[301] Objects/References

Tyler Caraza-Harter

Learning Objectives Today

More data types

- tuple (immutable list)
- custom types: creating objects from namedtuple and recordclass

References

- Motivation
- “is” vs “==”
- Gotchas (interning and argument modification)

Read:

- **Downey Ch 10 ("Objects and Values" and “Aliasing")**
- **Downy Ch 12**

Announcement:

- **My office hour today is cancelled**
- **Tomorrow: 1-5pm (an extra hour)**

Today's Outline

New Types

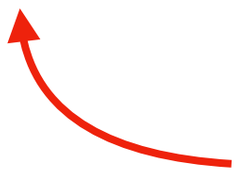
- **tuple**
- namedtuple
- recordclass

References

- motivation
- unintentional argument modification
- “is” vs. “==”

Tuple Type

```
nums_list  = [200, 100, 300]
nums_tuple = (200, 100, 300)
```



if you use parentheses (round)
instead of brackets [square]
you get a tuple instead of a list

Tuple Type

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nums_list  = [200, 100, 300]
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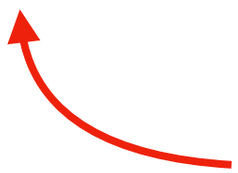

if you use parentheses (round)
instead of brackets [square]
you get a tuple instead of a list

What is a tuple?

Tuple Type

```
nums_list  = [200, 100, 300]
nums_tuple = (200, 100, 300)
```

Like a list

- for loop, indexing, slicing, other methods

Unlike a list:

- immutable (like a string)

Tuple Type

```
nums_list  = [200, 100, 300]
nums_tuple = (200, 100, 300)

print(nums_list[2])
print(nums_tuple[2])
```

Like a list

- for loop, **indexing**, slicing, other methods

Unlike a list:

- immutable (like a string)

Tuple Type

```
nums_list  = [200, 100, 300]
nums_tuple = (200, 100, 300)
```

```
print(nums_list[2])
print(nums_tuple[2])
```

both of these print 300

Like a list

- for loop, **indexing**, slicing, other methods

Unlike a list:

- immutable (like a string)

Tuple Type

```
nums_list  = [200, 100, 300]
nums_tuple = (200, 100, 300)

nums_list[0] = 22
nums_tuple[0] = 22
```

Like a list

- for loop, indexing, slicing, other methods

Unlike a list:

- **immutable** (like a string)

Tuple Type

```
nums_list  = [200, 100, 300]
nums_tuple = (200, 100, 300)

nums_list[0] = 22
nums_tuple[0] = 22
```

changes list to
[22, 100, 300]

Like a list

- for loop, indexing, slicing, other methods

Unlike a list:

- **immutable** (like a string)

Tuple Type

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nums_list  = [200, 100, 300]
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nums_list[0] = 22
nums_tuple[0] = 22
```

changes list to
[22, 100, 300]

Crashes!

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
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Like a list

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Tuple Type

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Like a list

- for loop, indexing, slicing, other methods

Unlike a list:

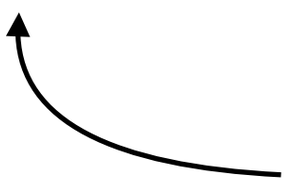
- **immutable** (like a string)

Why would we ever want immutability?

1. avoid certain bugs
2. some use cases require it (e.g., dict keys)

Example: location -> building mapping

```
buildings = {
   [0,0]: “Comp Sci”,
   [0,2]: “Psychology”,
   [4,0]: “Noland”,
   [1,8]: “Van Vleck”
}
```



trying to use x,y coordinates as key

FAILS!

```
Traceback (most recent call last):
  File "test2.py", line 1, in <module>
    buildings = {[0,0]: "CS"}
TypeError: unhashable type: 'list'
```

Example: location -> building mapping

```
buildings = {
   (0,0): “Comp Sci”,
   (0,2): “Psychology”,
   (4,0): “Noland”,
   (1,8): “Van Vleck”
}
```

trying to use x,y coordinates as key

Succeeds!

(with tuples)

Today's Outline

New Types

- tuple
- **namedtuple**
- recordclass

References

- motivation
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- “is” vs. “==”

Organizing Attributes

Often, we have **entities/objects** in programming with many **attributes**. E.g., a tornado. Or a **person**:

- first name, last name
- birth date
- SSN
- address
- phone number

Organizing Attributes

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- birth date
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One representation strategy: dictionaries

```
person = {
    “lname”: “Turing”, “fname”: Alan, …
}
```

Organizing Attributes

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- first name, last name
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One representation strategy: dictionaries

```
person = {
    “lname”: “Turing”, “fname”: Alan, …
}
print(person[“fname”] + “ “ + person[“lname”])
```

Organizing Attributes

Often, we have **entities/objects** in programming with many **attributes**. E.g., a tornado. Or a **person**:

- first name, last name
- birth date
- SSN
- address
- phone number

Problem with using dicts:

- it's verbose (always typing quotes)
- error prone (same attributes not enforced)

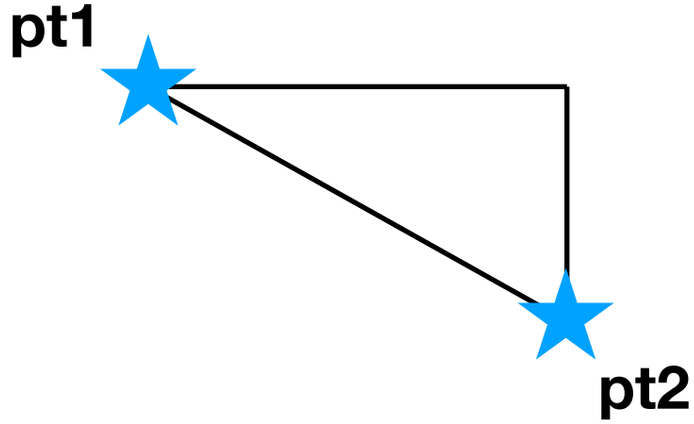
One representation strategy: dictionaries

```
person = {
    "lname": "Turing", "fname": Alan, …
}
print(person["fname"] + " " + person["lname"])
```

Tuples, with and without names

regular tuples (**remember** x then y)

```
pt1 = (50,60)
pt2 = (90,10)
distance = ((pt1[0]-pt2[0])**2 + (pt1[1]-pt2[1])**2) ** 0.5
```



Tuples, with and without names

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pt1[0] is x

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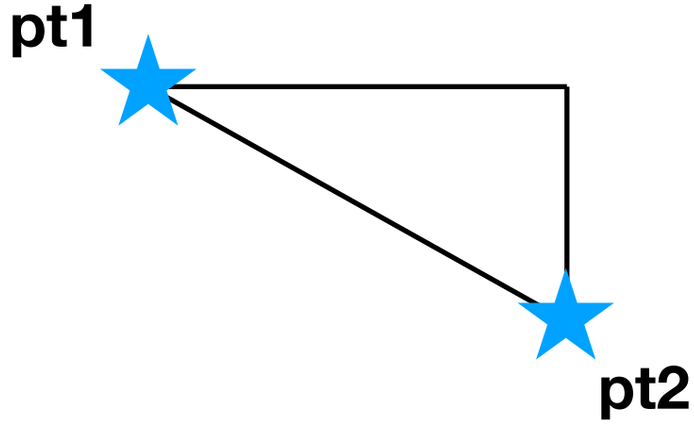

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```

```
from collections import namedtuple
```

need to import namedtuple
(not there by default)

Tuples, with and without names

regular tuples (**remember** x then y)

pt1[0] is x

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pt1 = (50,60)
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distance = ((pt1[0]-pt2[0])**2 + (pt1[1]-pt2[1])**2) ** 0.5
```

```
from collections import namedtuple
Point = namedtuple("Point", ["x", “y”])
```

Point is a new type

“Point” is the type’s name

A Point will have an x and y

Tuples, with and without names

regular tuples (**remember** x then y)

pt1[0] is x

```
pt1 = (50,60)
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Point is a new type

“Point” is the type’s name

A Point will have an x and y

```
>>> L = list()
>>> type(L)
<class 'list'>

>>> type(list)
<class 'type'>

>>> type(Point)
<class 'type'>
```

Tuples, with and without names

regular tuples (**remember** x then y)

pt1[0] is x

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pt1 = (50,60)
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Point is a new type

“Point” is the type’s name

A Point will have an x and y

```
>>> L = list()
>>> type(L)
<class 'list'>

>>> type(list)
<class 'type'>

>>> type(Point)
<class 'type'>
```

Point is a now a datatype, like a list or dict.
Just like dict(…) and list(…) create new instances,
Point(…) will create new instances

Tuples, with and without names

regular tuples (**remember** x then y)

pt1[0] is x

```
pt1 = (50,60)
pt2 = (90,10)
distance = ((pt1[0]-pt2[0])**2 + (pt1[1]-pt2[1])**2) ** 0.5
```

```
from collections import namedtuple

Point = namedtuple("Point", ["x", "y"])

pt1 = Point(50,60)
```

x y

Tuples, with and without names

regular tuples (**remember** x then y)

pt1[0] is x

```
pt1 = (50,60)
pt2 = (90,10)
distance = ((pt1[0]-pt2[0])**2 + (pt1[1]-pt2[1])**2) ** 0.5
```

