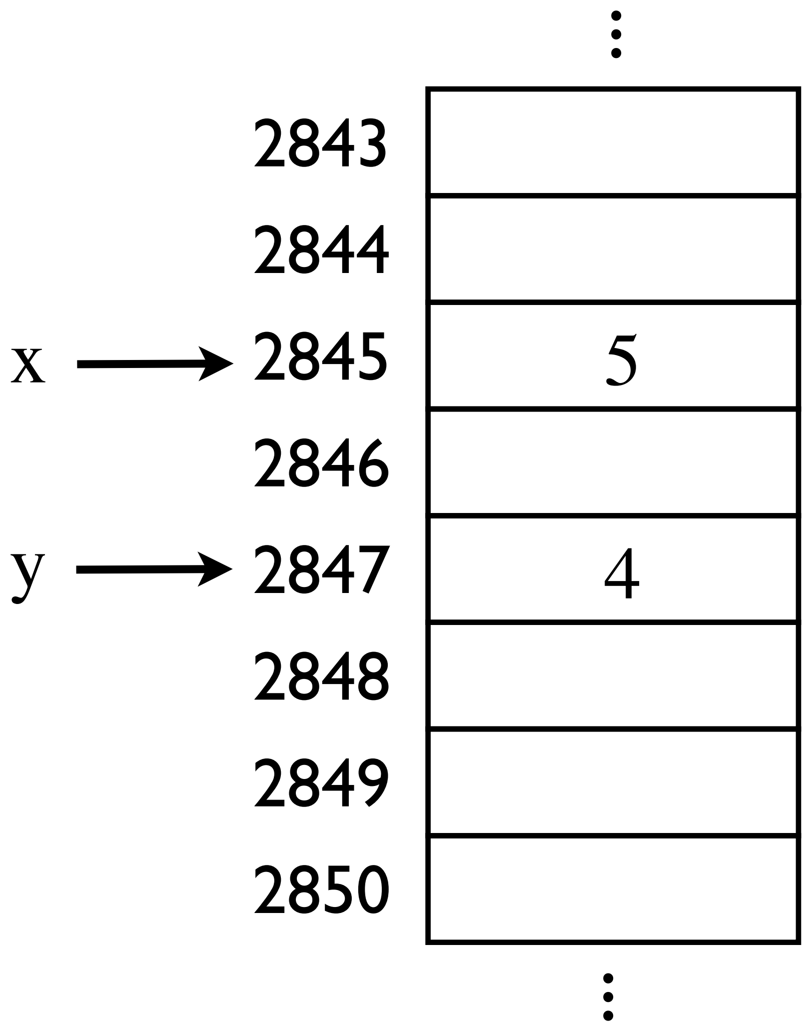
Immutable objects

x = 5

y = 4

x = 1

y -= 2



immutable vs mutable

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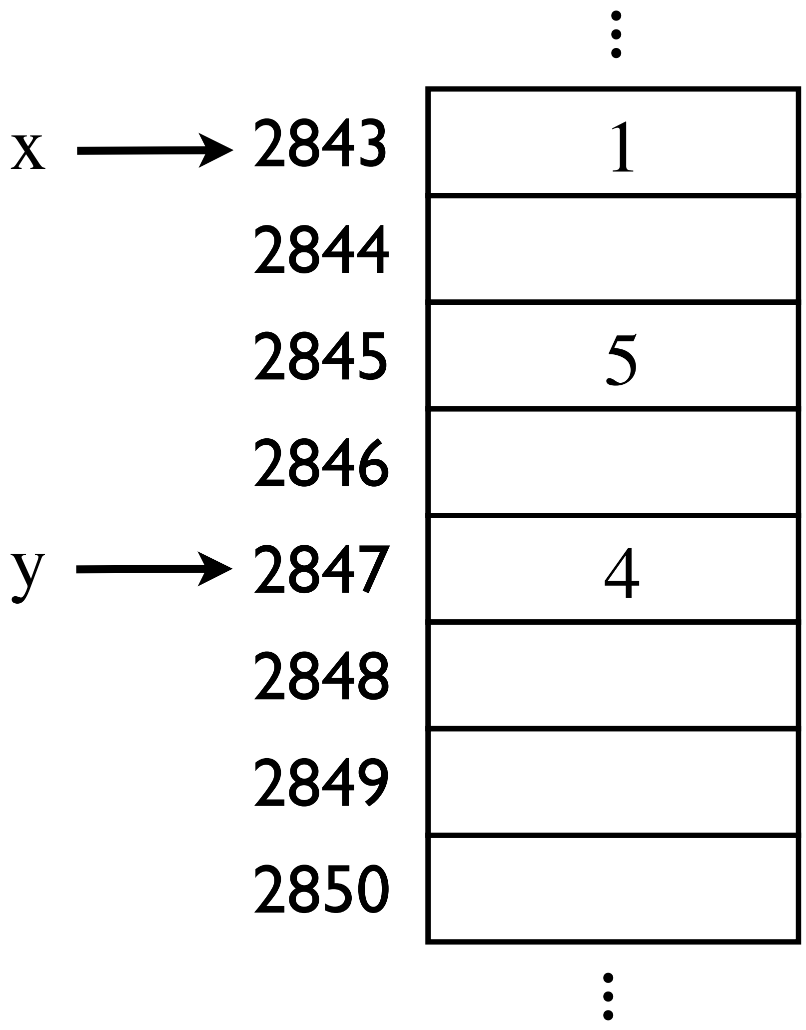

