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Objects + References

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Readings:
Chapter 10 & 12 of Think Python
Chapter 11.1 to 11.7 of Python for Everybody

Test yourself!

A **what is the type of the following?** `{}`

1 **set**

2 **dict**

B **if `S` is a string and `L` is a list, which line definitely fails?**

1 `S[-1] = "."`

2 `L[len(S)] = S`

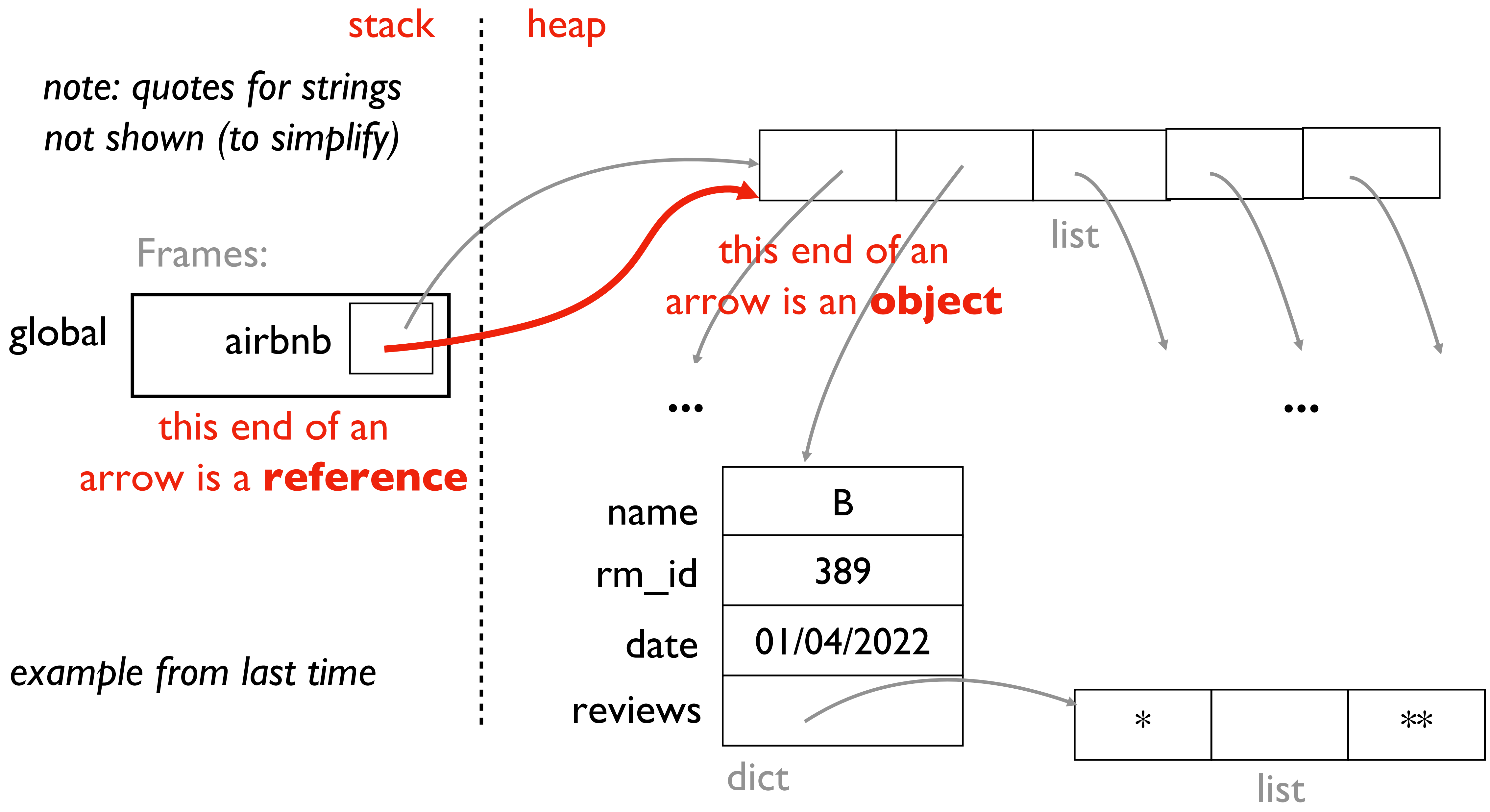
C **which type is immutable?**

1 `str`

2 `list`

3 `dict`

Objects and References



stack

heap

note: quotes for strings
not shown (to simplify)

Frames:

global

airbnb

this end of an
arrow is a **reference**

this end of an
arrow is an **object**

list

...

...

name

B

rm_id

389

date

01/04/2022

reviews

dict

*

**

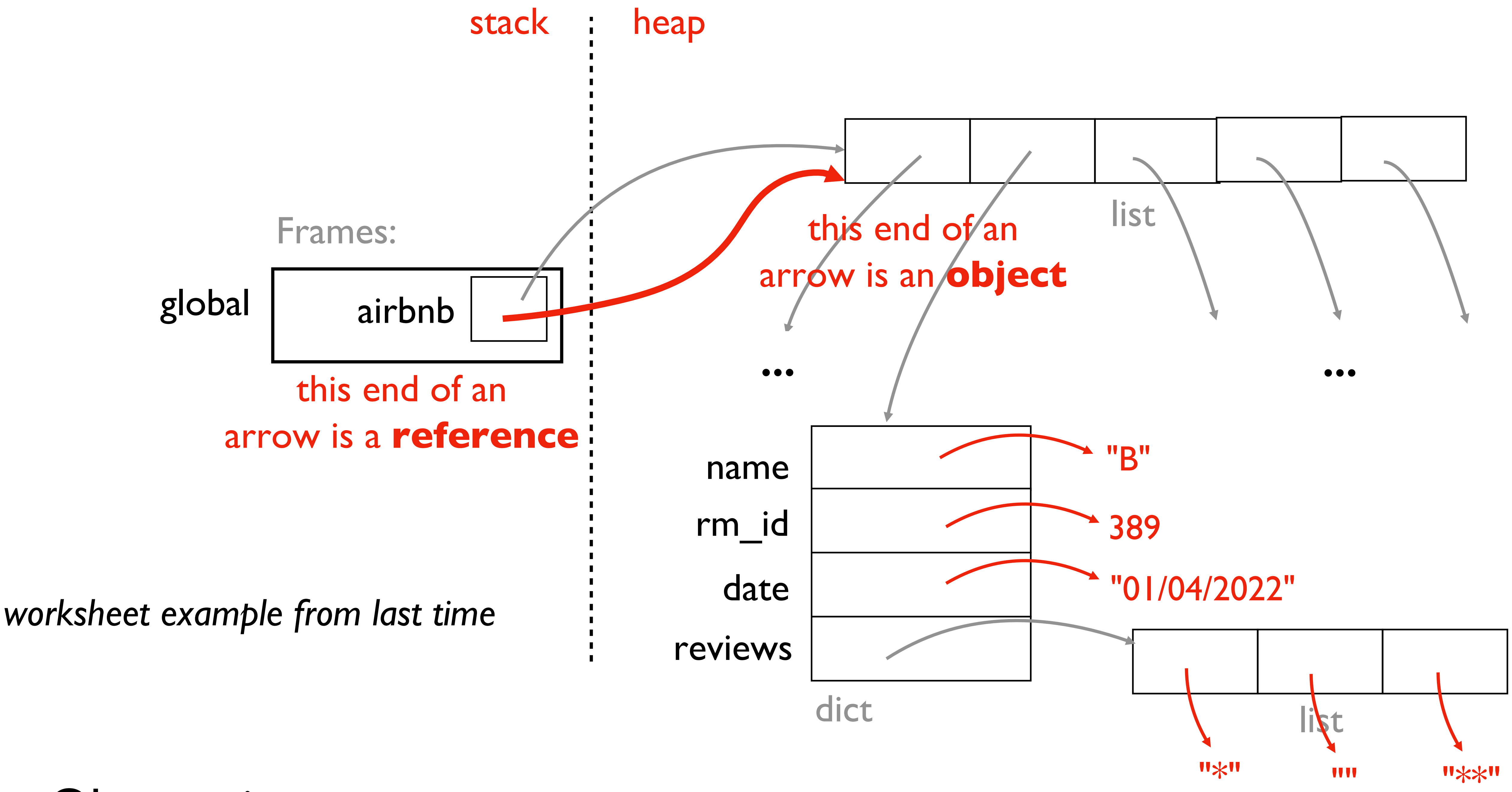
list

worksheet example from last time

Observations

1. objects have a "life of their own" beyond variables or even function frames
2. here there are dict and list objects (others are possible)
3. references show up two places: as variables and values in data structures

