

CS 220 / CS319

Tuples

Objects and References

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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

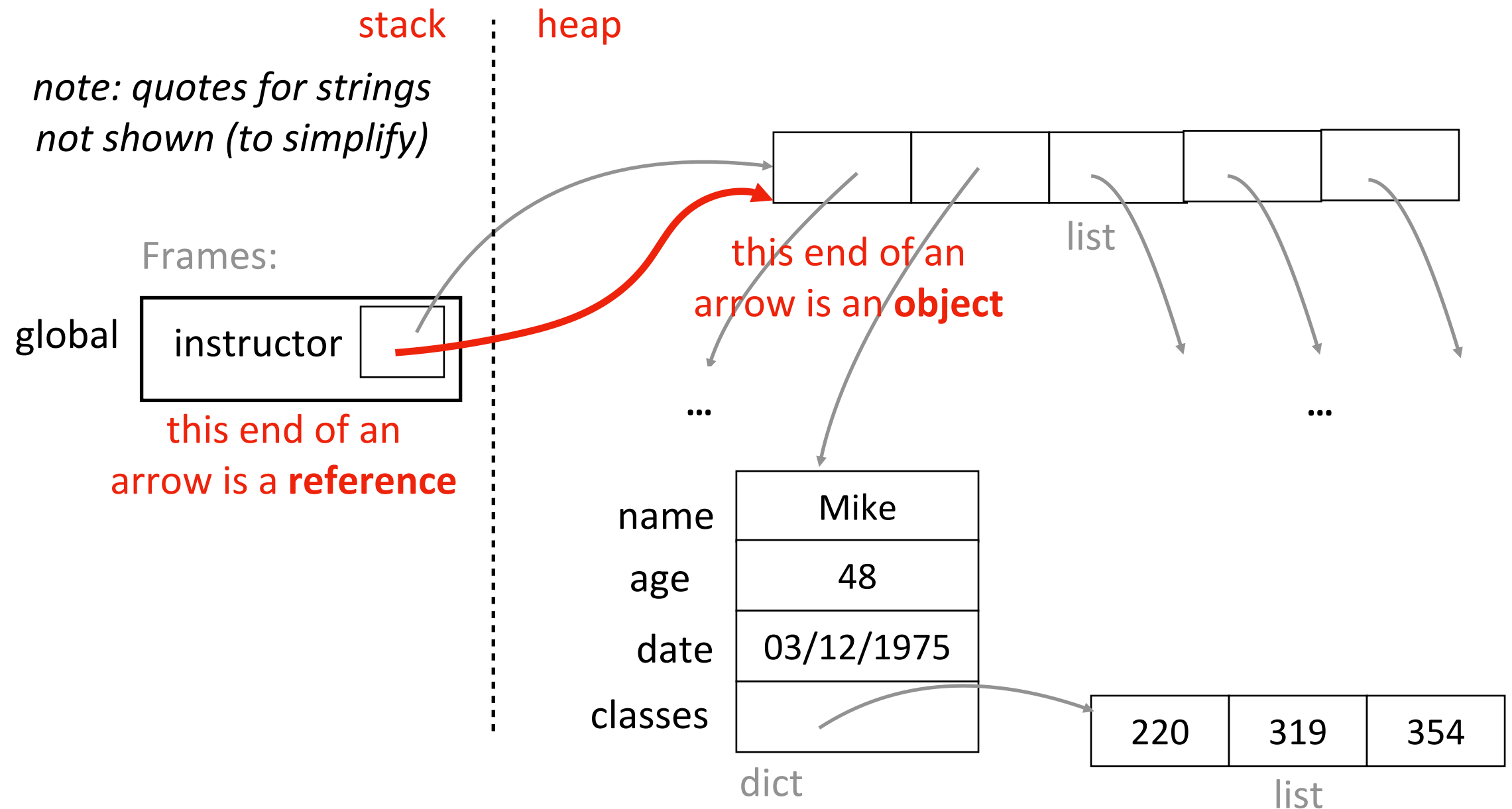
2

list

3

dict