immutable vs mutable

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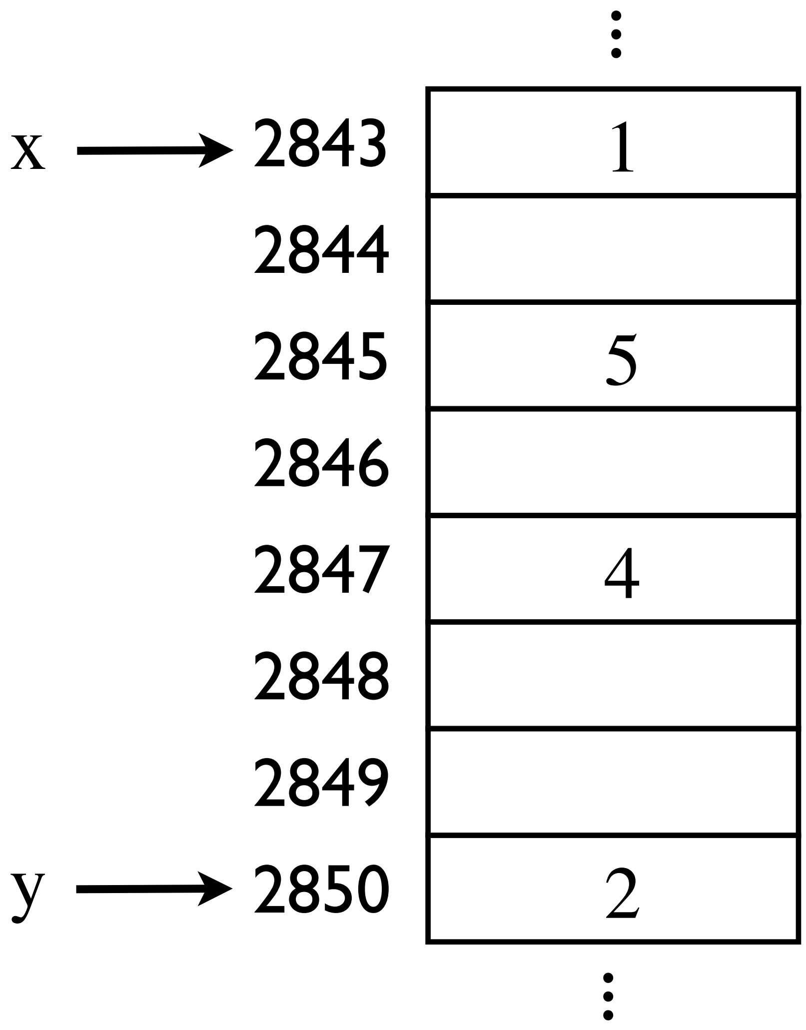