Objects and References

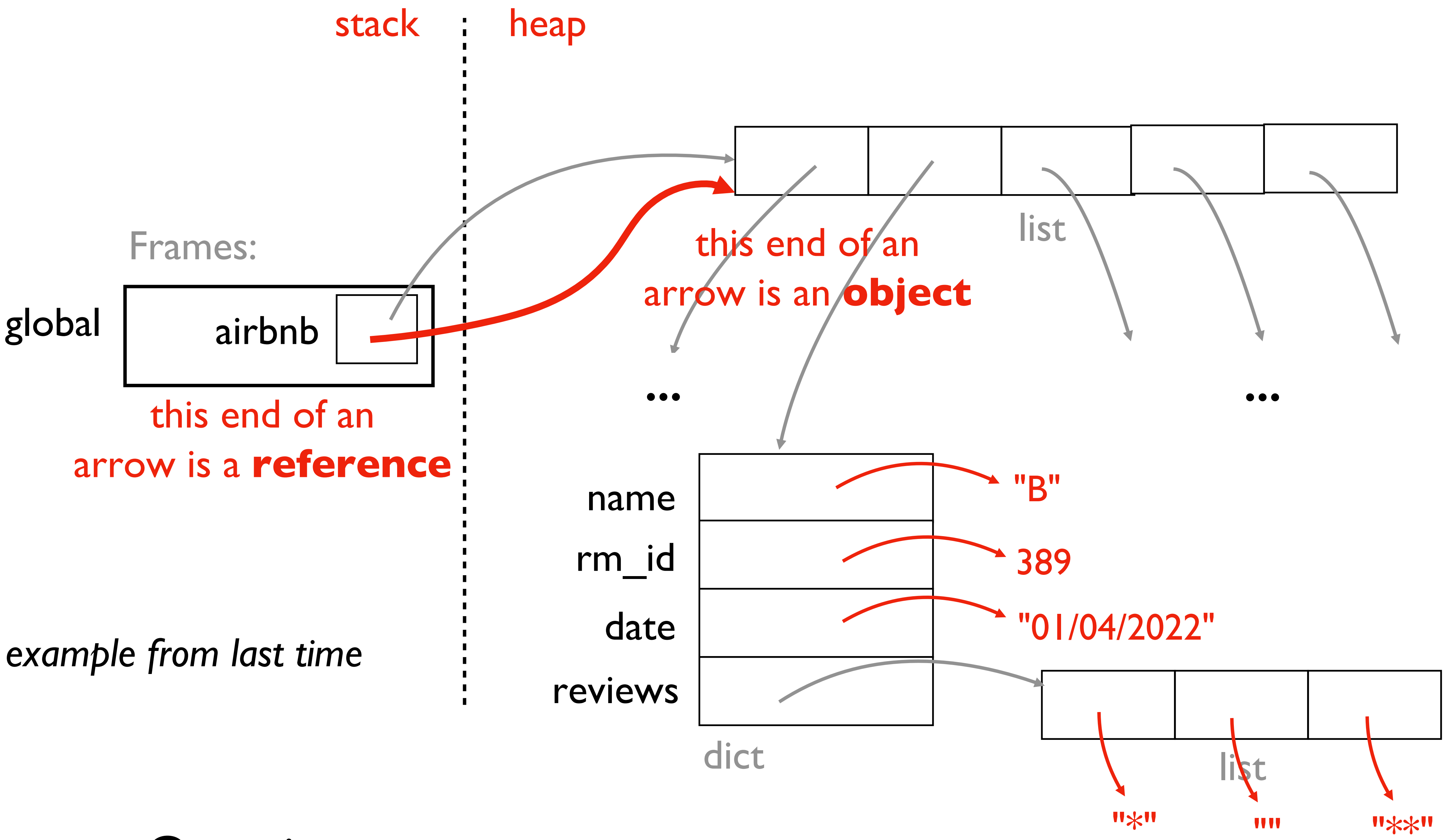


worksheet example from last time

Observations

1. objects have a "life of their own" beyond variables or even function frames
2. here there are dict and list objects (others are possible)
3. references show up two places: as variables and values in data structures
4. technically ints and strs (and all values) are objects too in Python...

Objects and References



worksheet example from last time

Questions

1. why do we need this more complicated model?
2. how can we create new types of objects?
3. how can we copy objects to create new objects?

Today's Outline

let's evolve our mental model of state!

References

- Mental Model for State (v2)
- examples and bugs: accidental argument modification

New Types of Objects

- tuple
- namedtuple

Motivation for objects and references

- why do we need this new mental model?

Mental Model for State (v1)

Code:

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

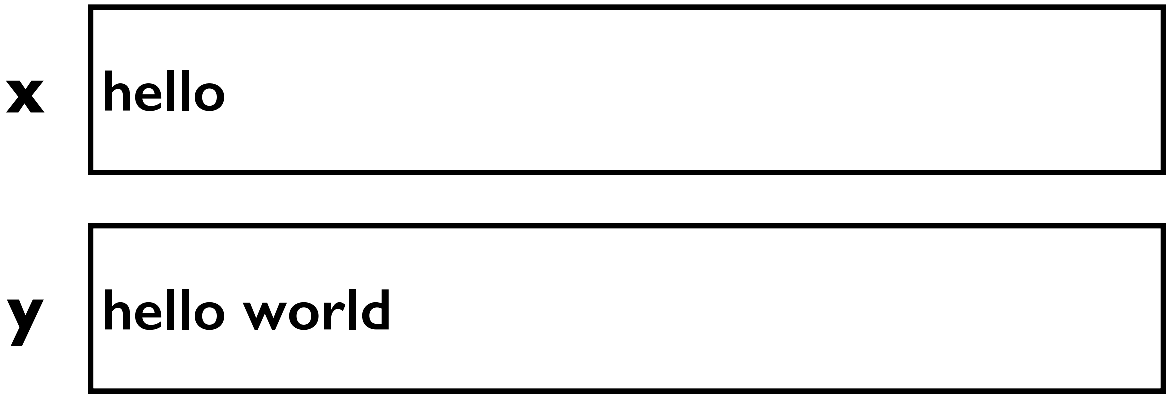
Common mental model

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

Issues

- incorrect for mutable types
- ignores performance

State:



x hello

y hello world

note: *we're not drawing frame boxes for simplicity since everything is in the global frame*

Mental Model for State (v2)

Code:

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

State:

references

objects

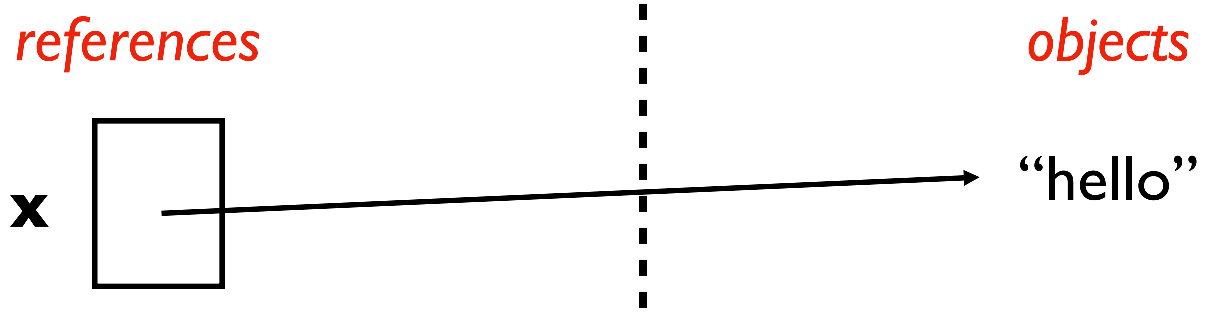
note: *we're still not drawing frame boxes for simplicity since everything is in the global frame*

Mental Model for State (v2)

Code:

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

State:



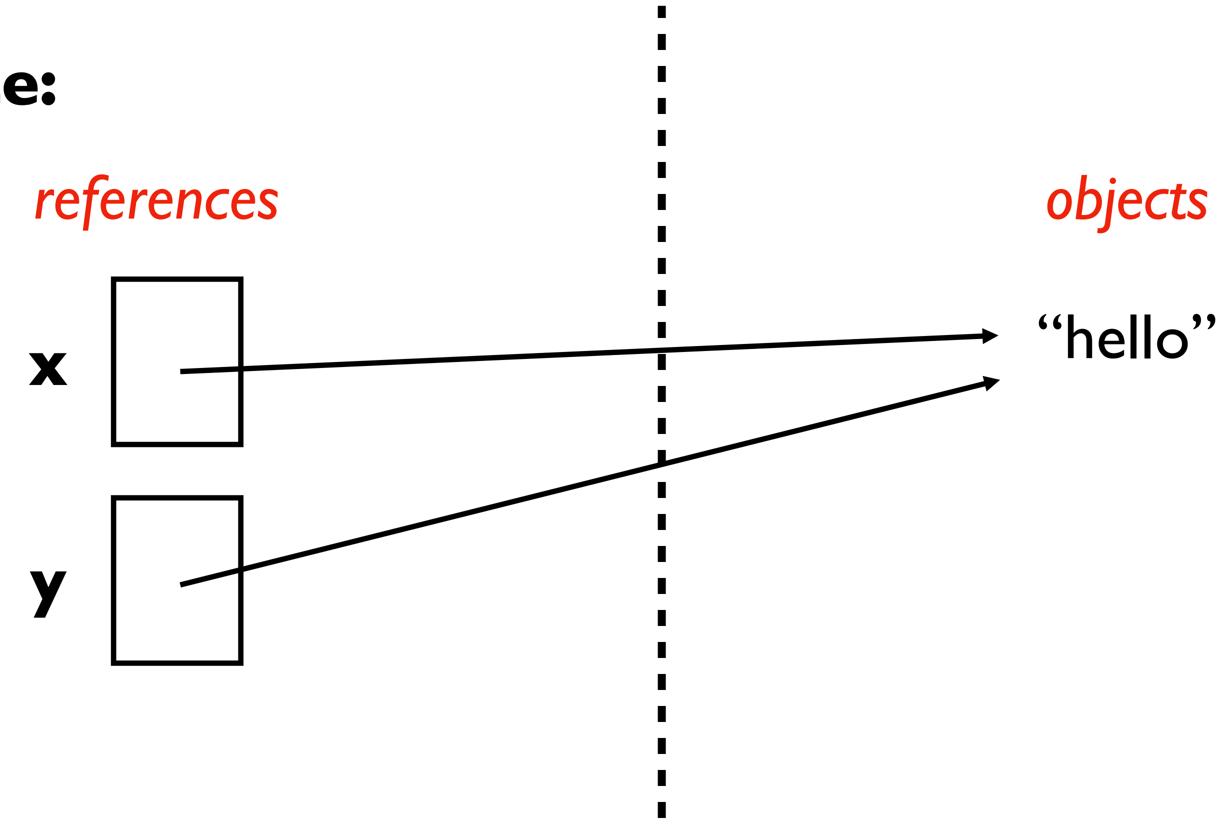
any box with an arrow is a reference
(variables are one kind of reference)

Mental Model for State (v2)

Code:

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

State:

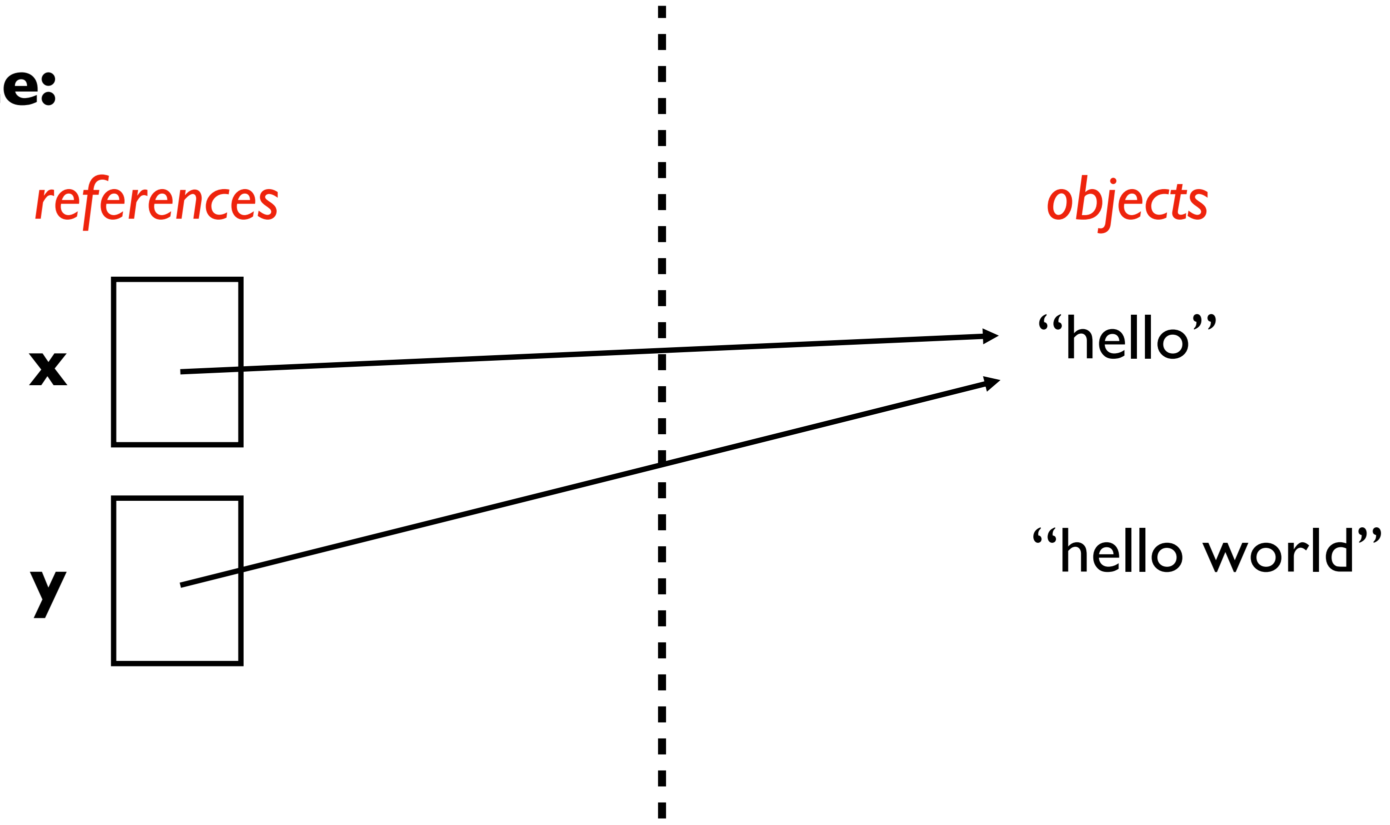


Mental Model for State (v2)

Code:

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

State:

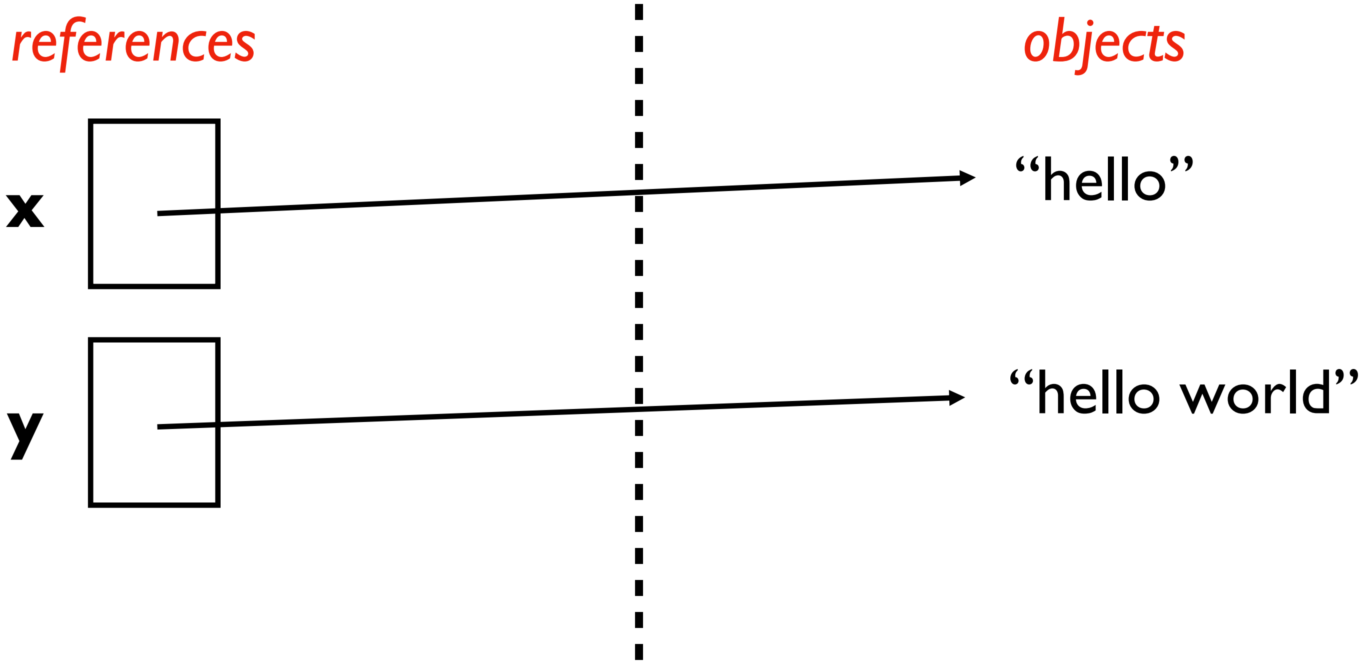


Mental Model for State (v2)