```
from collections import namedtuple

Point = namedtuple("Point", ["x", "y"])

pt1 = Point(50,60)
pt2 = Point(x=90, y=10)
```

x

y

Tuples, with and without names

regular tuples (**remember** x then y)

pt1[0] is x

```
pt1 = (50,60)
pt2 = (90,10)
distance = ((pt1[0]-pt2[0])**2 + (pt1[1]-pt2[1])**2) ** 0.5
```

```
from collections import namedtuple

Point = namedtuple("Point", ["x", "y"])

pt1 = Point(50,60)
pt2 = Point(x=90, y=10)

distance = ((pt1.x - pt2.x)**2 + (pt1.y - pt2.y) ** 2) ** 0.5
```

don’t need to remember anything (e.g., “x” is first)

Tuples, with and without names

regular tuples (**remember** x then y)

pt1[0] is x

```
pt1 = (50,60)
pt2 = (90,10)
distance = ((pt1[0]-pt2[0])**2 + (pt1[1]-pt2[1])**2) ** 0.5
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```
from collections import namedtuple

Point = namedtuple("Point", ["x", "y"])

pt1 = Point(50,60)
pt2 = Point(x=90, y=10)

distance = ((pt1.x - pt2.x)**2 + (pt1.y - pt2.y) ** 2) ** 0.5
```

```
>>> pt1.x = 3
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: can't set attribute
```

note that nametuples are also immutable

Today's Outline

New Types

- tuple
- namedtuple
- **recordclass**

References

- motivation
- unintentional argument modification
- “is” vs. “==”

recordclass example

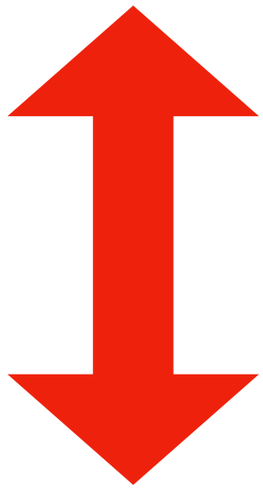
```
>>> from recordclass import recordclass
```

module is recordclass

so is function

recordclass example

```
>>> from recordclass import recordclass
>>> Point = recordclass("Point", ["x", "y"])
```



```
Point = namedtuple(“Point", ["x", "y"])
```

recordclass example

```
>>> from recordclass import recordclass
>>> Point = recordclass("Point", ["x", "y"])
>>> pt1 = Point(0,0)
>>> pt1
Point(x=0, y=0)
```

recordclass example

```
>>> from recordclass import recordclass
>>> Point = recordclass("Point", ["x", "y"])
>>> pt1 = Point(0,0)
>>> pt1
Point(x=0, y=0)
>>> pt1.x = 5
>>> pt1.y = 6
```

mutations

recordclass example

```
>>> from recordclass import recordclass
>>> Point = recordclass("Point", ["x", "y"])
>>> pt1 = Point(0,0)
>>> pt1
Point(x=0, y=0)
>>> pt1.x = 5
>>> pt1.y = 6
>>> pt1
Point(x=5, y=6)
```

recordclass example

```
>>> from recordclass import recordclass
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Point(x=0, y=0)
>>> pt1.x = 5
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>>> pt1
Point(x=5, y=6)
```

Note: recordclass does not come with Python.
You must install it yourself.

Aside: installing packages

There are many Python packages available on PyPI

- https://pypi.org/
- short for Python Package Index

Installation example (from terminal):

```
pip install recordclass
```

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Installation example (from terminal):

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pip install recordclass
```

Anaconda is just Python with a bunch of packages related to data science and quantitative work pre-installed.

Today's Outline

New Types

- tuple
- namedtuple
- **recordclass** ← **mutable equivalent of a namedtuple**

References

- motivation
- unintentional argument modification
- “is” vs. “==”

Today's Outline

New Types

- tuple
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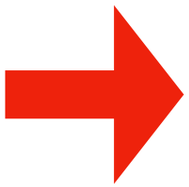
Mental Model for State (v1)

Code:



```
x = “hello”
y = x
y += “ world”
```

State:

x

y

Mental Model for State (v1)

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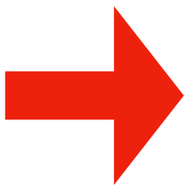

```
x = “hello”
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```

State:

x	hello
y	

Mental Model for State (v1)

Code:

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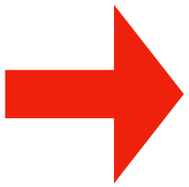

State:

x	hello
y	hello

Mental Model for State (v1)

Code:

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x = “hello”
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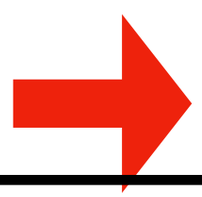

State:

x	hello
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Mental Model for State (v1)

Code:

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```

Common mental model

- correct for immutable types
- PythonTutor uses for strings, etc

State:

x	hello
y	hello world

Mental Model for State (v1)

Code:

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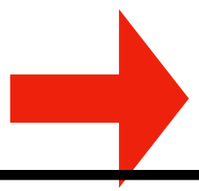


Common mental model

- correct for immutable types
- PythonTutor uses for strings, etc

Issues

- incorrect for mutable types
- ignores performance

State:

x	hello
y	hello world

Mental Model for State (v2)

Code:

```
x = “hello”
y = x
y += “ world”
```

State:

references *objects*

x

y

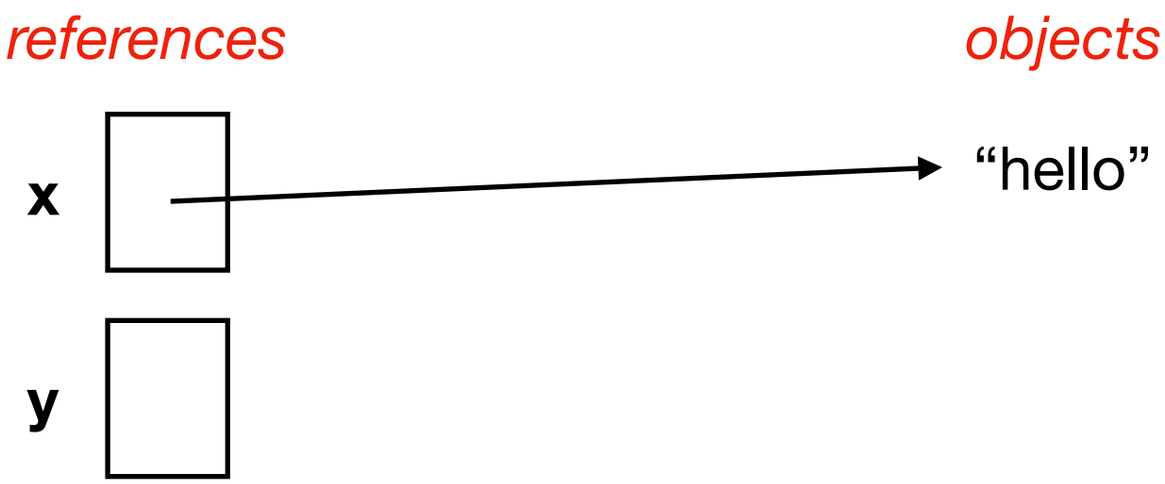
(a variable is one kind of reference)

Mental Model for State (v2)

Code:

```
x = “hello”
y = x
y += “ world”
```

State:



Mental Model for State (v2)

Code:

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```

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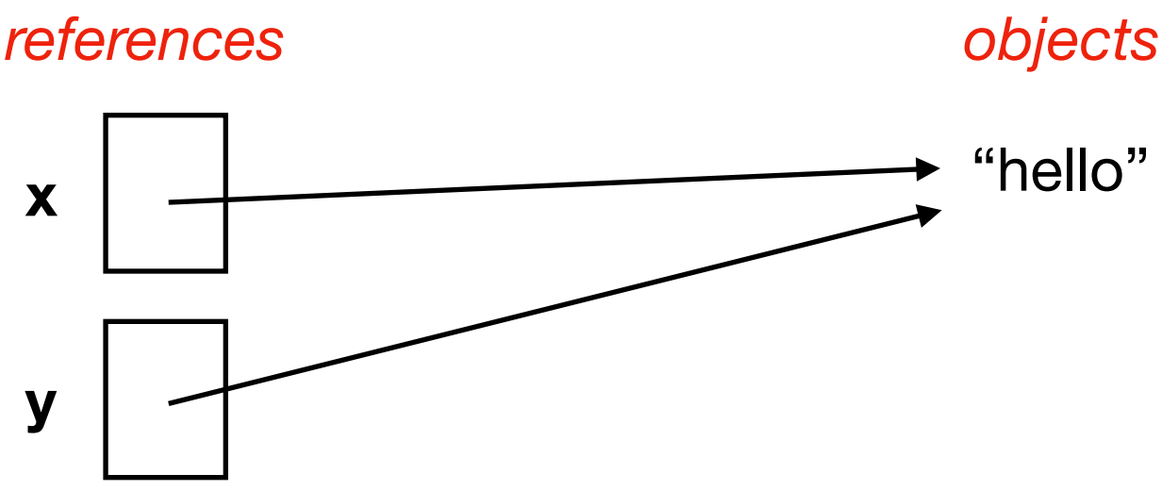

Mental Model for State (v2)

Code:

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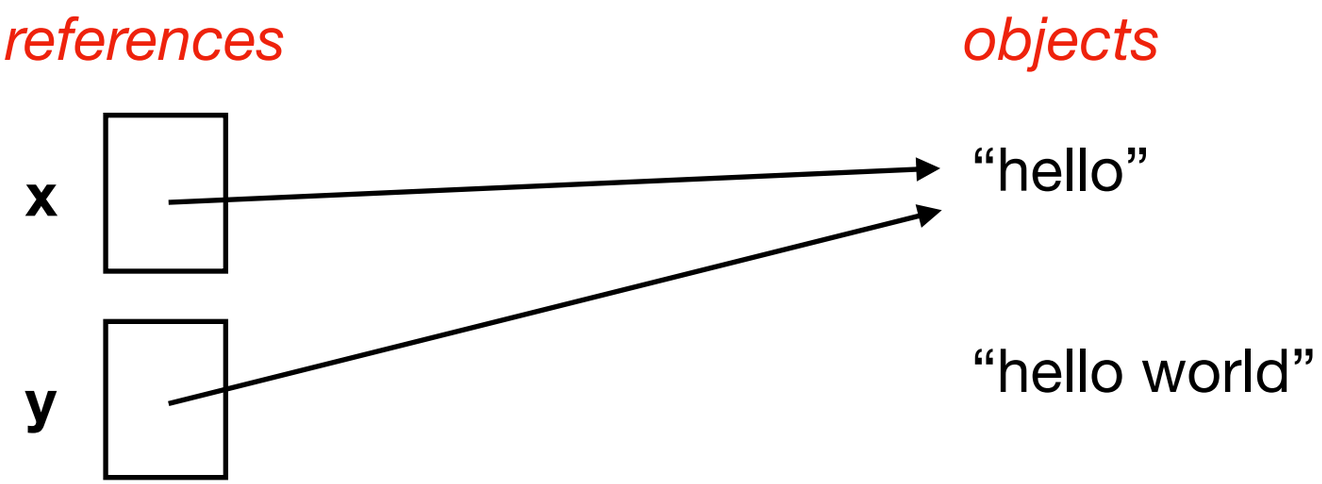

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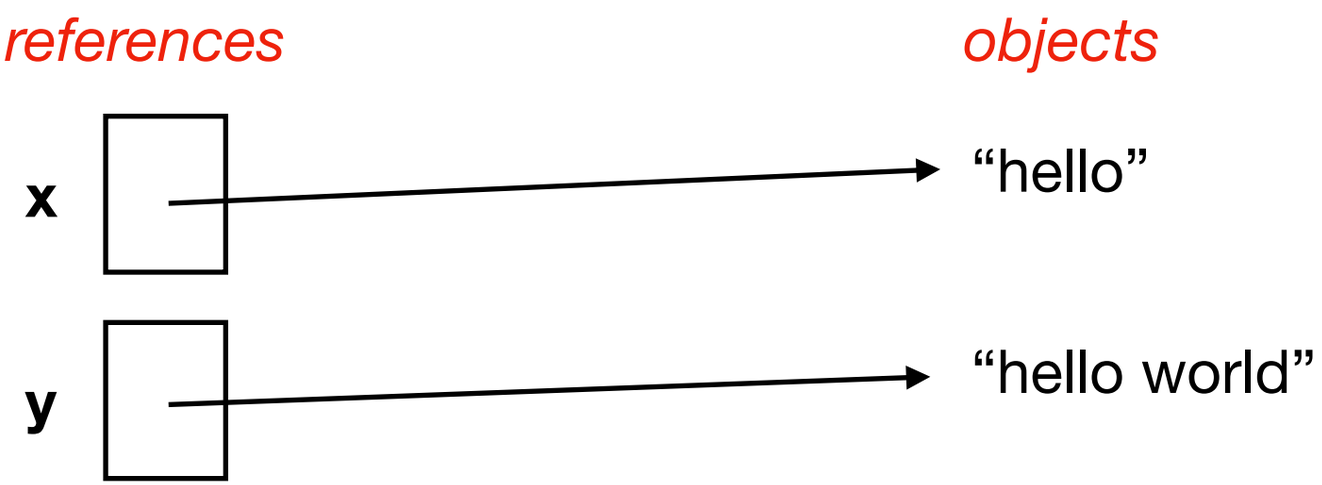

Today's Outline

New Types

- tuple
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References

- **motivation**
- unintentional argument modification
- “is” vs. “==”

Why does Python have the complexity of separate **references** and **objects**?

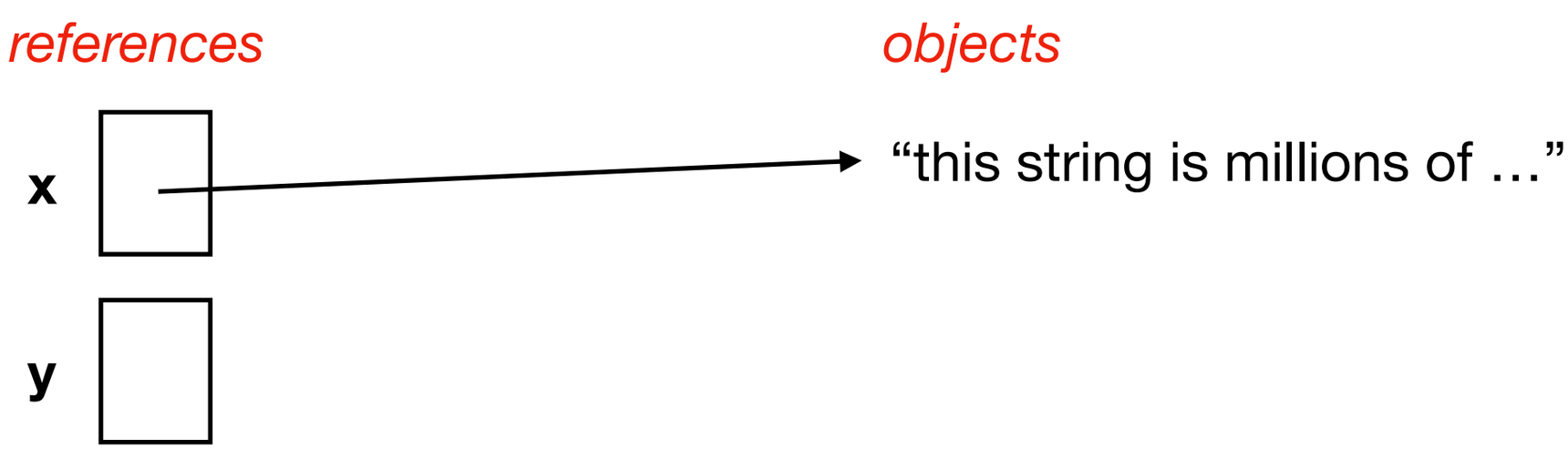
Why not follow the original strategy we learned (i.e., boxes of data with labels)?

Reason 1: Performance

Code:

```
x = “this string is millions of characters…”
y = x # this is fast!
```

State:



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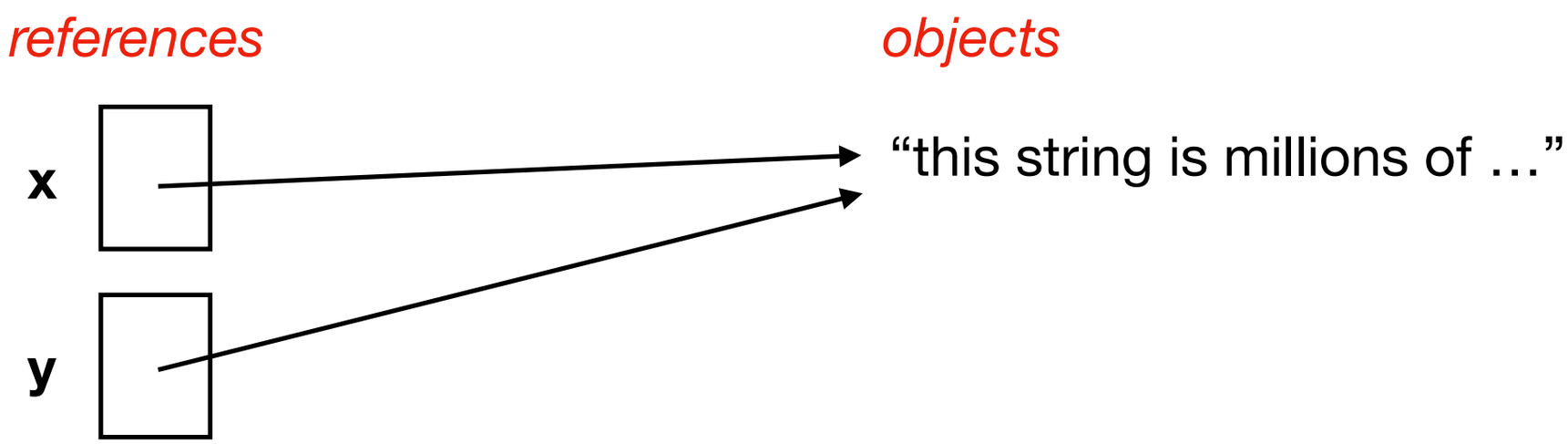

Reason 2: Centralized Updates