immutable vs mutable

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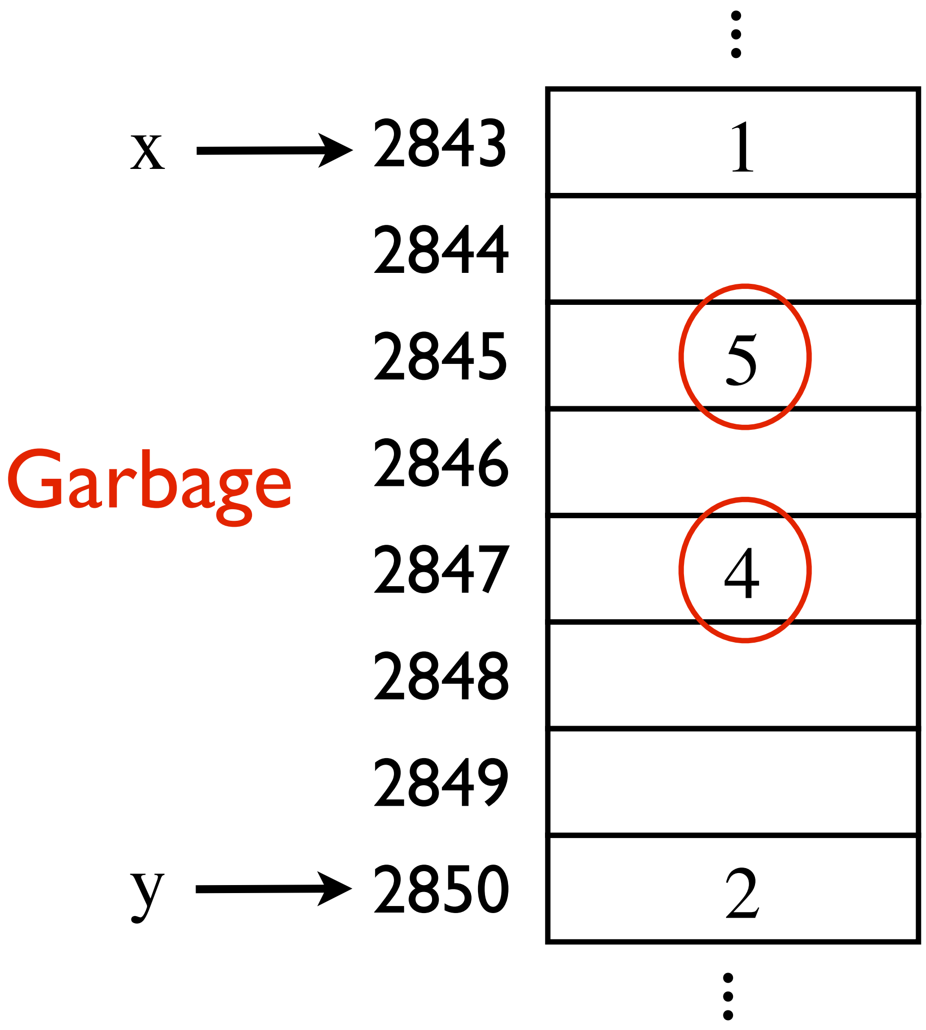