Code:

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

State:

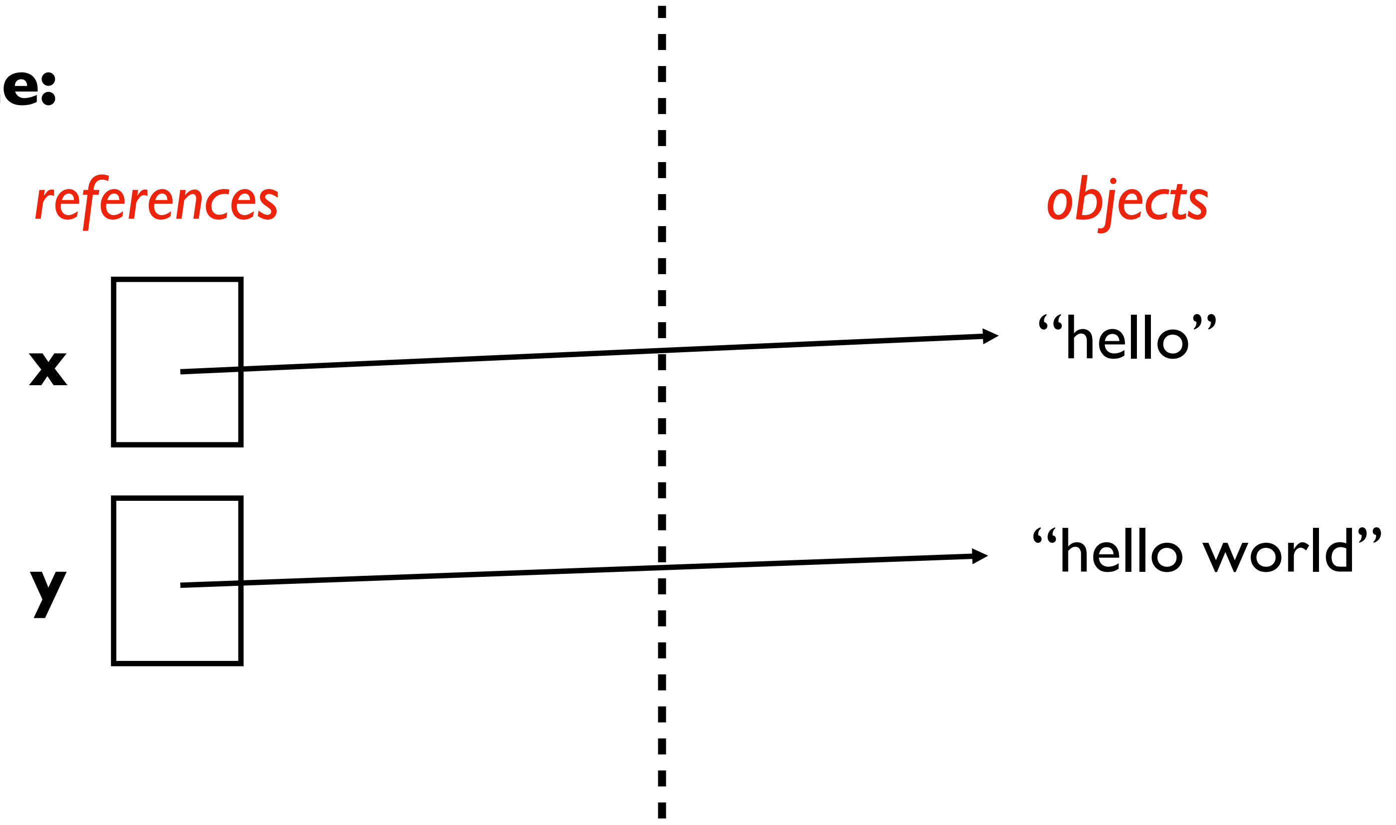


Mental Model for State (v2)

Code:

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

State:



Revisiting Assignment and Passing Rules for v2

```
# RULE 1 (assignment)
x = ????
y = x  # y should reference whatever x references
```

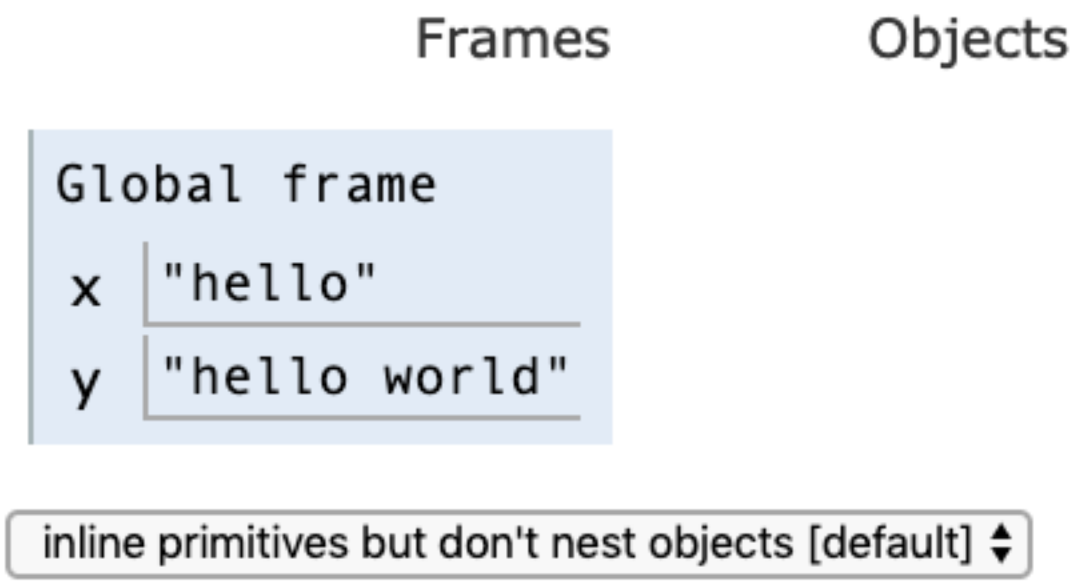
```
# RULE 2 (argument passing)
def f(y):
    pass

x = ????
f(x)  # y should reference whatever x references
```

How PythonTutor renders immutable types is configurable...

Code:

```
x = "hello"
y = x
y += " world"
```

v1



Frames

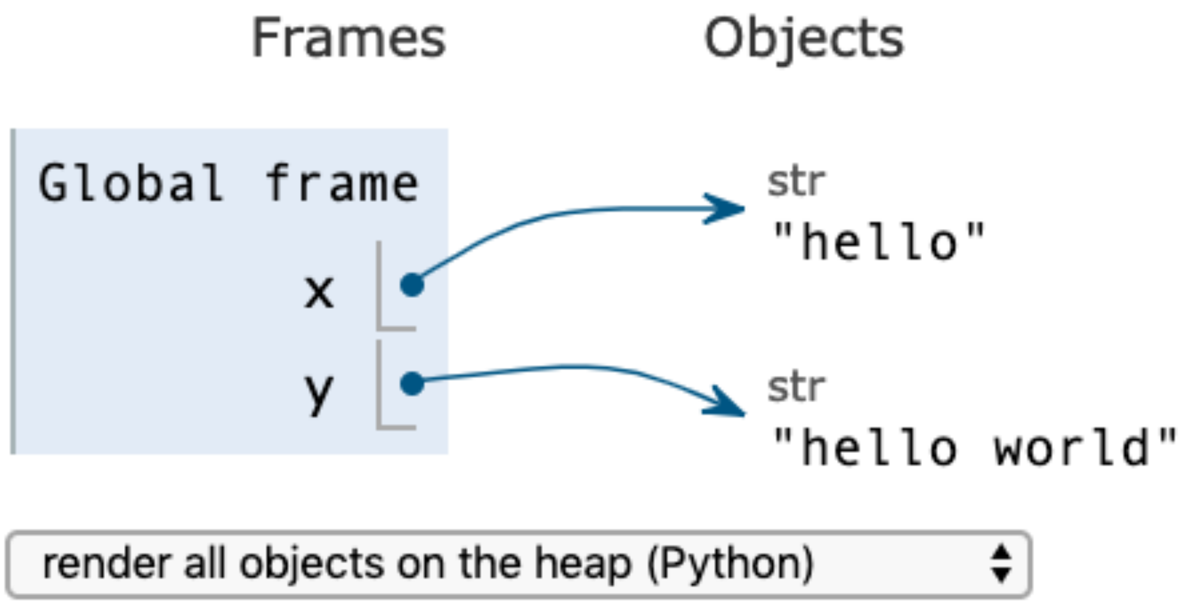
Objects

Global frame

x	"hello"
y	"hello world"

inline primitives but don't nest objects [default]

v2



Frames

Objects

Global frame

x

y

str
"hello"

str
"hello world"

render all objects on the heap (Python)

Today's Outline

References

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New Types of Objects

- tuple
- namedtuple

Motivation for objects and references

- why do we need this new mental model?