```python
from recordclass import recordclass

Person = recordclass("Person", ["name", "score", "age"])

alice = Person(name="Alice", score=10, age=30)
bob = Person(name="Bob", score=8, age=25)
winner = alice

alice.age = 31
print("Winner age:", winner.age)
```

State:

references *objects*

alice

bob

winner

Reason 2: Centralized Updates

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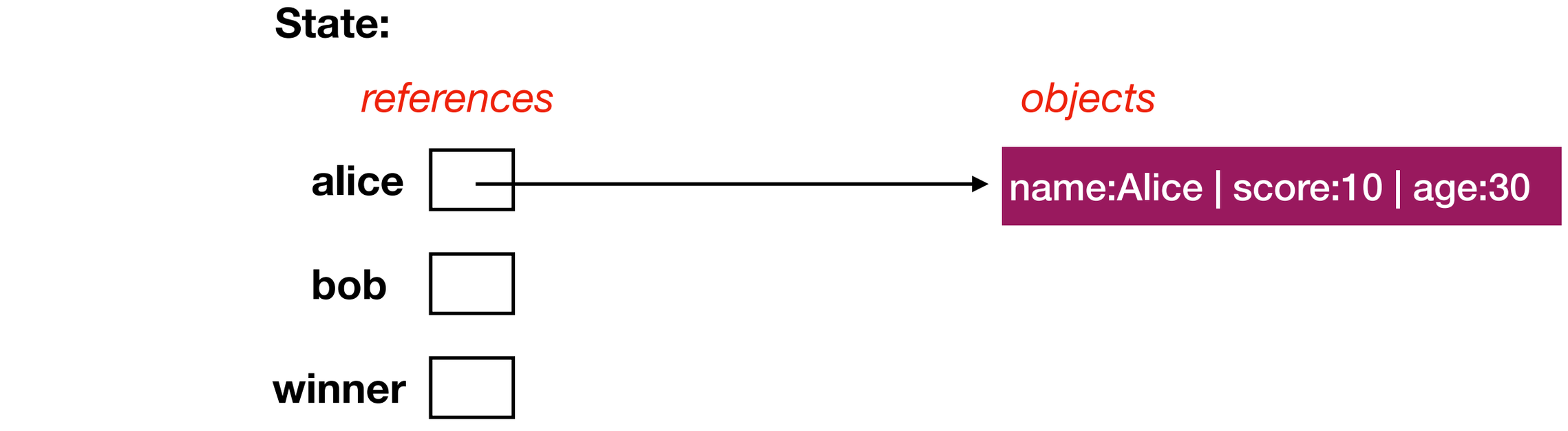

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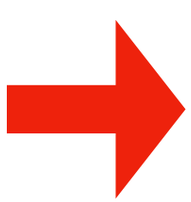

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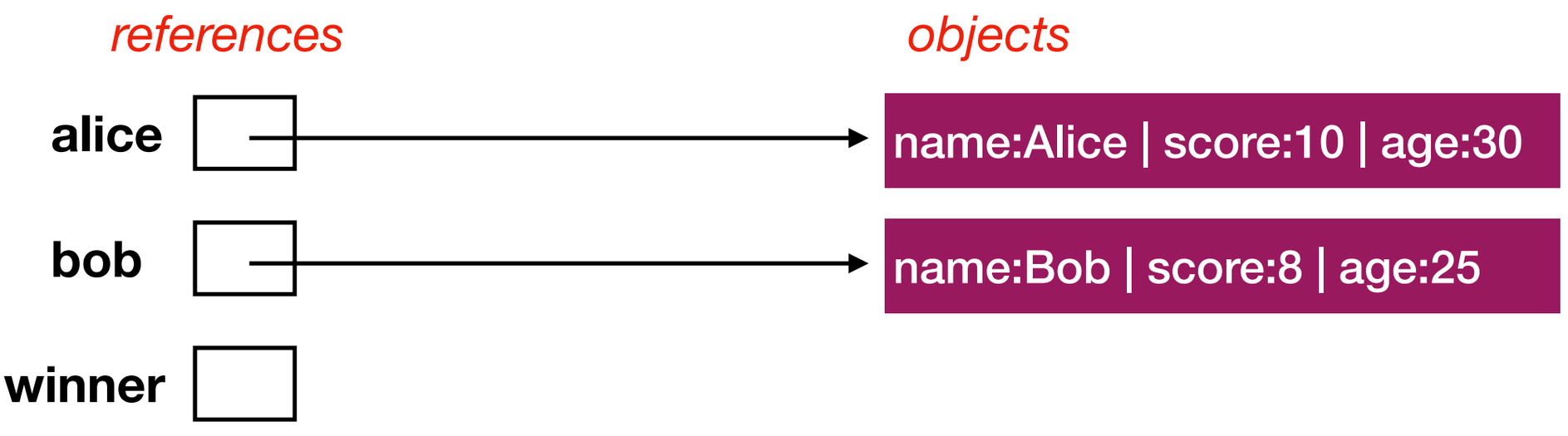

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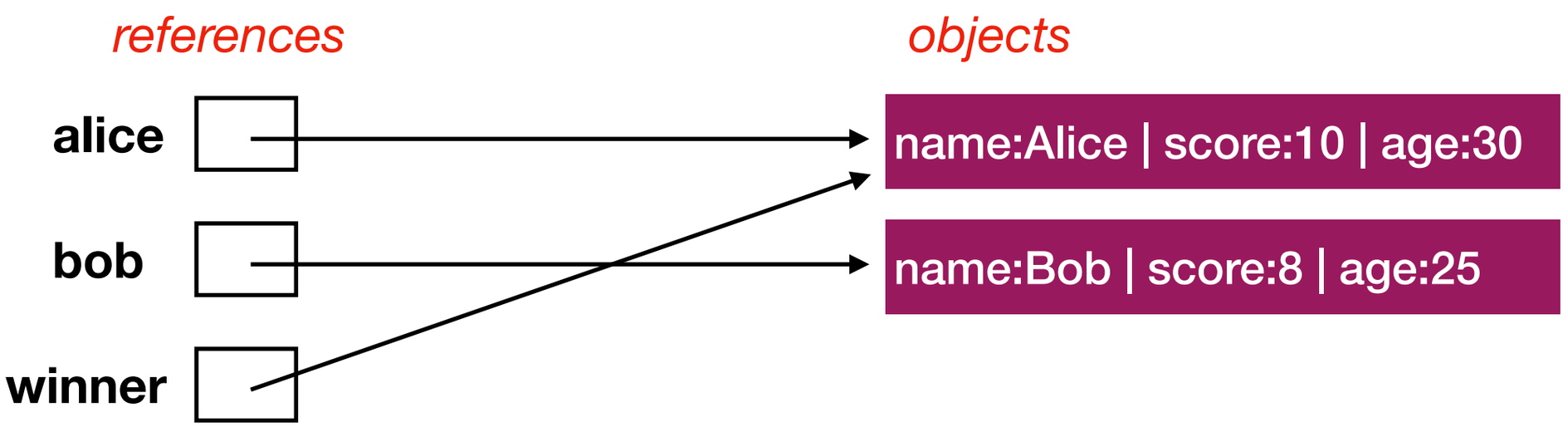
```

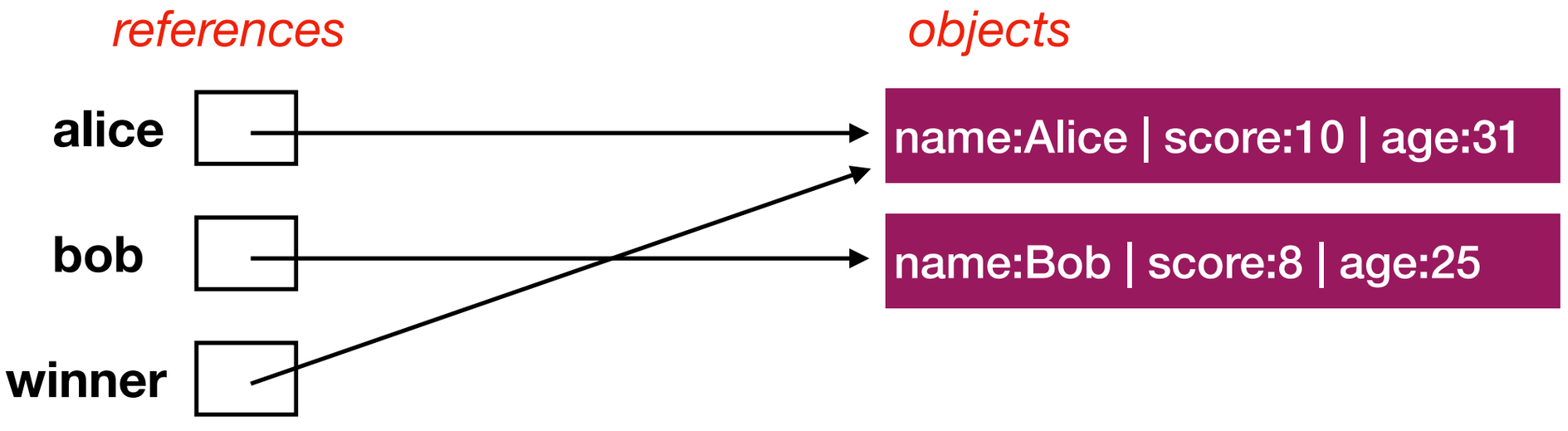
State:



Reason 2: Centralized Updates

```python
from recordclass import recordclass

Person = recordclass("Person", ["name", "score", "age"])

alice = Person(name="Alice", score=10, age=30)
bob = Person(name="Bob", score=8, age=25)
winner = alice

alice.age = 31
print("Winner age:", winner.age)
```