immutable vs mutable

Immutable objects

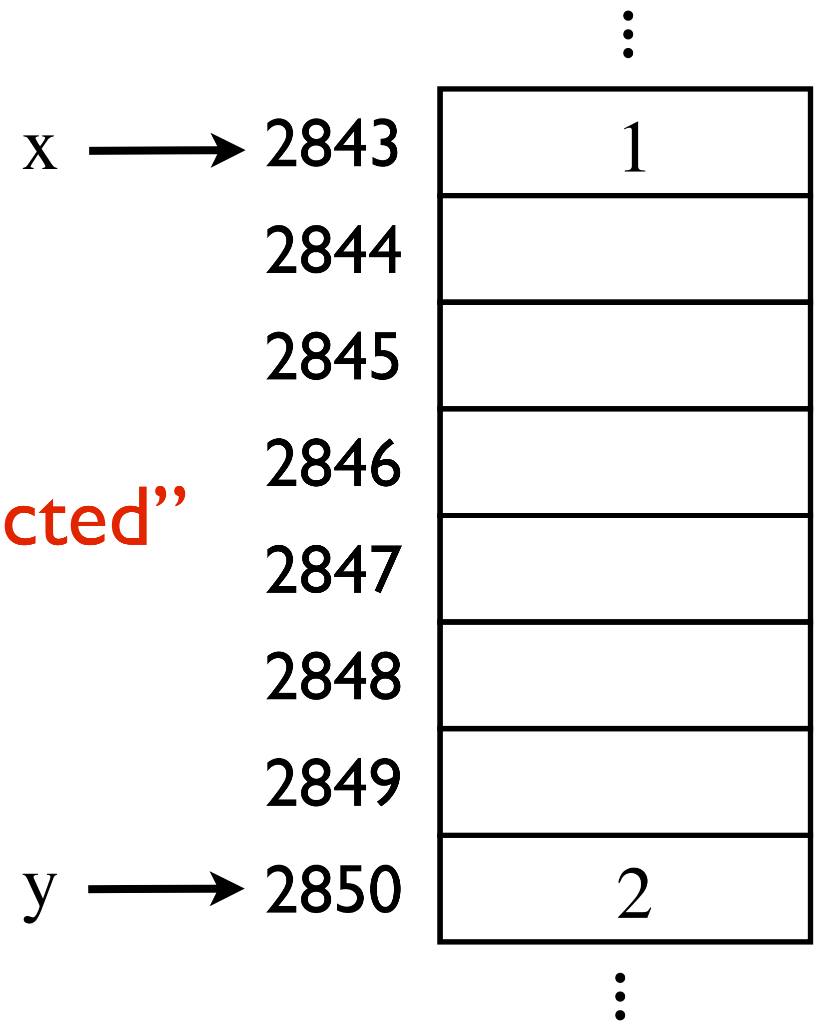
x = 5

y = 4

x = 1

y -= 2

"Garbage is collected"



immutable vs mutable

Immutable objects

x = 5

y = 4

immutable vs mutable

Immutable objects

x = 5

y = 4

x = 1

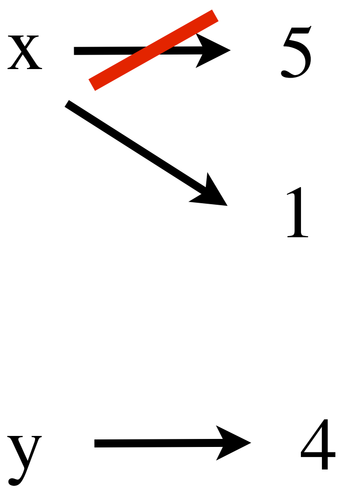
immutable vs mutable

Immutable objects

x = 5

y = 4

x = 1



immutable vs mutable

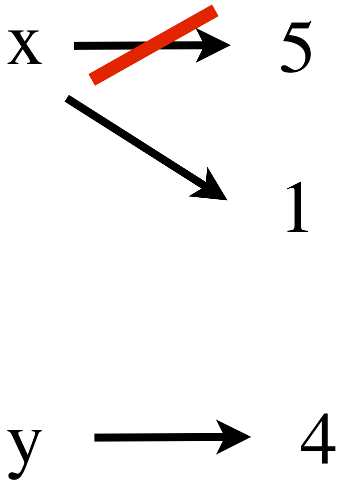
Immutable objects

x = 5

y = 4

x = 1

y -= 2



immutable vs mutable

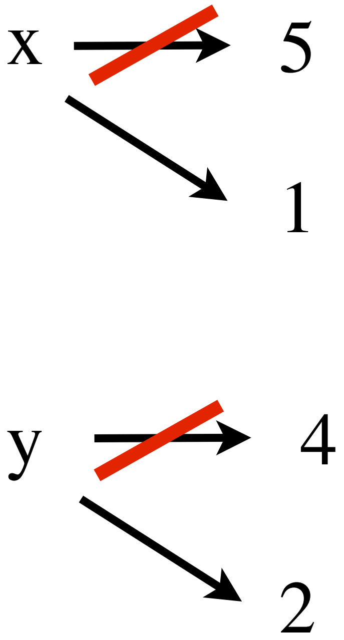
Immutable objects

x = 5

y = 4

x = 1

y -= 2



immutable vs mutable

Immutable objects

x = 5

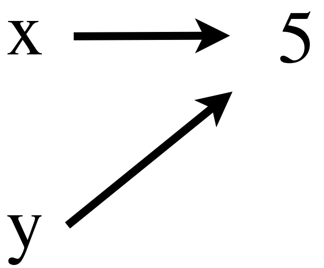
x ⟶ 5

immutable vs mutable

Immutable objects

x = 5

y = x



immutable vs mutable

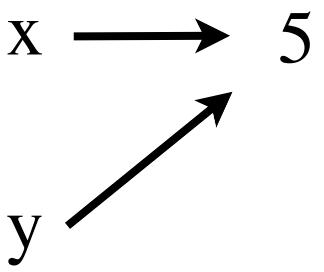
Immutable objects

x = 5

y = x

x += 1

print(x, y)



immutable vs mutable

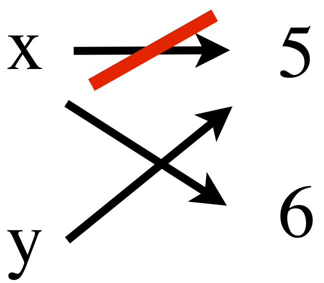
Immutable objects

x = 5

y = x

x += 1

print(x, y) 6 5



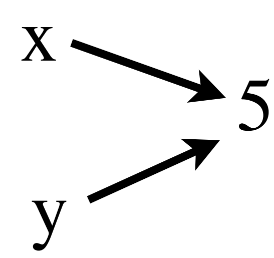
immutable vs mutable

Immutable objects

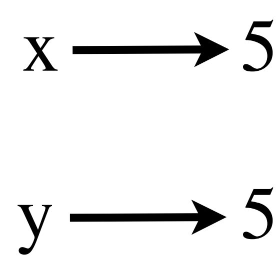
x = 5

y = x

In reality:



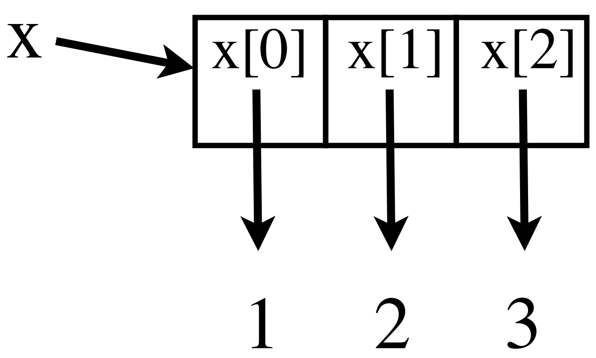
In practice:



(seems like a good thing)

Mutable objects

x = [1, 2, 3]



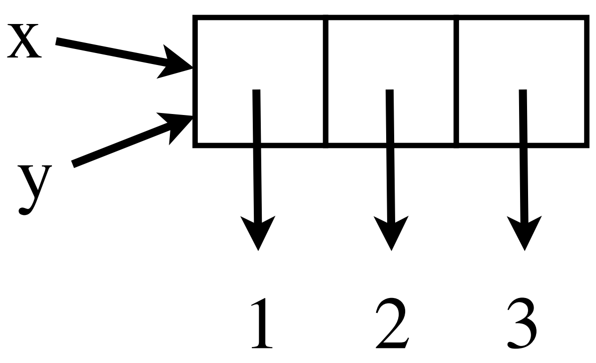
So **actually**,
a list is a sequence of references (variables)!

immutable vs mutable

Mutable objects

x = [1, 2, 3]

y = x



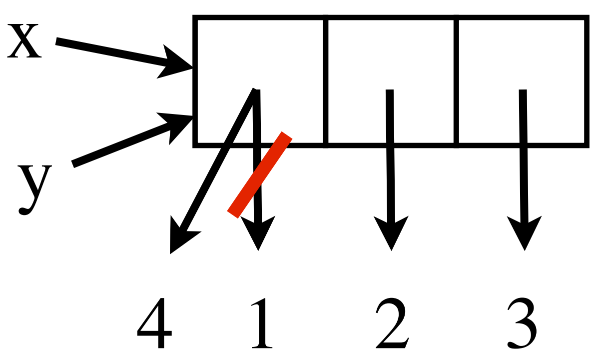
immutable vs mutable

Mutable objects

x = [1, 2, 3]

y = x

x[0] = 4



immutable vs mutable

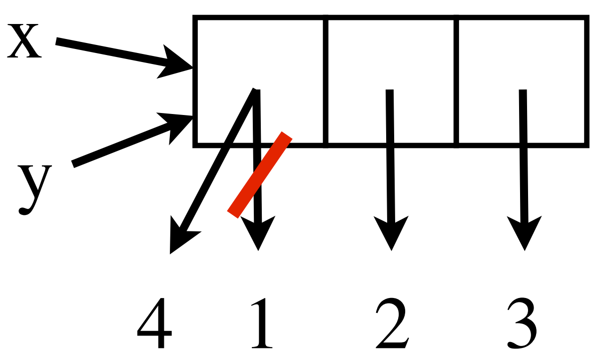
Mutable objects

x = [1, 2, 3]