References and Arguments/Parameters

Python Tutor **always** illustrates references with an arrow for mutable types

Thinking carefully about a few examples will prevent many debugging headaches…

Example 1: reassign parameter

```
def f(x):
  x *= 3
  print("f:", x)

num = 10
f(num)
print("after:", num)
```

interactive

exercises

Example 2: modify list via param

```
def f(items):
  items.append("!!!")
  print("f:", items)

words = ['hello', 'world']
f(words)
print("after:", words)
```

interactive

exercises

Example 3: reassign new list to param

```
def f(items):
   items = items + ["!!!"]
   print("f:", items)

words = ['hello', 'world']
f(words)
print("after:", words)
```

interactive
exercises

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))
```

interactive

exercises

Example 5: sorted sort

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

def smallest(items):
    items = sorted(items)
    return items[0]

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

interactive

exercises

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Tuple Sequence

```
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

What is a tuple? A new kind of sequence!

Like a list

- for loop, indexing, slicing, other methods

Unlike a list:

- immutable (like a string)

Tuple Sequence

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

```
x = nums_list[2]
x = nums_tuple[2]
```

both put 300 in x

Like a list

- for loop, indexing, slicing, other methods

Unlike a list:

- immutable (like a string)

Tuple Sequence

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

✓ `nums_list[0] = 99`

✗ `nums_tuple[0] = 99`

changes list to
[99, 100, 300]

Crashes!

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

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

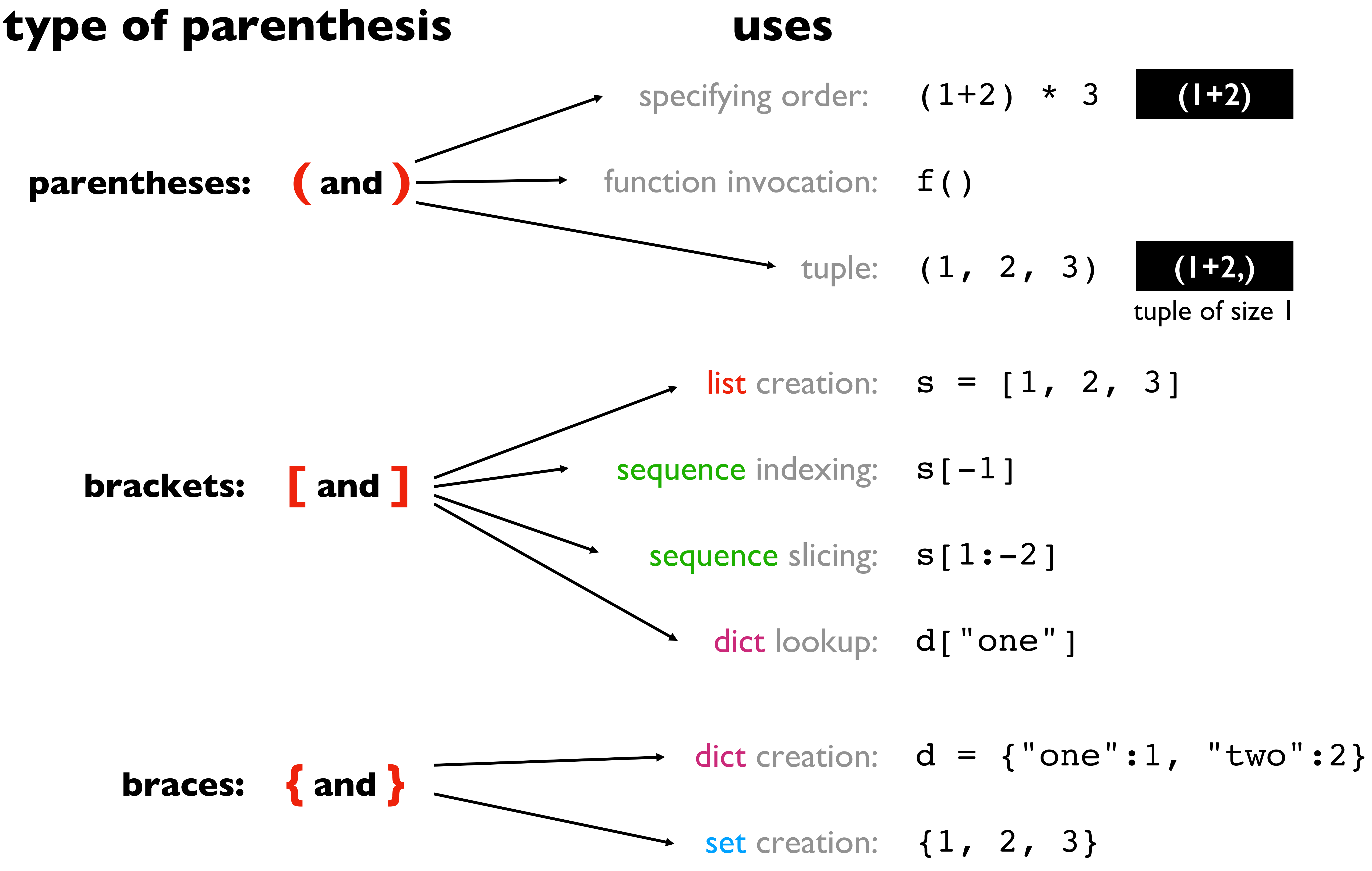
```
buildings = {
   (0,0): “Comp Sci”,
   (0,2): “Psychology”,
   (4,0): “Noland”,
   (1,8): “Van Vleck”
}
```

trying to use x,y coordinates as key

Succeeds!

(with tuples)

A note on parenthetical characters



type of parenthesis **uses**

parentheses: (and)

- specifying order: `(1+2) * 3` **(1+2)**
- function invocation: `f()`
- tuple: `(1, 2, 3)` **(1+2,)** tuple of size 1

brackets: [and]

- list creation: `s = [1, 2, 3]`
- sequence indexing: `s[-1]`
- sequence slicing: `s[1:-2]`
- dict lookup: `d["one"]`

braces: { and }

- dict creation: `d = {"one":1, "two":2}`
- set creation: `{1, 2, 3}`

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New Types of Objects

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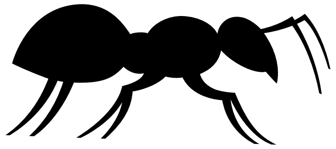
- namedtuple

Motivation for objects and references

- why do we need this new mental model?

See any bugs?



1

```
people=[
  {"Fname": "Alice", "lname": "Anderson", "age": 30},
  {"fname": "Bob", "lname": "Baker", "age": 31},
]
p = people[0]
print("Hello " + p["fname"] + " " + p["lname"])
```

dict

2

```
people=[
  ("Alice", "Anderson", 30),
  ("Bob", "Baker", 31),
]
p = people[1]
print("Hello " + p[1] + " " + p[2])
```

tuple

Vote: Which is Better Code?