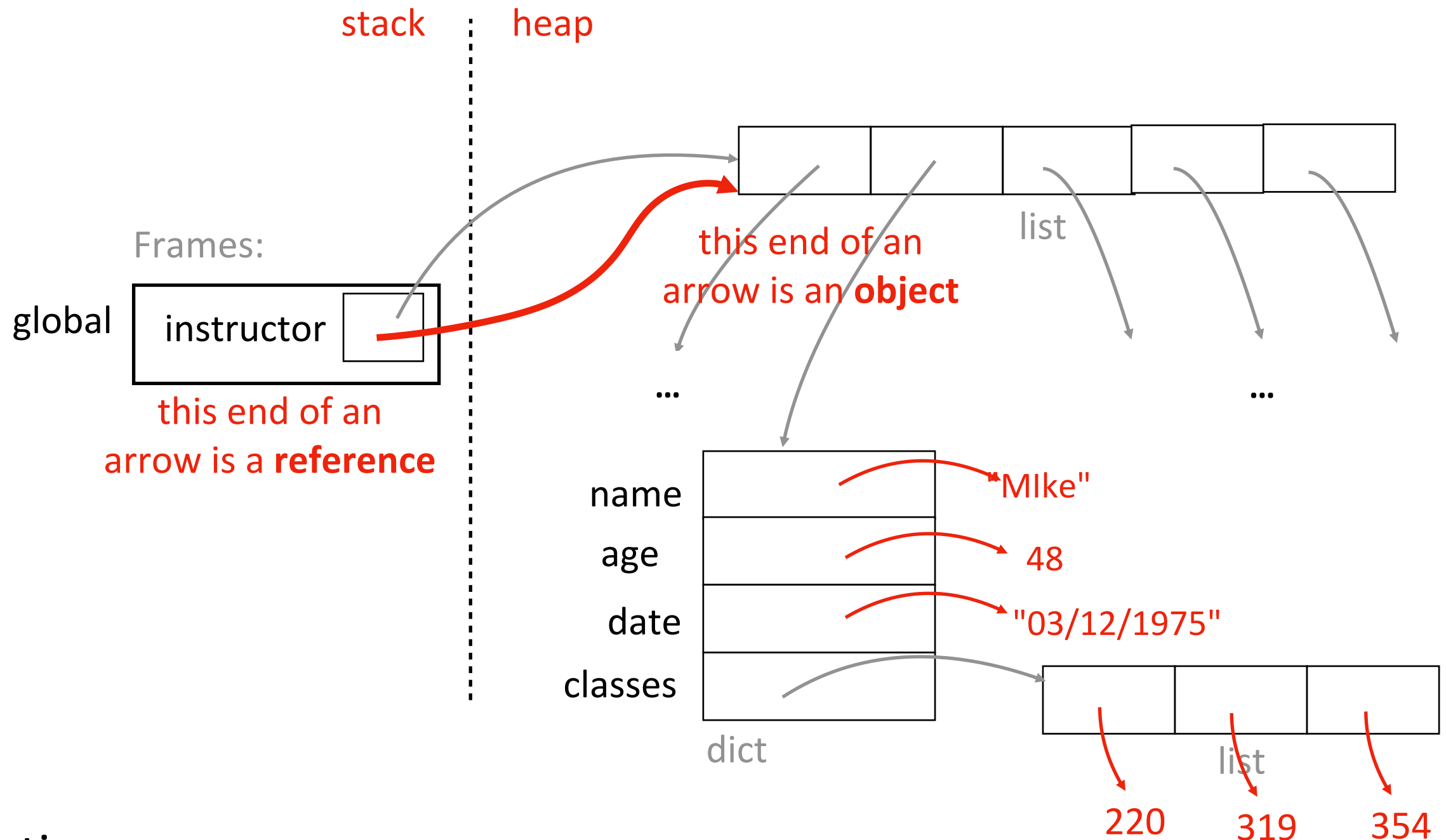
Objects and References



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

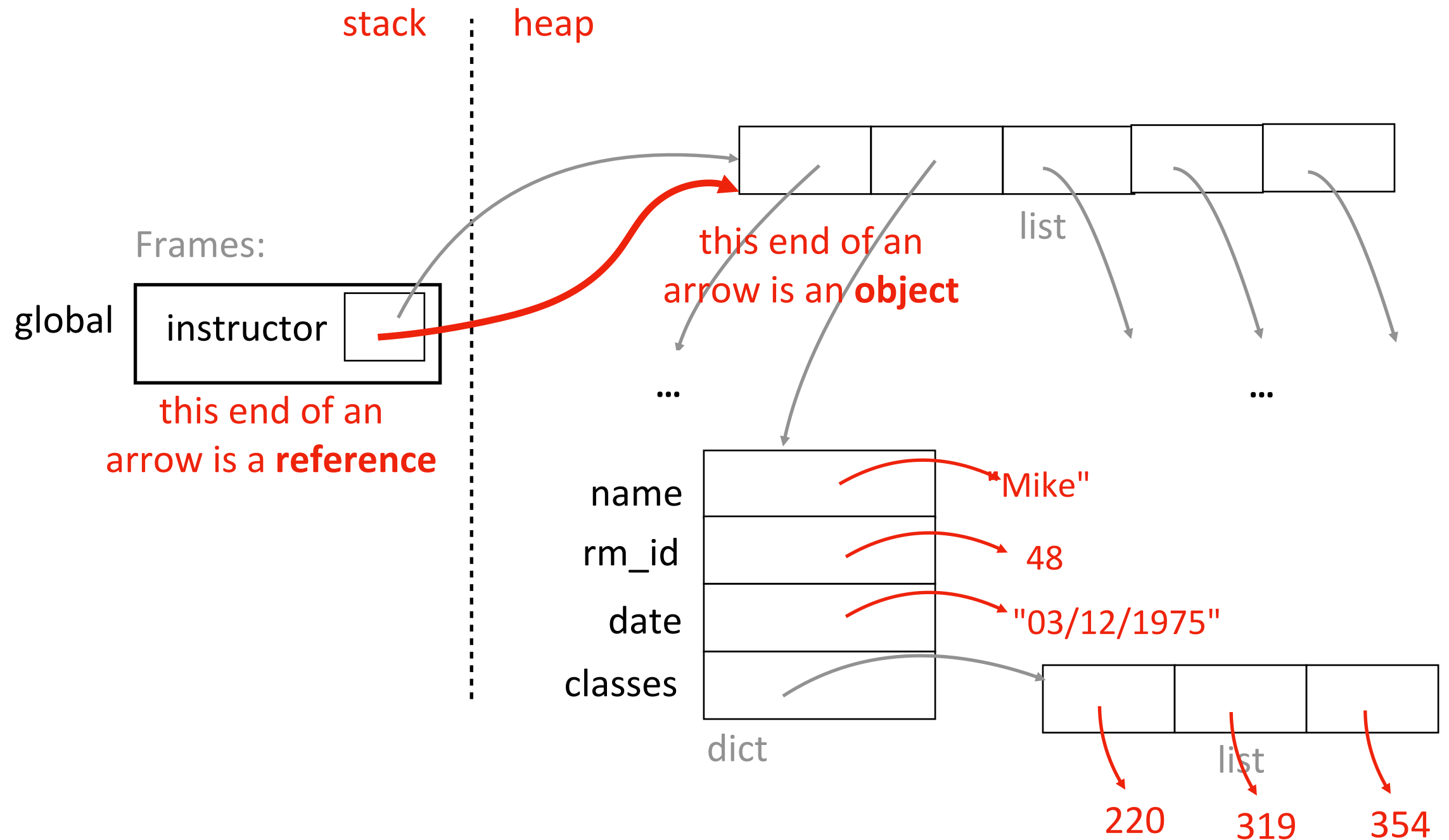
Objects and References



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



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

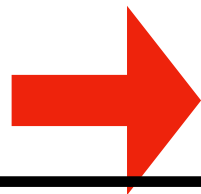
Motivation for objects and references

- 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:

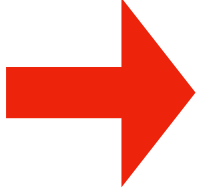
x hello

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

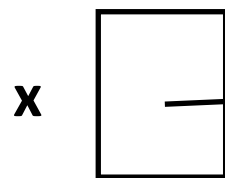
Mental Model for State (v2)

Code:

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

State:

references



objects

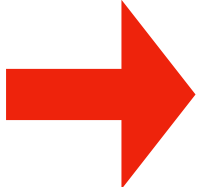
"hello"

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

Mental Model for State (v2)

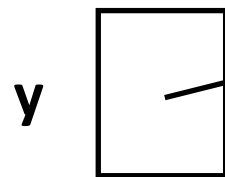
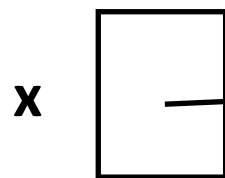
Code:

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



State:

references



objects

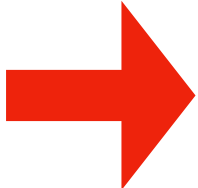
"hello"



Mental Model for State (v2)

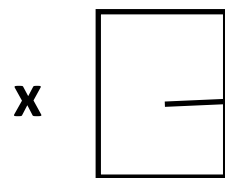
Code:

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



State:

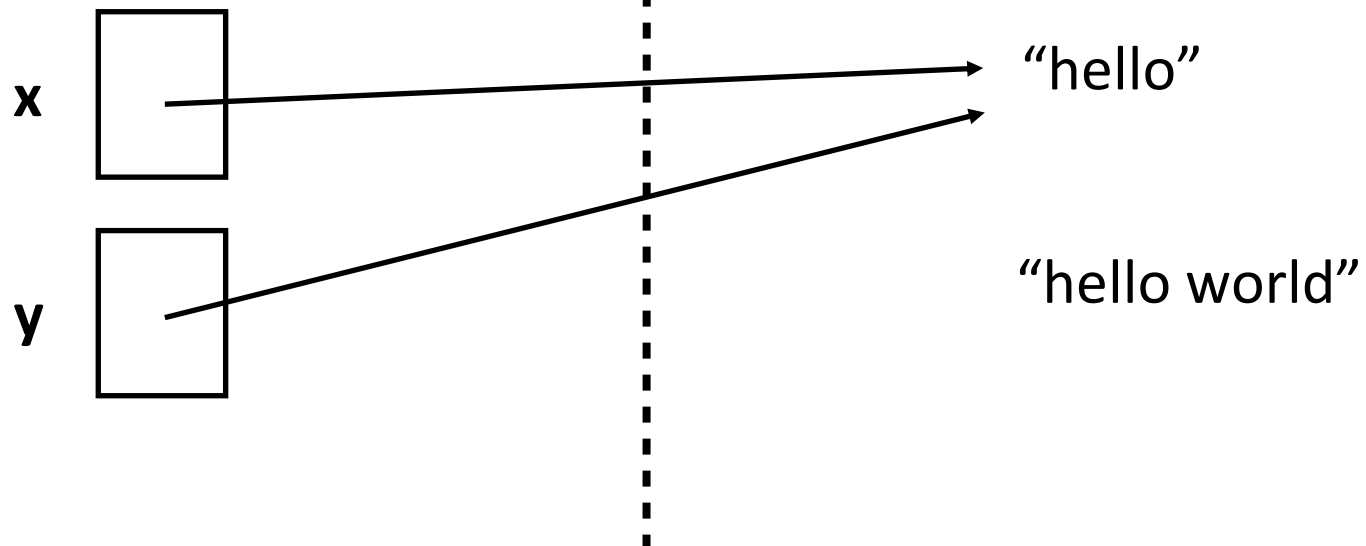
references



objects

"hello"