y = x

x[0] = 4

print(y[0]) 4



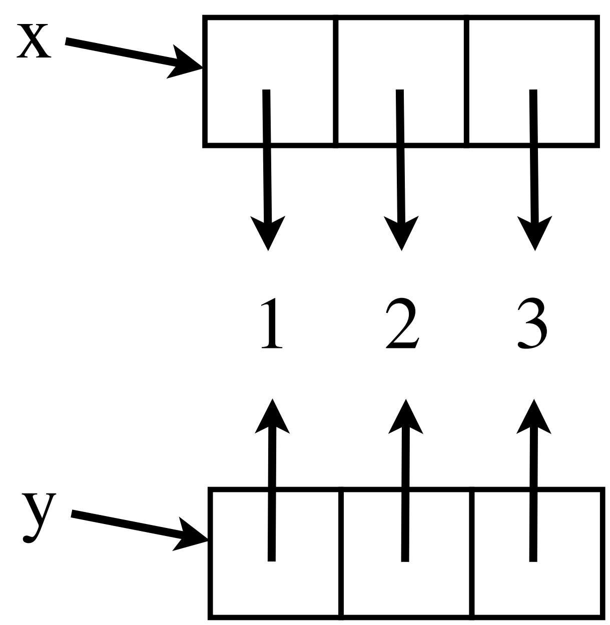
x and y are **aliases**.

immutable vs mutable

Mutable objects

x = [1, 2, 3]

y = [1, 2, 3]



print(x == y) True

print(x **is** y) False

print(x[0] **is** y[0]) True

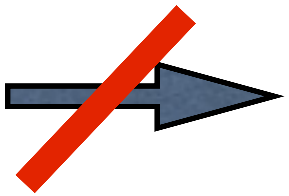
immutable vs mutable

With simpler data types, immutabality is useful.
(no side effects)

With complex data types, mutability and aliasing is useful.
(avoid copying large data)

Suppose you have a list of names.

You add another name to the list



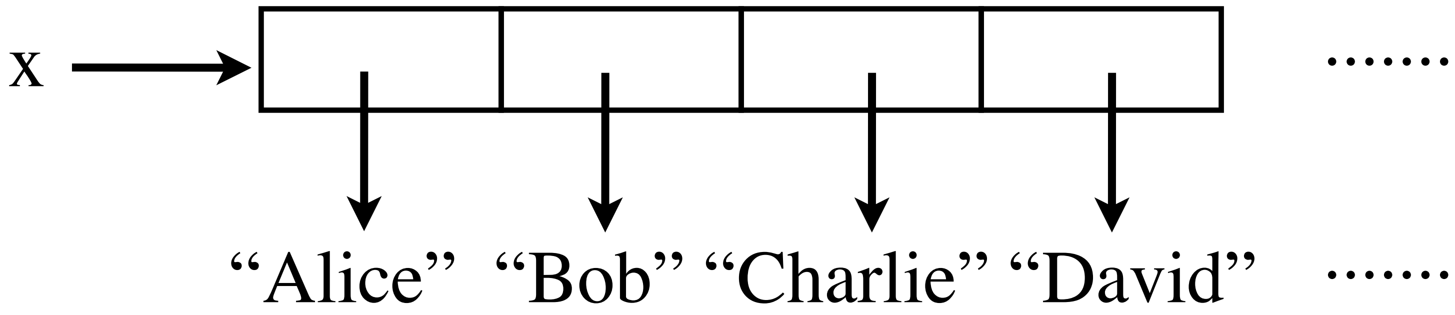
copy the whole list.

immutable vs mutable

If lists were <u>immutable</u>:

x = [“Alice”, “Bob”, “Charlie”, “David”, …….]