1

```
people=[
  {"fname": "Alice", "lname": "Anderson", "age": 30},
  {"fname": "Bob", "lname": "Baker", "age": 31},
]
p = people[0]
print("Hello " + p["fname"] + " " + p["lname"])
```

dict

2

```
people=[
  ("Alice", "Anderson", 30),
  ("Bob", "Baker", 31),
]
p = people[1]
print("Hello " + p[0] + " " + p[1])
```

tuple

1

```
people=[
  {"fname": "Alice", "lname": "Anderson", "age": 30},
  {"fname": "Bob", "lname": "Baker", "age": 31},
]
p = people[0]
print("Hello " + p["fname"] + " " + p["lname"])
```

dict

2

```
people=[
  ("Alice", "Anderson", 30),
  ("Bob", "Baker", 31),
]
p = people[1]
print("Hello " + p[0] + " " + p[1])
```

tuple

3

```
from collections import namedtuple
Person = namedtuple("Person", ["fname", "lname", "age"])
people=[
    Person("Alice", "Anderson", 30),
    Person("Bob", "Baker", 31),
]
p = people[0]
print("Hello " + p.fname + " " + p.lname)
```

namedtuple

```python
from collections import namedtuple
```

need to import this data struct

name of that type

creates a new type!

name of that type

```python
Person = namedtuple("Person", ["fname", "lname", "age"])
```

```python
p = Person("Alice", "Anderson", 30)
```

```python
print("Hello " + p.fname + " " + p.lname)
```

```
from collections import namedtuple
```

need to import this data struct

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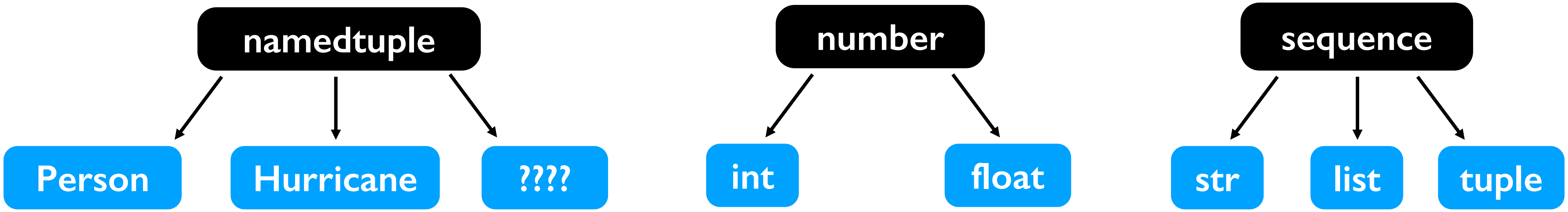
name of that type

```
Person = namedtuple("Person", ["fname", "lname", "age"])
```



namedtuple

Person

Hurricane

????

number

int

float

sequence

str

list

tuple

```
p = Person("Alice", "Anderson", 30)



print("Hello " + p.fname + " " + p.lname)
```

```python
from collections import namedtuple
```

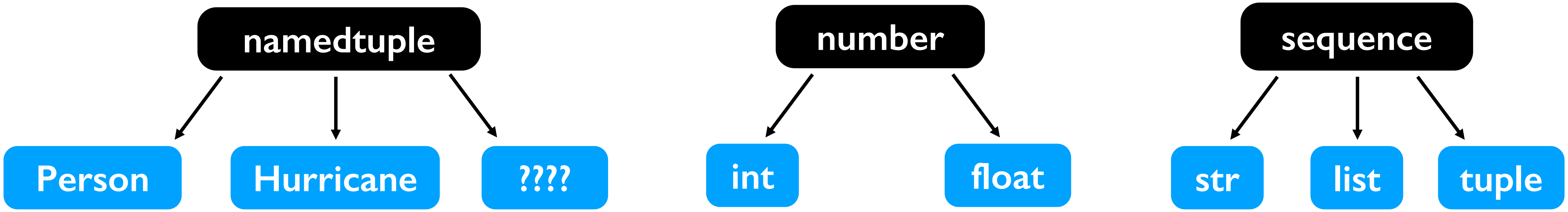
need to import this data struct

name of that type

creates a new type!

name of that type

```python
Person = namedtuple("Person", ["fname", "lname", "age"])
```



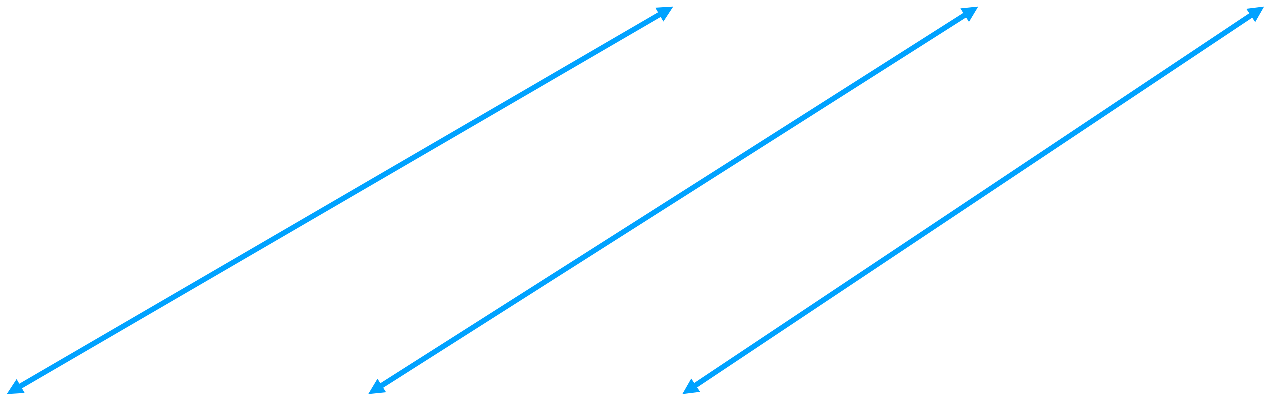
```python
p = Person("Alice", "Anderson", 30)
```

creates a object of type Person (sub type of namedtuple)
(like **`str(3)`** creates a new string or **`list()`** creates a new list)

```python
print("Hello " + p.fname + " " + p.lname)
```

```
from collections import namedtuple


Person = namedtuple("Person", ["fname", "lname", "age"])
```



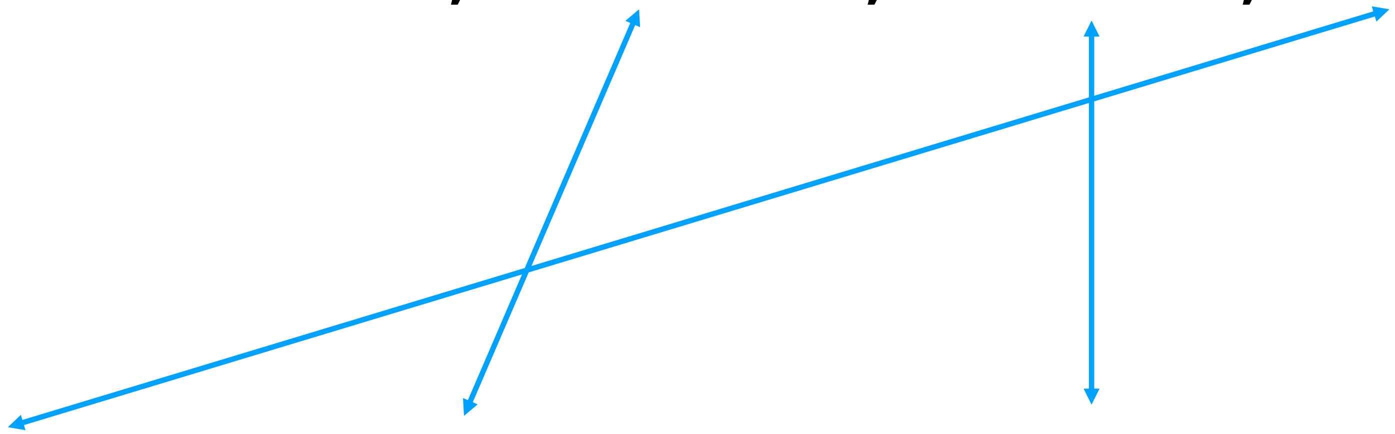
```
p = Person("Alice", "Anderson", 30)
```

can use either **positional** or keyword arguments to create a Person

```
print("Hello " + p.fname + " " + p.lname)
```

```
from collections import namedtuple
```

```
Person = namedtuple("Person", ["fname", "lname", "age"])
```



```
p = Person(age=30, fname="Alice", lname="Anderson")
```

can use either positional or **keyword** arguments to create a Person

```
print("Hello " + p.fname + " " + p.lname)
```

```
from collections import namedtuple

Person = namedtuple("Person", ["fname", "lname", "age"])

p = Person(age=30, Fname="Alice", lname="Anderson")
```

crashes
immediately
(good!)

```
print("Hello " + p.fname + " " + p.lname)
```

```python
from collections import namedtuple

Person = namedtuple("Person", ["fname", "lname", "age"])

p = Person(age=30, fname="Alice", lname="Anderson")
```

```python
print("Hello " + p.fname + " " + p.lname)
```

Today's Outline

New Types of Objects

- tuple
- namedtuple

References

- motivation
- bugs: accidental argument modification

Today's Outline

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- Mental Model for State (v2)
- examples and bugs: accidental argument modification

New Types of Objects

- tuple
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Motivation for objects and references

- why do we need this new mental model?