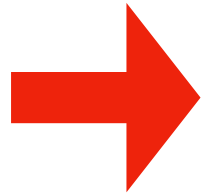
"hello world"



Mental Model for State (v2)

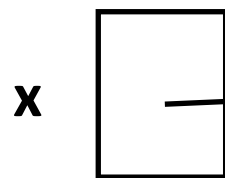
Code:

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



State:

references



objects

"hello"

"hello world"

—

—



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

Imagine a hidden y = x statement

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

- 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?

References and Arguments/Parameters

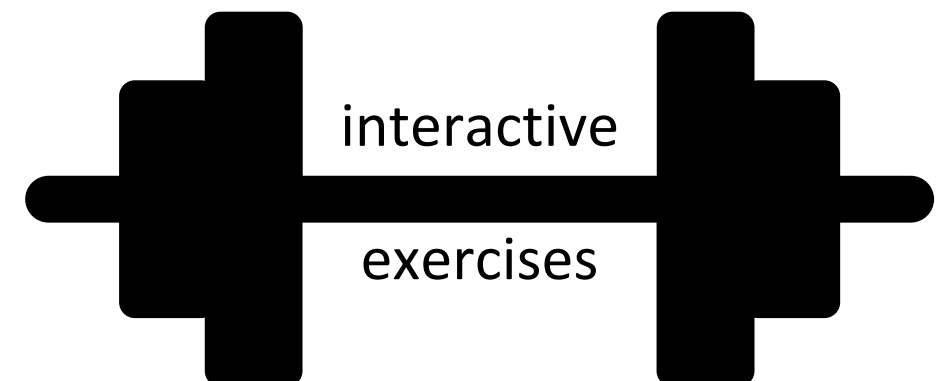
Python Tutor **always** illustrates references with an arrow for mutable types

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

Example 1: reassign parameter

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

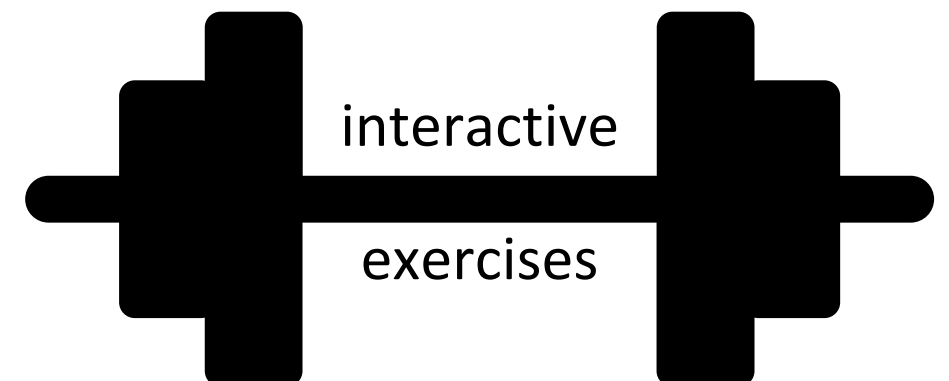
```
num = 10  
f(num)  
print("after:", num)
```