a million names



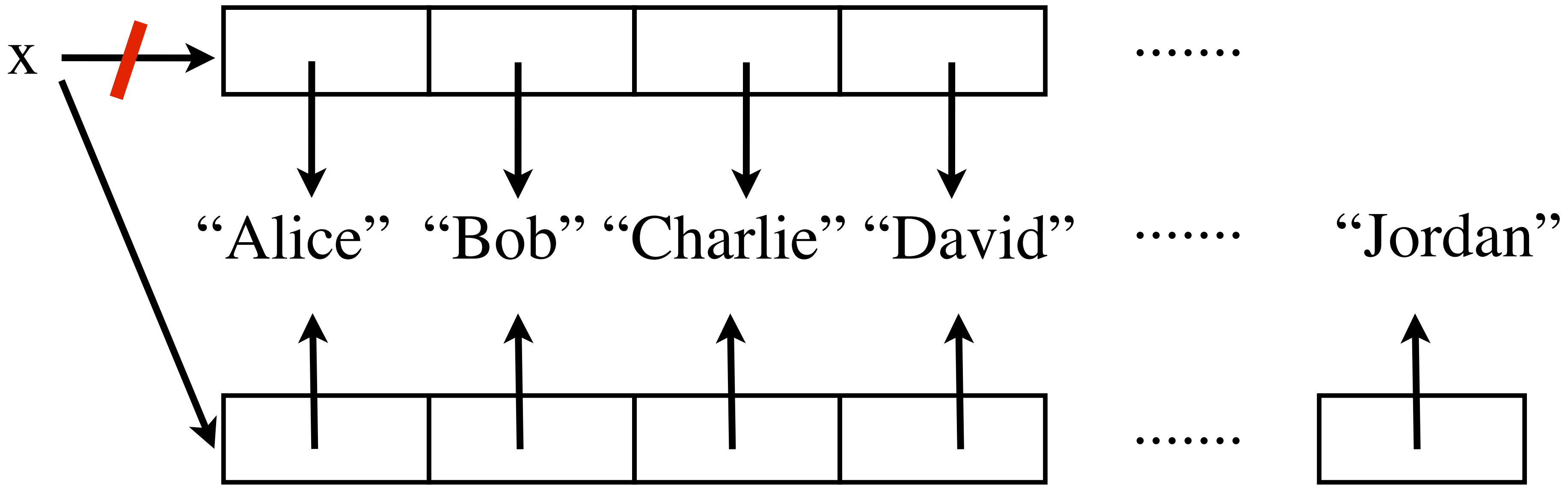
immutable vs mutable

If lists were immutable:

x = [“Alice”, “Bob”, “Charlie”, “David”, ...]

a million names

x += [“Jordan”]



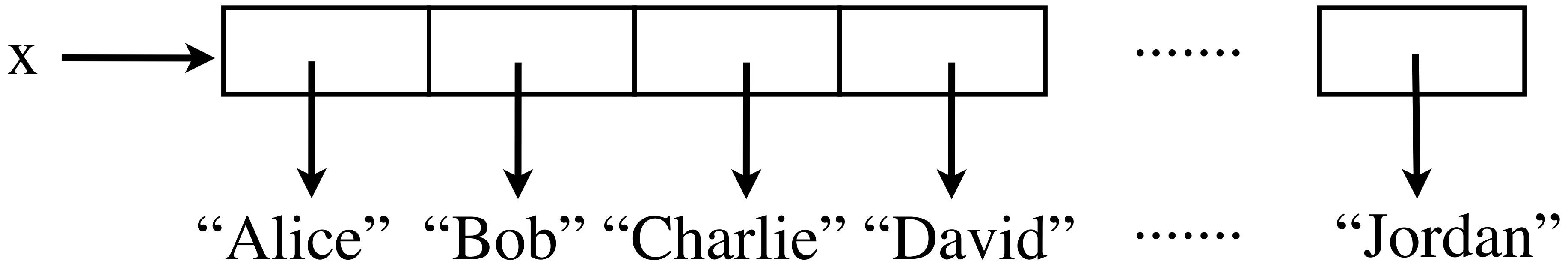
immutable vs mutable

But lists are **mutable**

x = [“Alice”, “Bob”, “Charlie”, “David”, …….]

a million names

x += [“Jordan”]



immutable vs mutable

```
def square(x):
    x = x**2
    return x


n = 5

squaredNum = square(n)

print(n, squaredNum)
```

5 25

```
def square(a):
    for i in range(len(a)):
        a[i] = a[i]**2
    return a     # Unnecessary


b = [1, 2, 3]

squaredList = square(b)

print(b, squaredList)
```

[1, 4, 9] [1, 4, 9]

Original b is <u>**destroyed**</u>

immutable vs mutable

```
def square(x):
    x = x**2
    return x


n = 5

squaredNum = square(n)

print(n, squaredNum)
```

5 25

```
import copy

def square(a):
    a = copy.copy(a)
    for i in range(len(a)):
        a[i] = a[i]**2
    return a

b = [1, 2, 3]

squaredList = square(b)

print(b, squaredList)
```

[1, 2, 3] [1, 4, 9]

Original b is **not** destroyed

immutable vs mutable

Strings vs Lists

names = "Alice,Bob,Charlie,…" a million names

Suppose you want to change Bob to William:

names = names.replace("Bob", "William")

Creates a new string with a million names.

immutable vs mutable

Strings vs Lists

names = ["Alice", "Bob", ...] a million names

changeName(names, "Bob", "William")

```
def changeName(a, oldName, newName):
    for index in range(len(a)):
        if (a[index] == oldName):
            a[index] = newName
```

names and a are aliases.

changes to a affect names.

The list of names is never duplicated/recreated.

immutable vs mutable

Strings vs Lists

Immutable ----> make copy every time you change it.