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

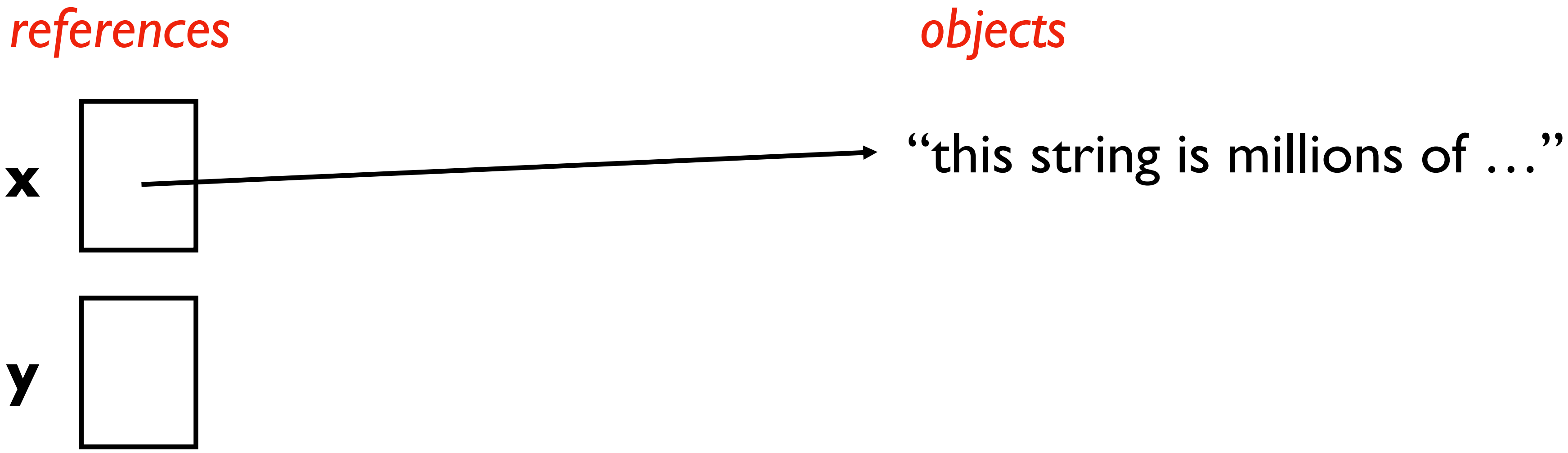
Why not follow the original organization we saw for everything (*i.e.*, boxes of data with labels)?

Reason 1: Performance

Code:

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

State:



references

objects

x

y

"this string is millions of …"

Reason 1: Performance

Code:

```
x = “this string is millions of characters…”
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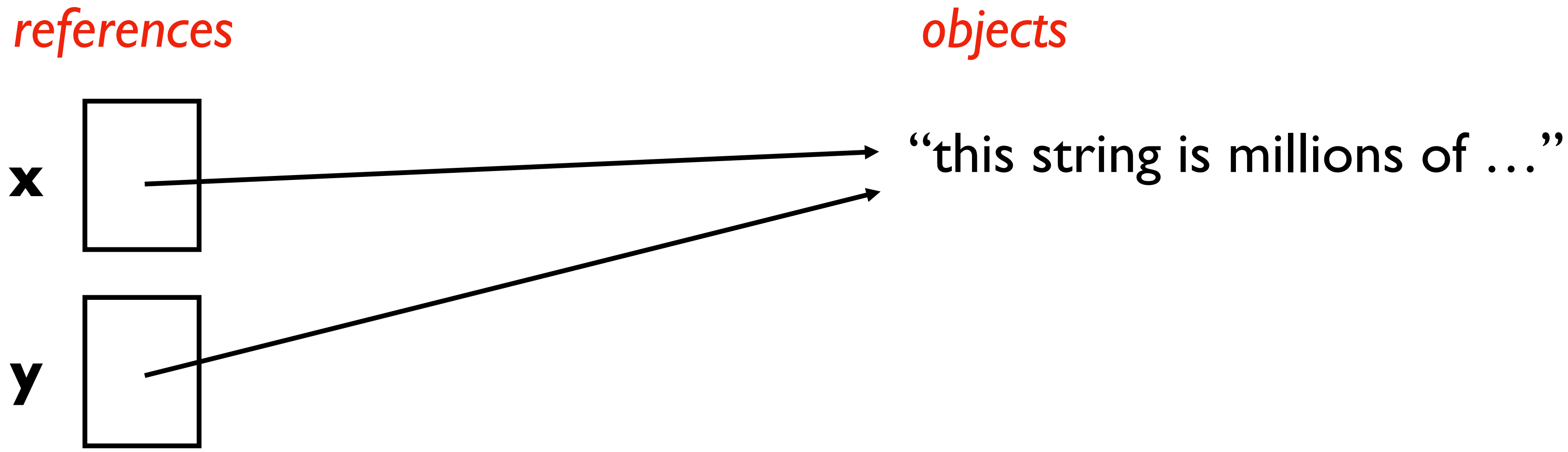
State:



references

objects

x

y

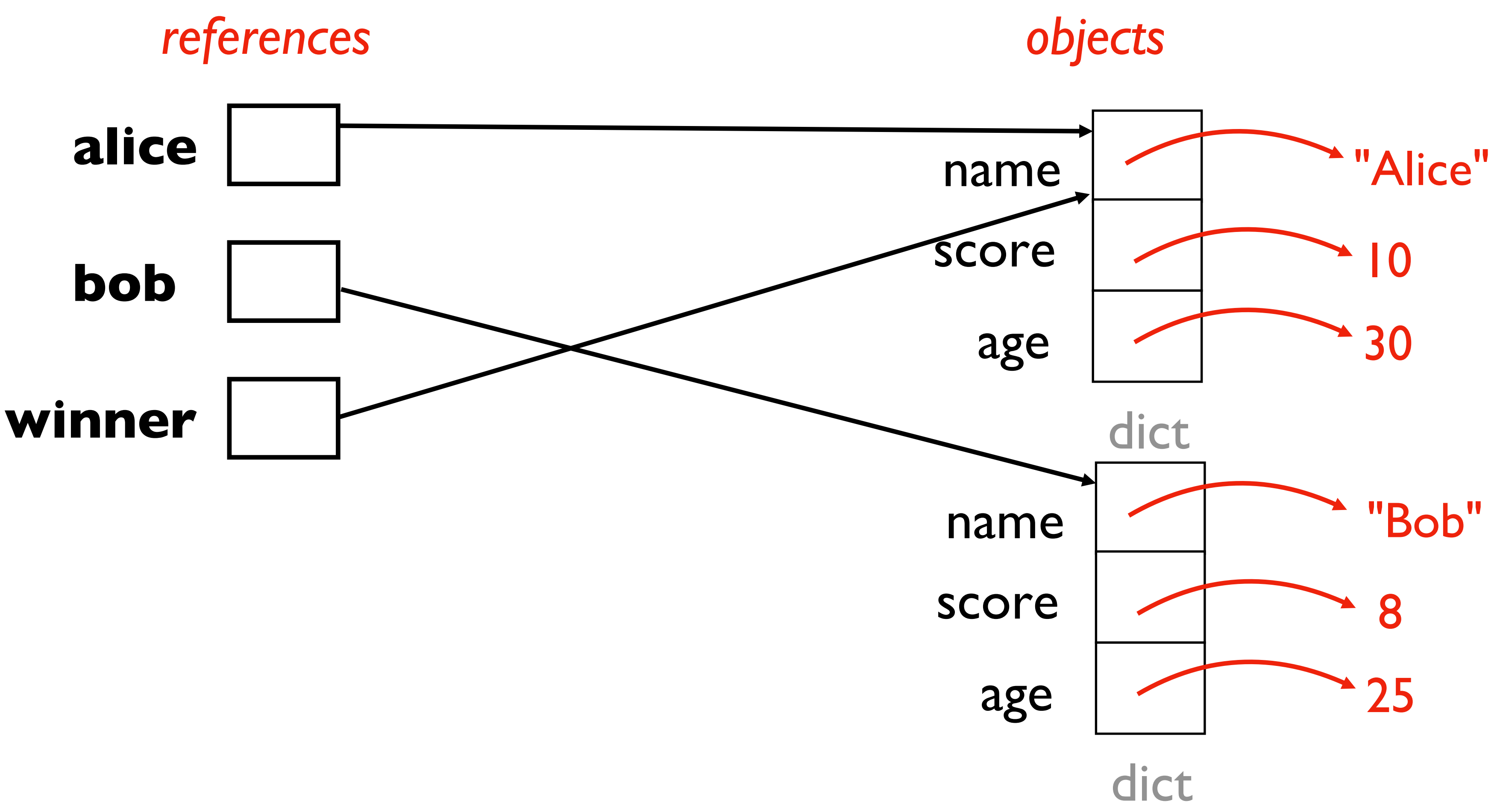
“this string is millions of …”

Reason 2: Centralized Updates