Example 2: modify list via param

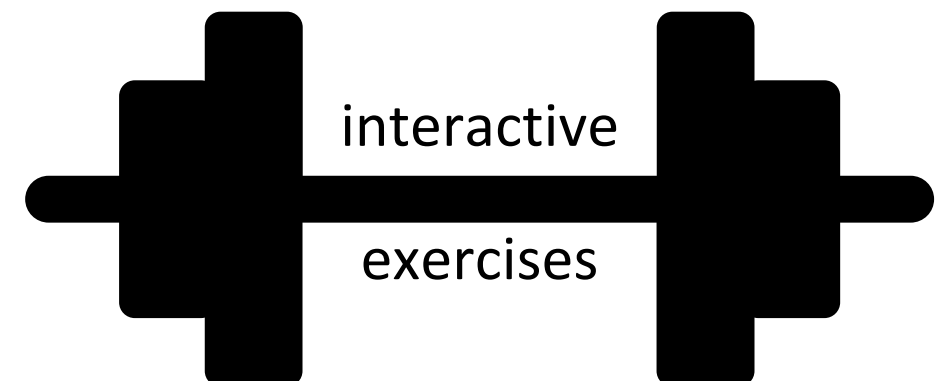
```
def f(items):  
    items.append("!!!")  
    print("f:", items)
```

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



Example 3: reassign new list to param

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

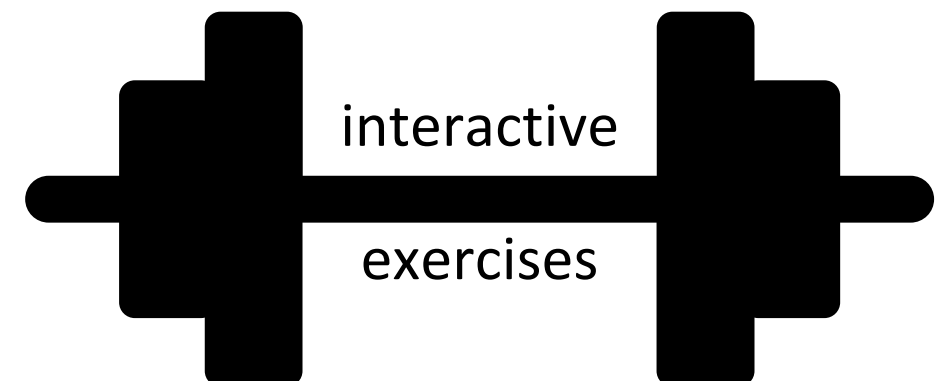


Example 4: in-place sort

```
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))
```

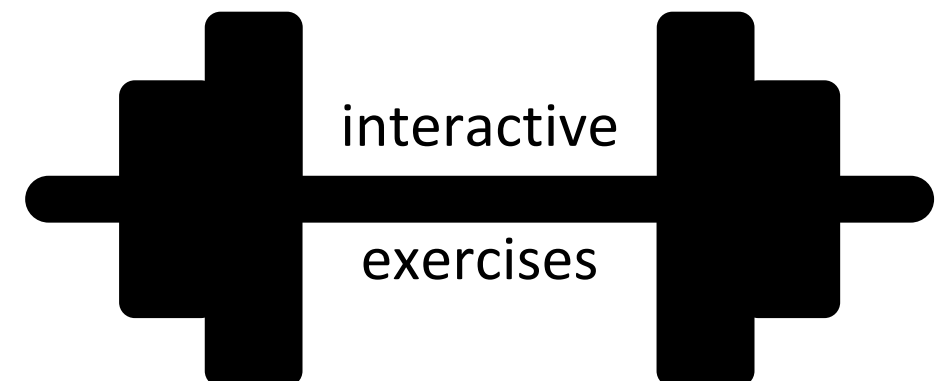


Example 5: sorted sort

```
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))
```



Today's Outline

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- examples and bugs: accidental argument modification

New Types of Objects

- tuple
- namedtuple

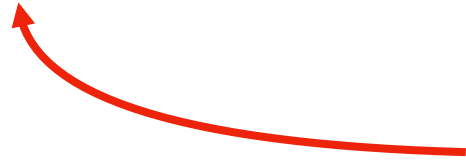
Motivation for objects and references

- why do we need this new mental model?