State:

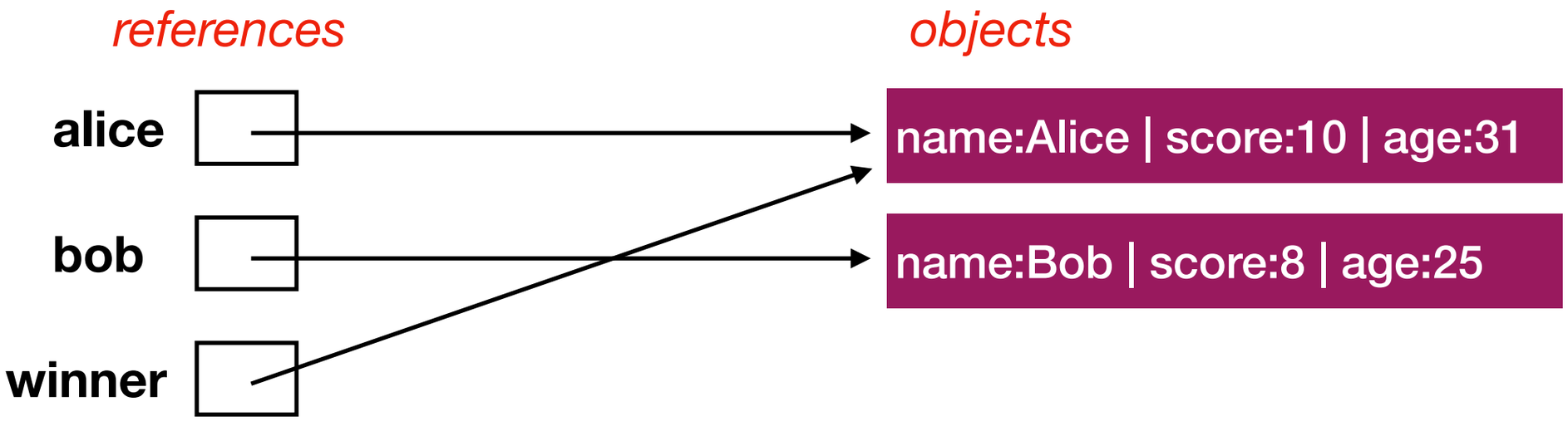


Reason 2: Centralized Updates

```
from recordclass import recordclass

Person = recordclass("Person", ["name", "score", "age"])

alice = Person(name="Alice", score=10, age=30)
bob = Person(name="Bob", score=8, age=25)
winner = alice

alice.age = 31
print("Winner age:", winner.age)
```

prints 31, even though we didn't directly modify winner

State:



Today's Outline

New Types

- tuple
- namedtuple
- recordclass

References

- motivation
- **unintentional argument modification**
- “is” vs. “==”

References and Arguments/Parameters

Python Tutor

- correctly illustrates references with an arrow for mutable types
- thinking carefully about a few examples will prevent many debugging headaches…

Example 1: reassign parameter

```
def test(items, x):
  x *= 3
  print("in test:", items, x)

words = ['hello', 'world']
letter = 'w'
print(“before:", words, letter)
test(words, letter)
print("after:", words, letter)
```

Example 2: modify list

```
def test(items, x):
  items.append(x)
  print("in test:", items, x)

words = ['hello', 'world']
letter = 'w'
print(“before:", words, letter)
test(words, letter)
print("after:", words, letter)
```

Example 3: reassign new list to param

```
def test(items, x):
   items = items + [x]
   print("in test:", items, x)

words = ['hello', 'world']
letter = 'w'
print(“before:", words, letter)
test(words, letter)
print("after:", words, letter)
```

Example 4: in-place sort

```
def first(items):
    return items[0]

def smallest(items):
    items.sort()
    return items[0]
```

```
numbers= [4,5,3,2,1]
print("first:", first(numbers))
print("smallest:", smallest(numbers))
print("first:", first(numbers))
```

Today's Outline

New Types

- tuple
- namedtuple
- recordclass

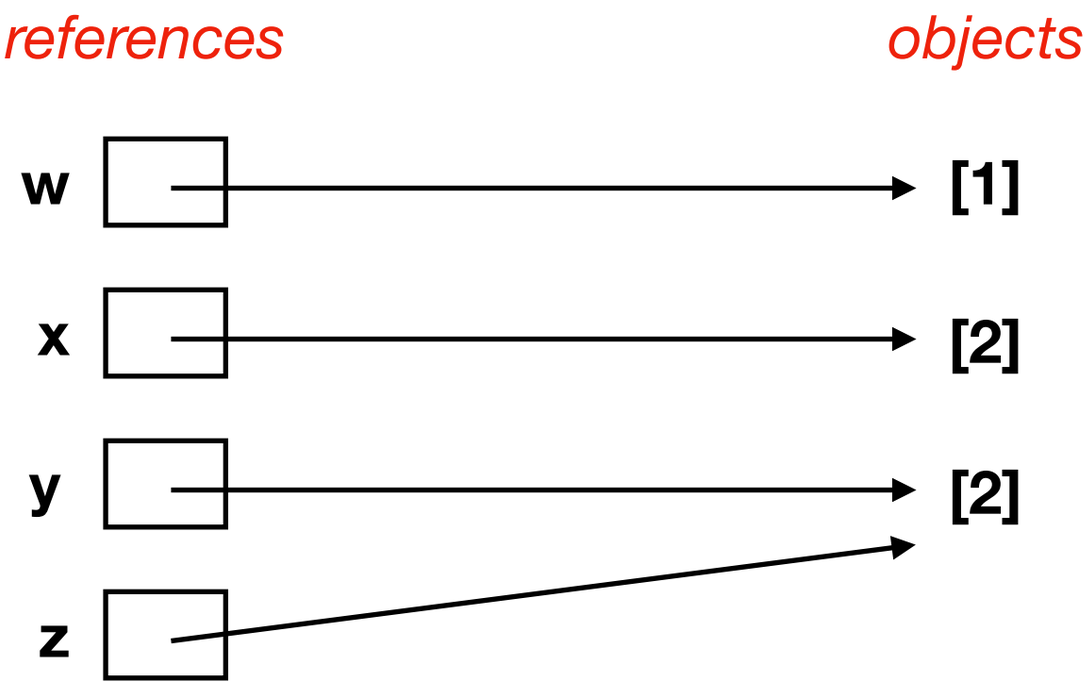
References

- motivation
- unintentional argument modification
- **“is” vs. “==”**

Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

State:

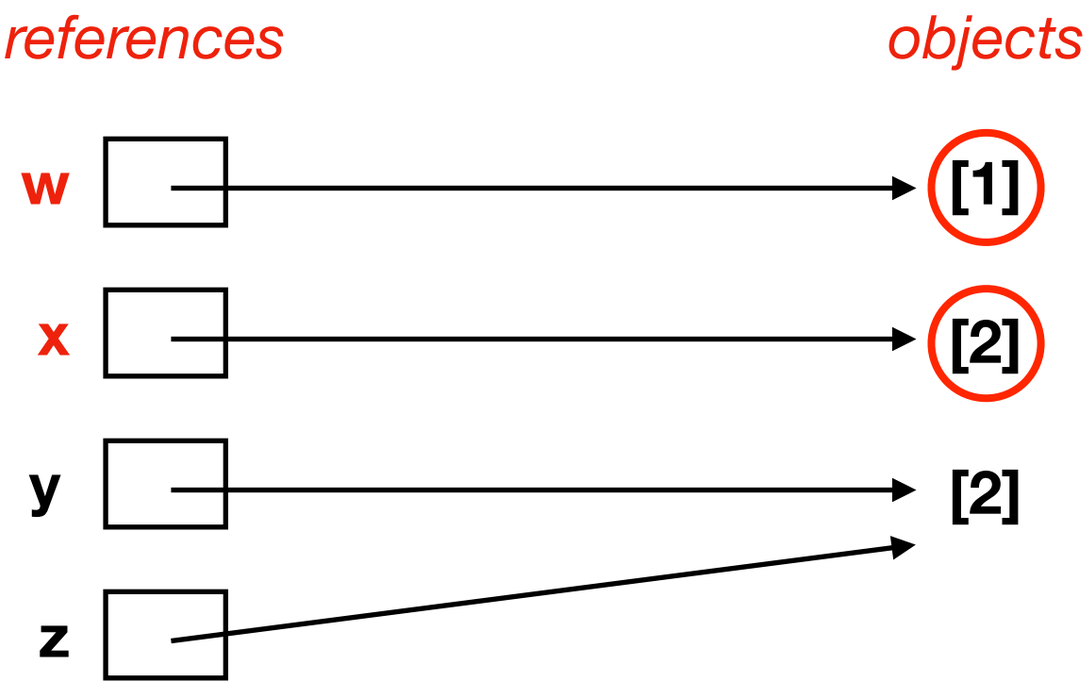


Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

w == x

State:



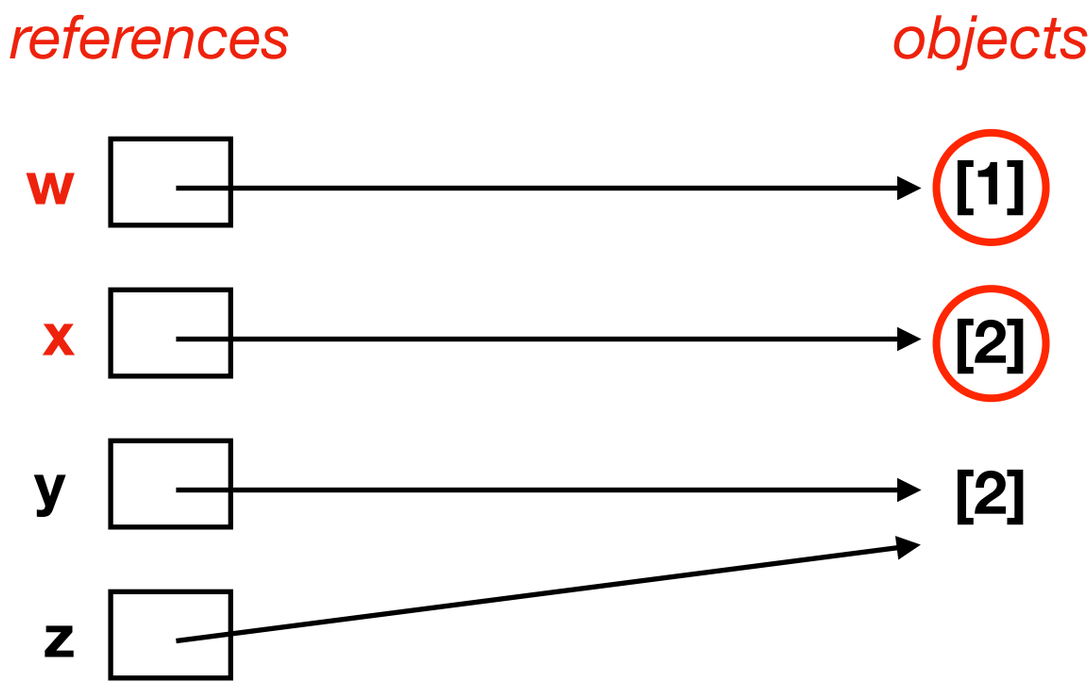
Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

w == x

False

State:

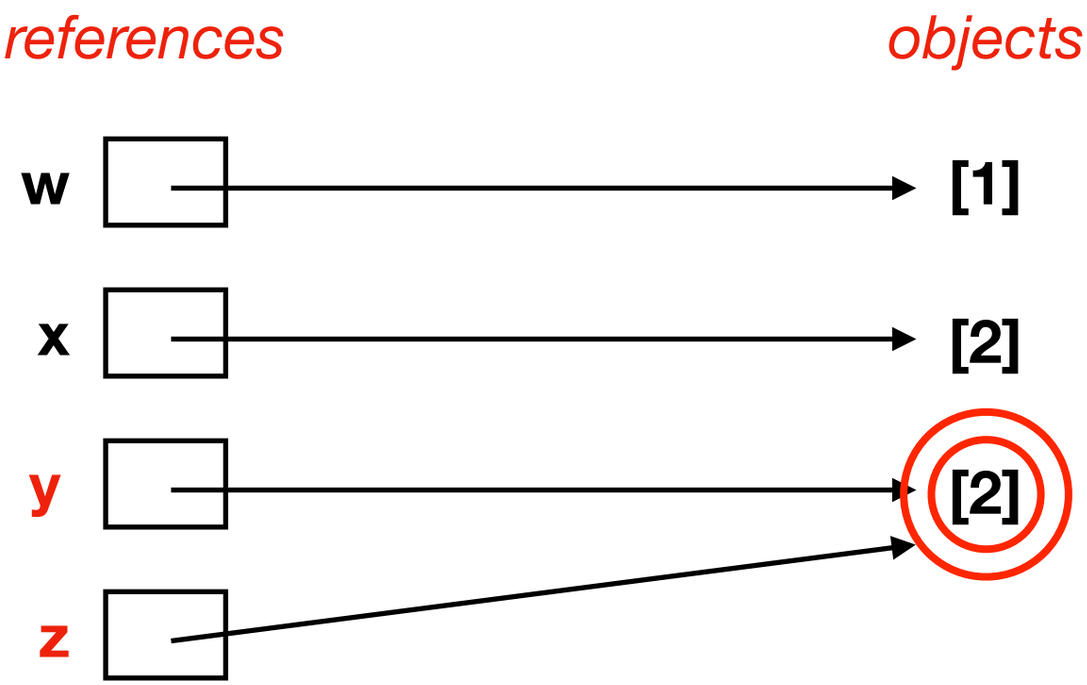


Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

y == z

State:



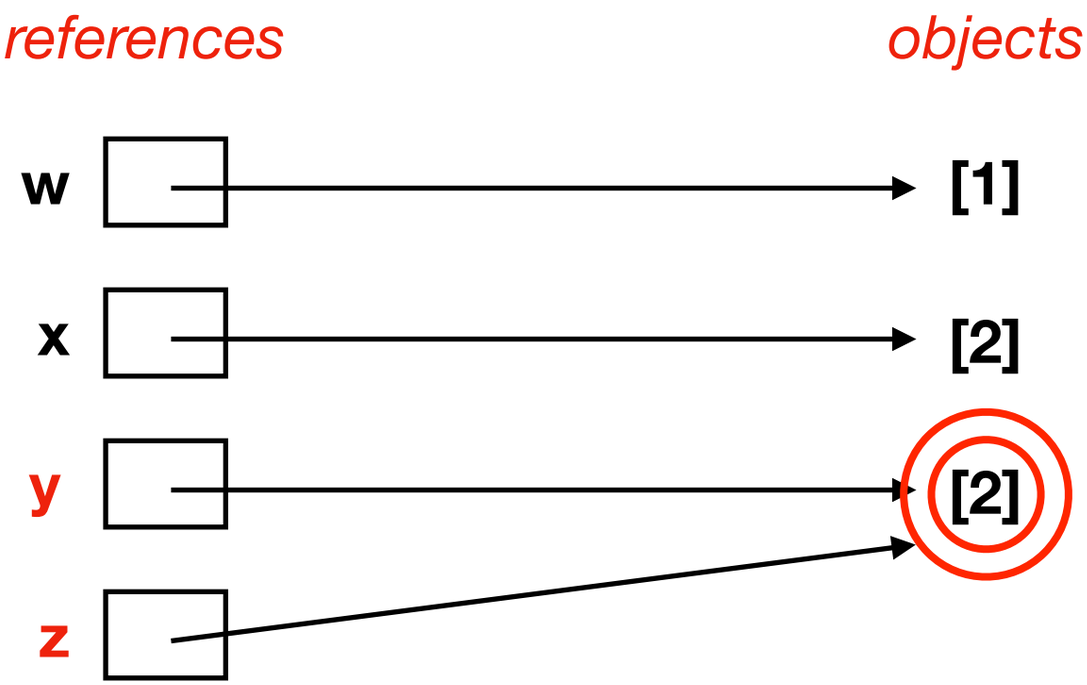
Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

y == z

True

State:

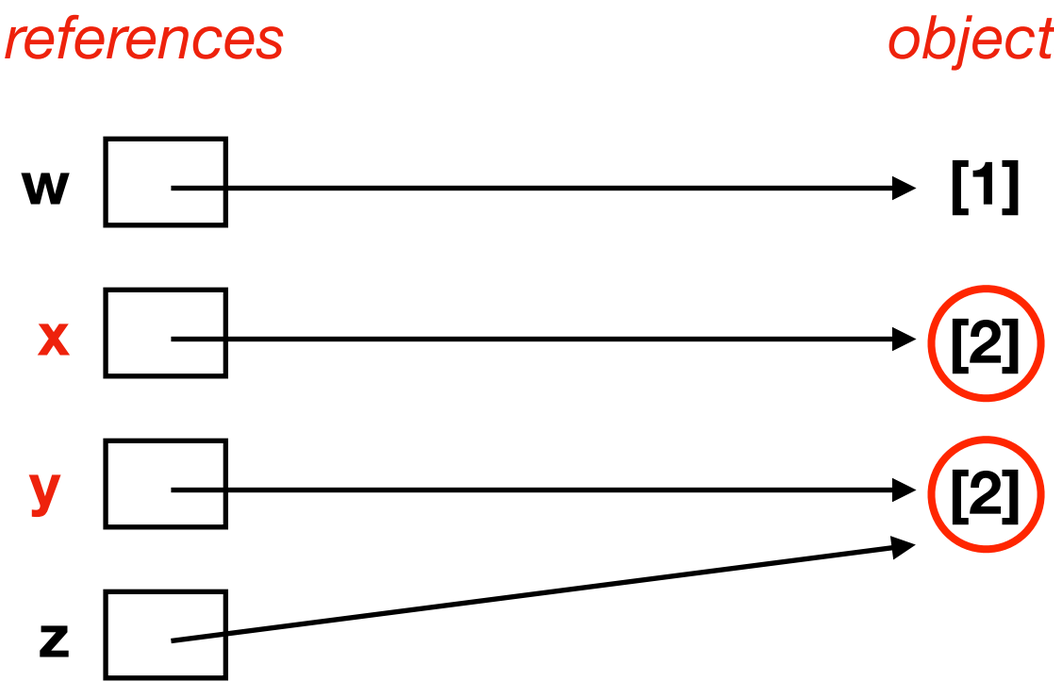


Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

x == y

State:



Equal and is

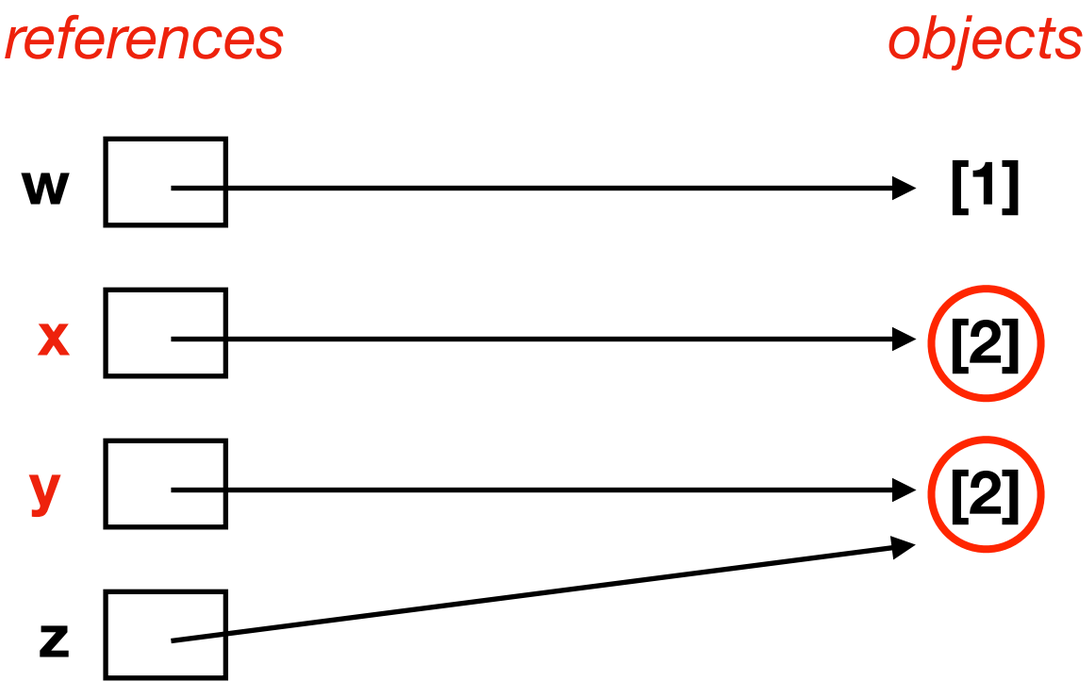
```
w = [1]
x = [2]
y = [2]
z = y
```

x == y

True

because x and y refer to equivalent
(though not identical) values

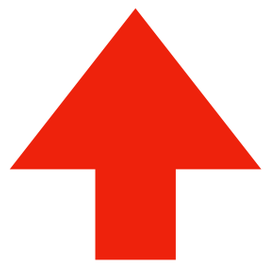
State:



Equal and is

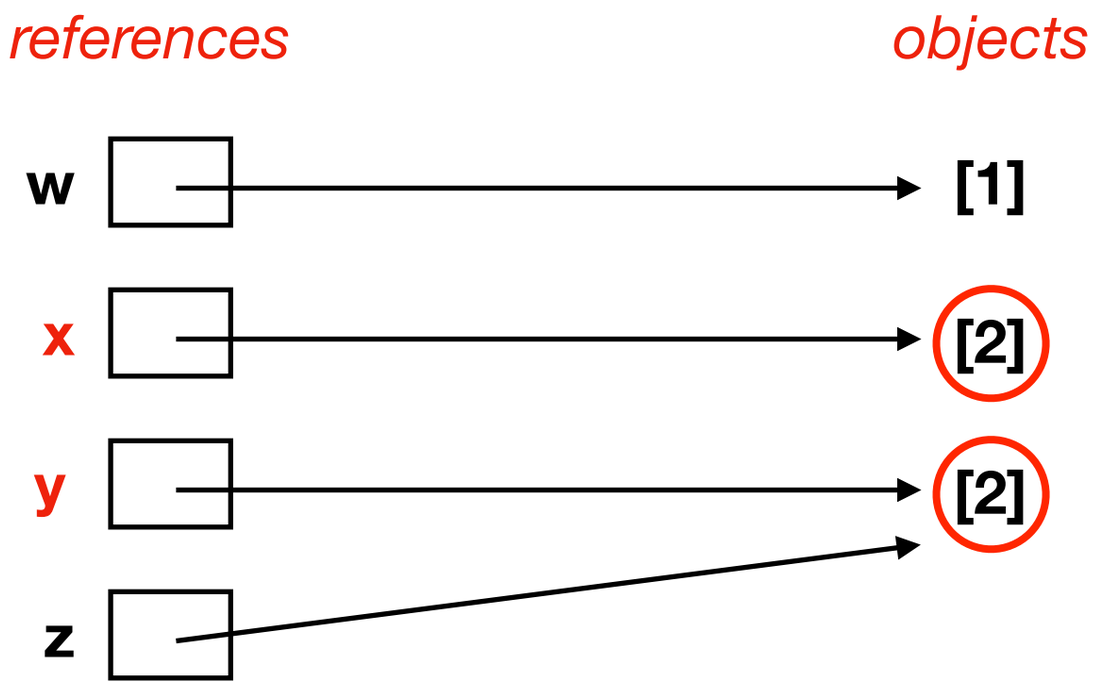
```
w = [1]
x = [2]
y = [2]
z = y
```

x is y



new operator to check if two references refer to the same object

State:



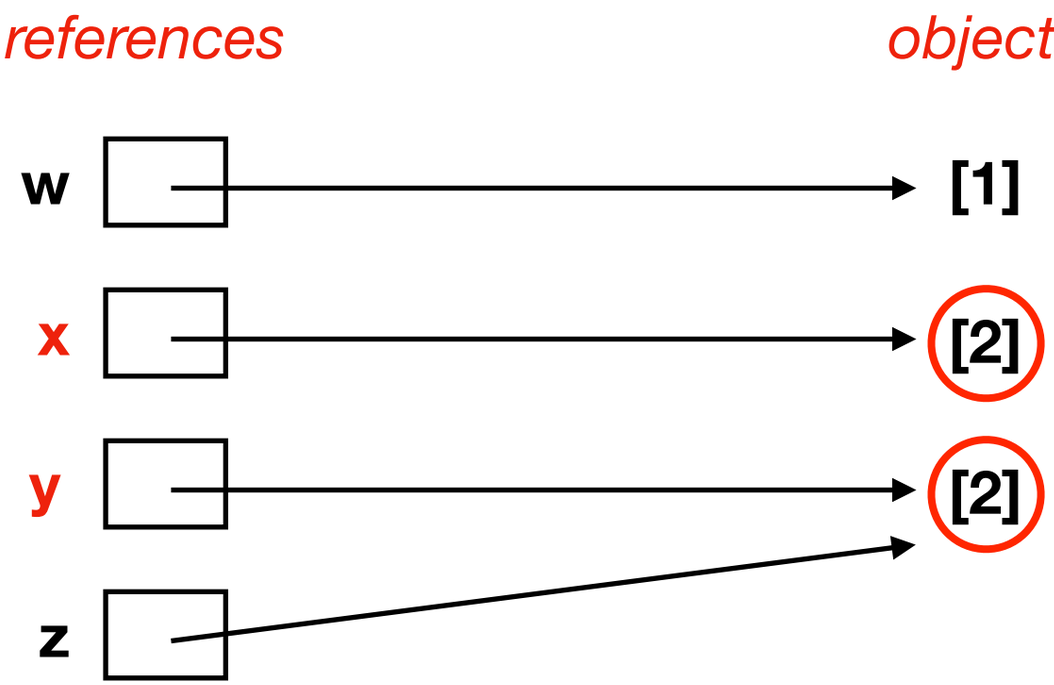
Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

x is y

False

State:

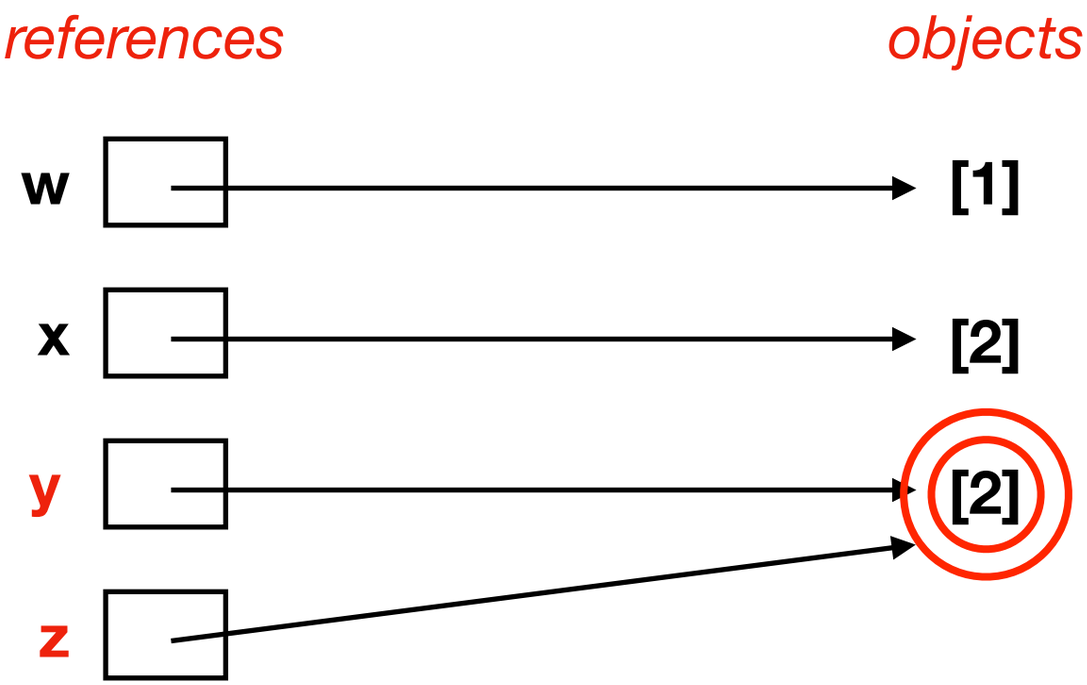


Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

y is z

State:



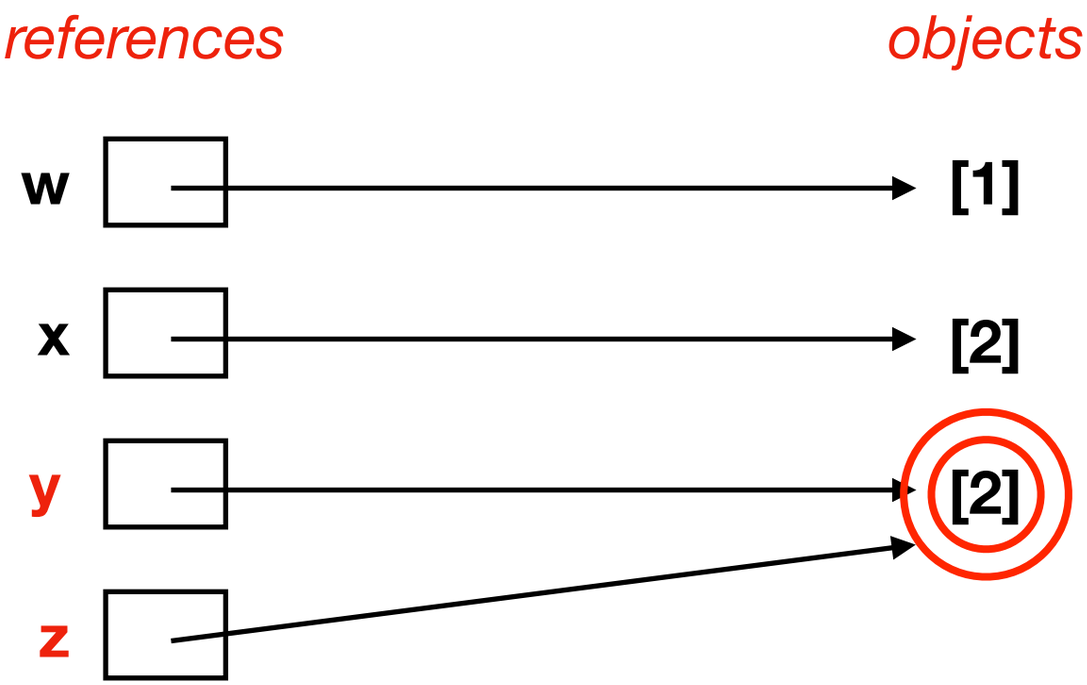
Equal and is

```
w = [1]
x = [2]
y = [2]
z = y
```

y is z

True

State:



Equal and is

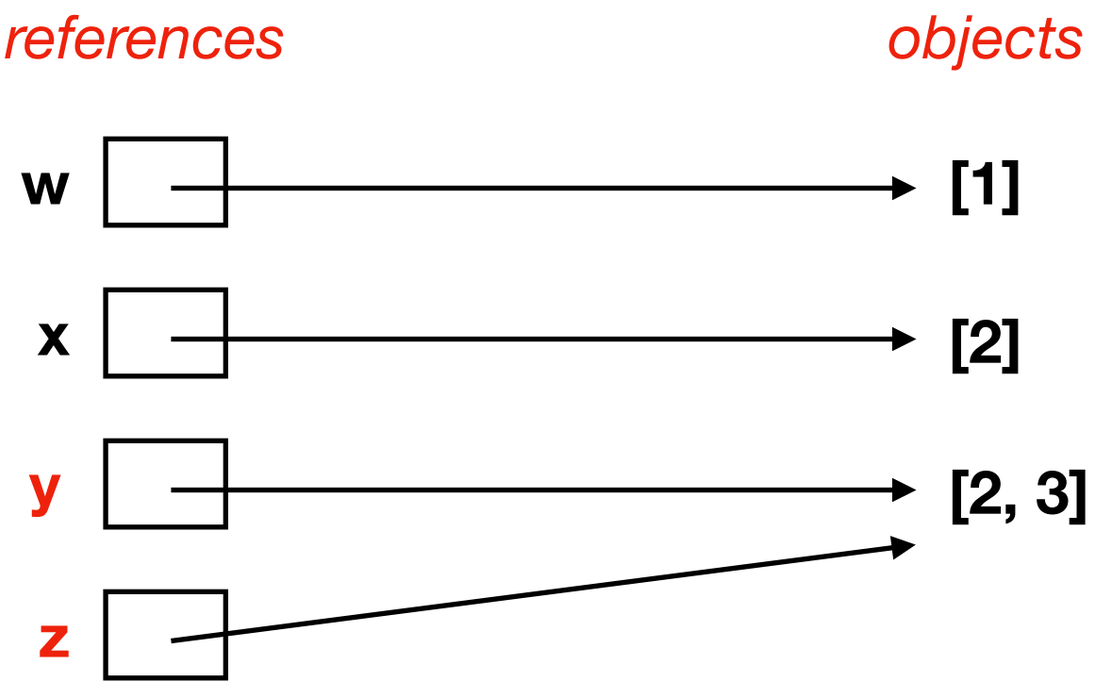
```
w = [1]
x = [2]
y = [2]
z = y
y.append(3)
```

y is z

True

This tells you that changes to
y will show up if we check z

State:



Equal and is

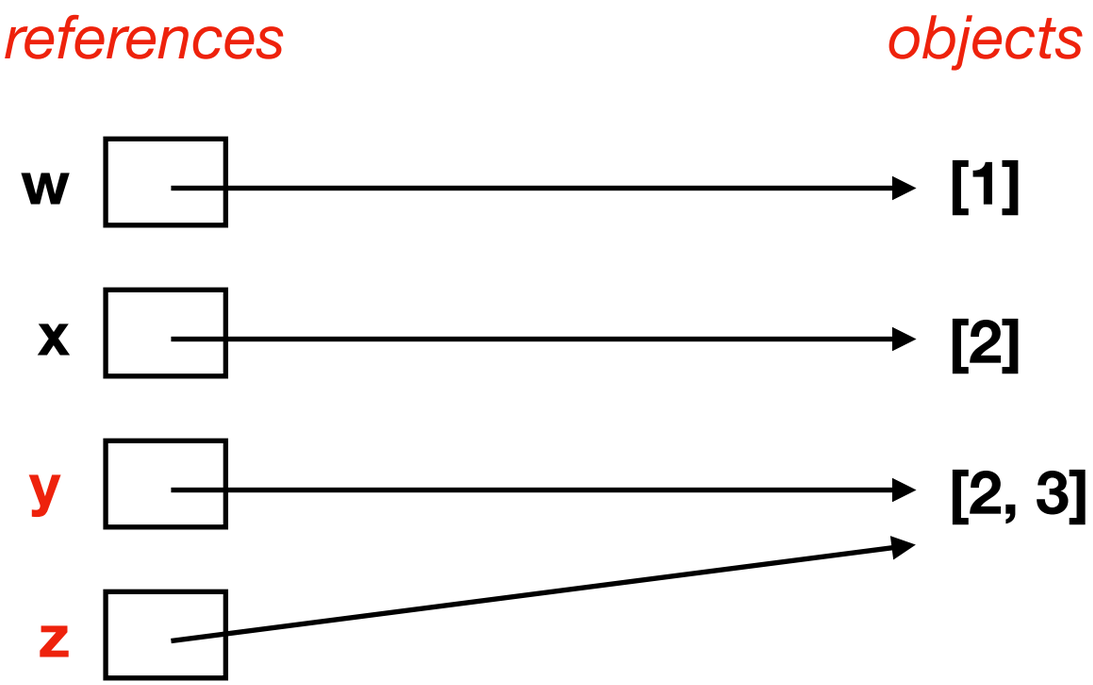
```
w = [1]
x = [2]
y = [2]
z = y
y.append(3)
print(z) # [2,3]
```

y is z

True

This tells you that changes to
y will show up if we check z

State:



Be careful with `is`!

Sometimes “deduplicates” equal immutable values

- This is an unpredictable optimization (called interning)
- 90% of the time, you want == instead of is
  (then you don’t need to care about this optimization)
- Play with changing replacing 10 with other numbers to see potential pitfalls:

```
a = 'ha' * 10
b = 'ha' * 10
print(a == b)
print(a is b)
```

Conclusion

New Types

- **tuple**: immutable equivalent as list
- **namedtuple**: make your own immutable types!
  - choose names, don’t need to remember positions
- **recordclass**: mutable equivalent of namedtuple
  - need to install with “pip install recordclass”

References

- **motivation**: faster and allows centralized update
- **gotchas**: mutating a parameter affects arguments
- **is operation**: do two variables refer to the same object?