```
alice = {"name":"Alice", "score":10, "age":30}
bob = {"name":"Bob", "score":8, "age":25}
winner = alice

alice["age"] += 1
print("Winner age:", winner["age"])
```

State:



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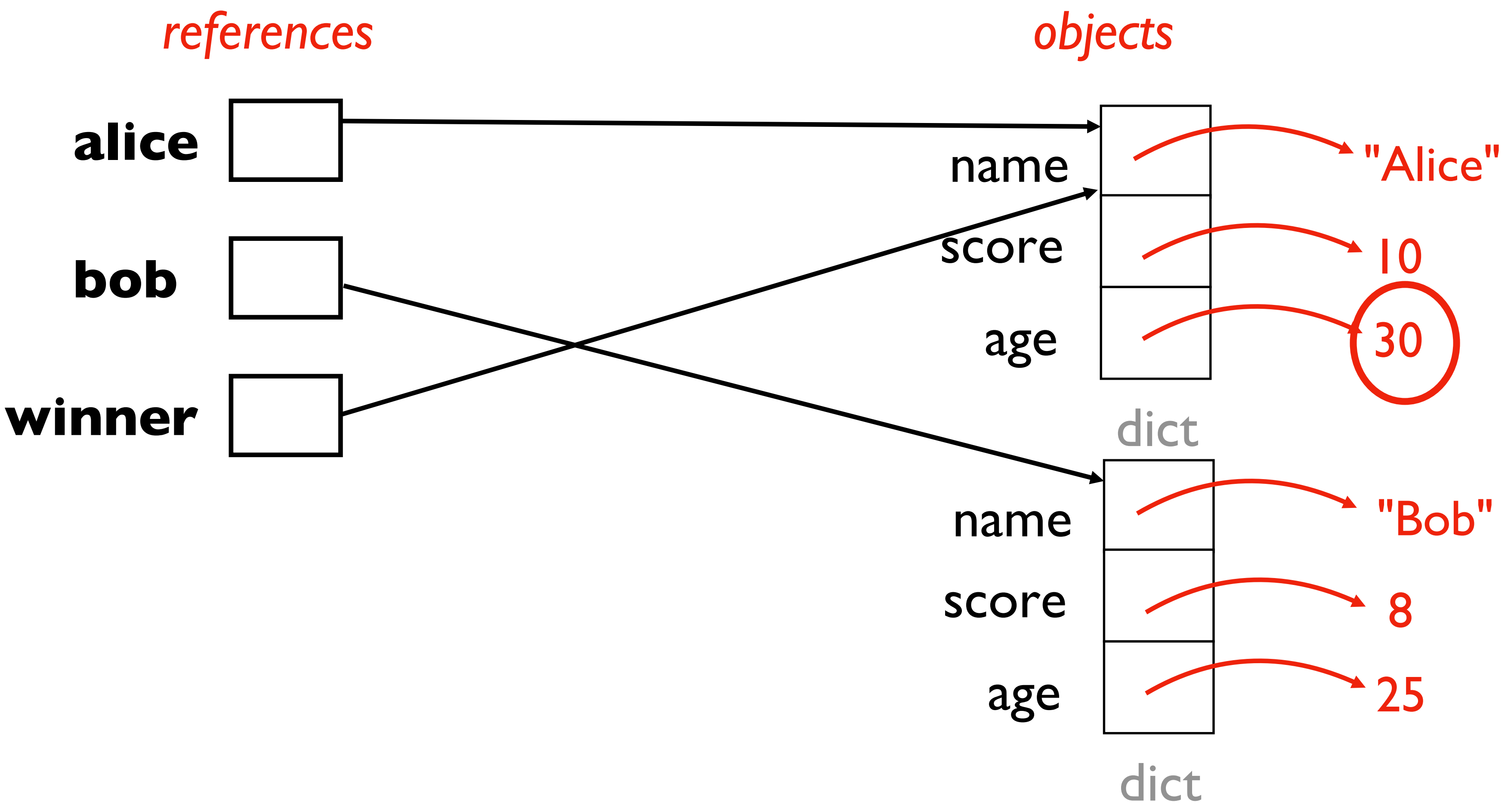
State:



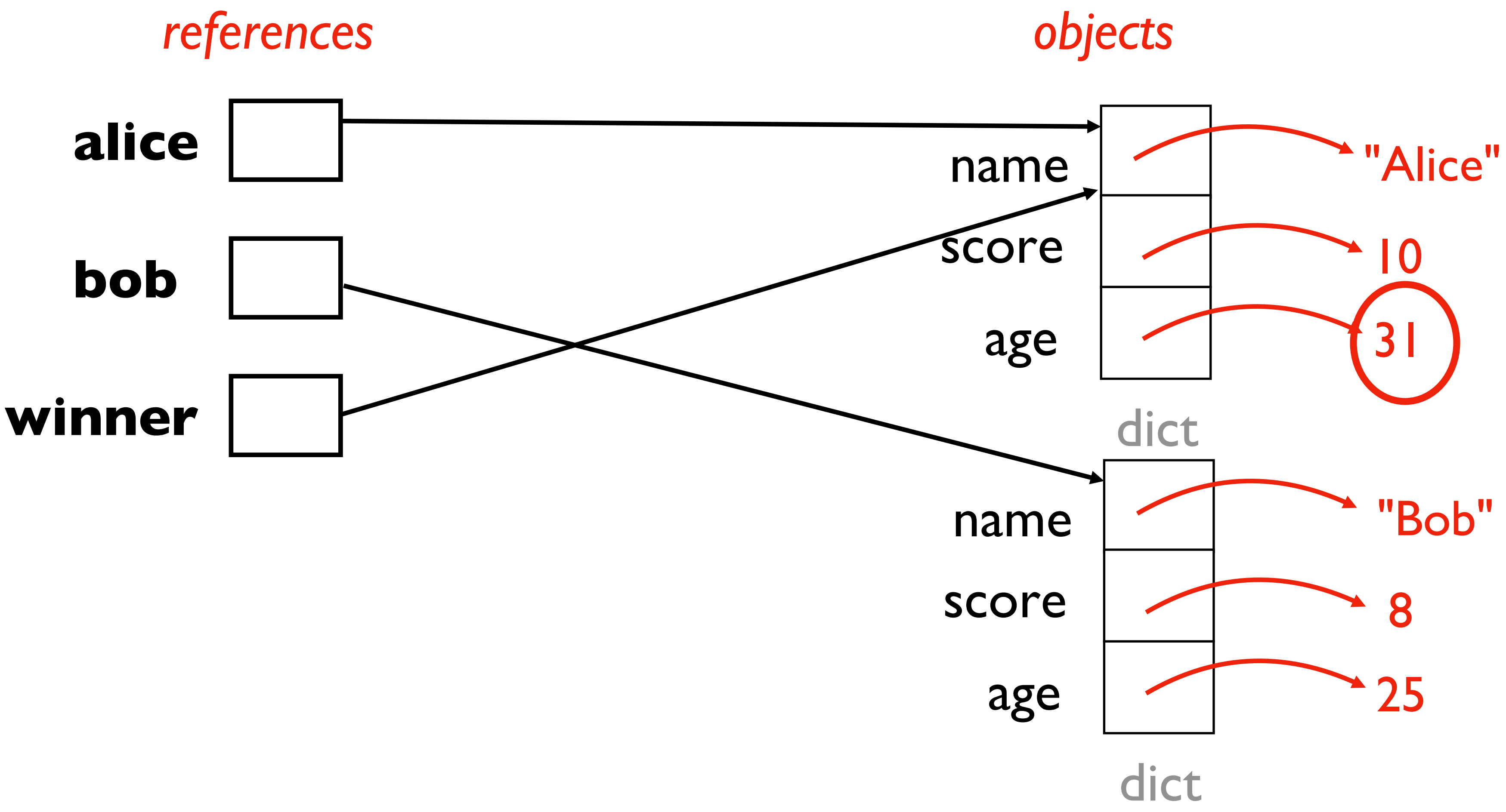
Reason 2: Centralized Updates

```
alice = {"name":"Alice", "score":10, "age":30}
bob = {"name":"Bob", "score":8, "age":25}
winner = alice

alice["age"] += 1
print("Winner age:", winner["age"])
```

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

State:



Conclusion

New Types of Objects

- tuple: immutable equivalent as list
- namedtuple: make your own immutable types!
  - choose names, don't need to remember positions

References

- motivation: faster and allows centralized update
- gotchas: mutating a parameter affects arguments