If dealing with huge strings, or
need to modify a string many times:

convert the string to a list first:

```
longText = list(“Once upon a time, in a land far far away...”)
```

converting the list back to a string:

```
longTextString = “”.join(longText)
```

Digression: Alan Turing (1912-1954)

British mathematician, logician, cryptanalyst, computer scientist.

Father of computer science and artificial intelligence.

List operators and methods

2 types:

Destructive

- modifies original list

Non-destructive

- does not modify original list
- creates a new list

(with strings, for example, this is what happens)

List operators and methods

Adding elements

Destructive

a = [1, 2, 3]
a.append(4)
a = [1, 2, 3, 4]

a.extend([5, 6])
a = [1, 2, 3, 4, 5, 6]

a += [7, 8] **# same as extend**
a = [1, 2, 3, 4, 5, 6, 7, 8]

a.insert(1, 1.5)
a = [1, 1.5, 2, 3, 4, 5, 6, 7, 8]

NonDestructive

a = [1, 2, 3]
b = a + [4]
b = [1, 2, 3, 4] a = [1, 2, 3]

c = b + [5, 6]
c = [1, 2, 3, 4, 5, 6]
b = [1, 2, 3, 4]

d = c[:1] + [1.5] + c[1:]
d = [1, 1.5, 2, 3, 4, 5, 6]

IMPORTANT!

a = [1, 2, 3]		a = [1, 2, 3]	
b = a		b = a	
a += [4]		a = a + [4]	
print(a)	[1, 2, 3, 4]	print(a)	[1, 2, 3, 4]
print(b)	[1, 2, 3, 4]	print(b)	[1, 2, 3]

a += [4]   **<u>not same as</u>**   a = a + [4]

List operators and methods

Removing elements

Destructive

a = [1, 2, 3, 1, 2, 3, 1, 2, 3]

a.remove(3)
  a = [1, 2, 1, 2, 3, 1, 2, 3]

a.remove(3)
  a = [1, 2, 1, 2, 1, 2, 3]

a.pop()
  a = [1, 2, 1, 2, 1, 2]

print(a.pop(0)) 1
  a = [2, 1, 2, 1, 2]

a[1:3] = [ ]
  a = [2, 1, 2]

del a[1:]
  a = [2]

NonDestructive

a = [2, 1, 2, 1, 2]

b = a[:1] + a[3:]
  b = [2, 1, 2] a = [2, 1, 2, 1, 2]

List operators and methods

Common Mistakes

```
def remove(someList, element):
    for index in range(len(someList)):
        if (someList[index] == element):
            someList.pop(index)
```

Index range changes every time you pop.

```
def total(someList):
    t = 0
    while(someList != []):
        t += someList.pop()
    return t

a = [1, 2, 3, 1, 2, 3, 1, 2, 3]
print(total(a))
print(a)          []
```

Never change the list if you don't need to!

List operators and methods

sort vs sorted

Destructive

```
a = [1, 2, 3, 1, 2, 3]
a.sort()
    a = [1, 1, 2, 2, 3, 3]
```

NonDestructive

```
a = [1, 2, 3, 1, 2, 3]
b = sorted(a)
    b = [1, 1, 2, 2, 3, 3]
    a = [1, 2, 3, 1, 2, 3]
```

List operators and methods

finding an element

a = [1, 2, 3, 1, 2, 3]

print(a.index(2)) 1

print(a.find(2)) ERROR: no method called ‘find’

print(a.index(4)) ERROR: 4 is not in the list

```
if (4 in a):
    print(“4 is at index”, a.index(4))
else:
    print(“4 is not in the list.”)
```

List operators and methods

others

https://docs.python.org/3/library/stdtypes.html#typesseq-mutable

https://docs.python.org/3/tutorial/datastructures.html#more-on-lists

Summary

Destructive (modifies the given list)	**NonDestructive**
+=	+, *
every method that manipulates the list	functions
del statement	slicing

Be careful about aliasing
(especially with function parameters)

Tuples

The immutable brother of lists

Tuples

myTuple = (1, 2, 3, 4, 5, 6, 7, 8, 9, 10)

myTuple = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 **# not recommended**

myTuple = (1, "hello", 3.14, True)

myTuple = (1,) **# Put comma for one element tuple**

myTuple[0] = 2 **ERROR**

parallel assignments

(x, y) = (1, 2)

Tuples

return multiple values in a function

```
def firstPrimeInList(a):
    for i in range(len(a)):
        if (isPrime(a[i])):
            return (i, a[i])
    return -1
```

Exercise Problem

Lockers Problem