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`  **Crashes!**

changes list to
[99, 100, 300]

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: $\{1, 2, 3\}$

Today's Outline

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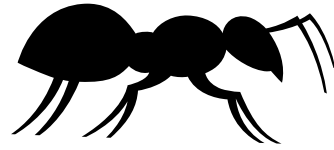
New Types of Objects

- tuple
- **namedtuple**

Motivation for objects and references

- why do we need this new mental model?

See any bugs?



1

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

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


```
from collections import namedtuple
```

need to import this data struct



name of that type



creates a new type!



name of that type



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

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

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

```
from collections import namedtuple
```

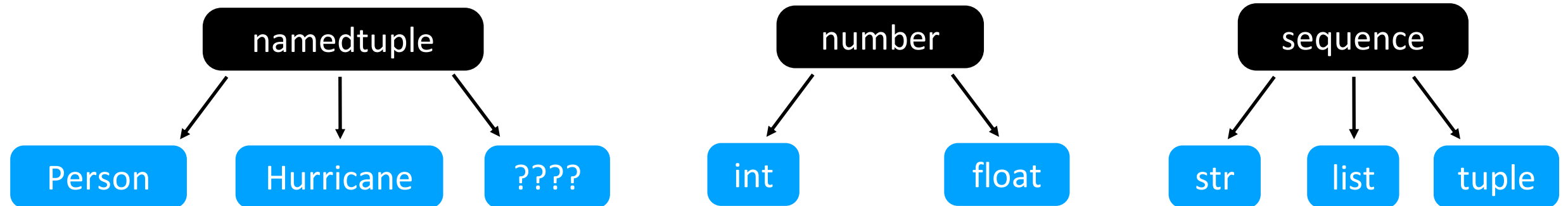
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name of that type

creates a new type!

name of that type

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



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

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

```
from collections import namedtuple
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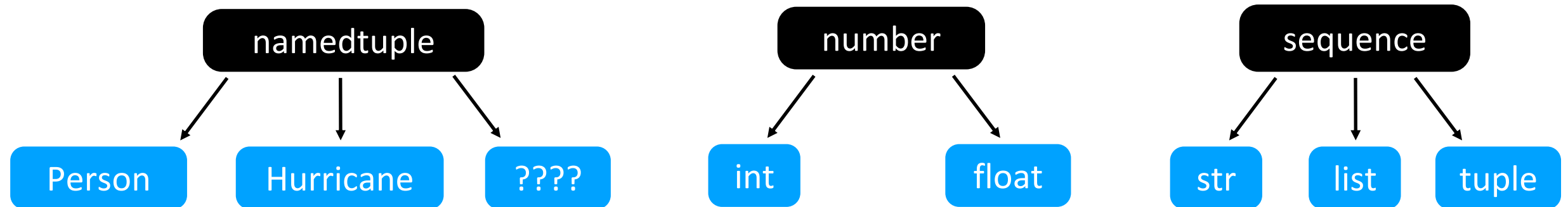
need to import this data struct

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

name of that type

creates a new type!

name of that type



```
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)

```
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")
```



The diagram consists of three blue arrows. One arrow originates from the 'p' variable in the line 'p = Person(...)' and points to the 'Person' class name in the line 'Person = namedtuple(...)'. A second arrow originates from the 'age' attribute access 'p.age' in the line 'print(... p.age ...)' and points to the 'age' field in the list '["fname", "lname", "age"]'. A third arrow originates from the 'lname' attribute access 'p.lname' in the line 'print(... p.lname ...)' and points to the 'lname' field in the same list.

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)
```

```
from collections import namedtuple
```

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

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

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



The diagram consists of two blue arrows. The first arrow originates from the `p.fname` attribute access in the `print` statement and points to the `fname="Alice"` argument in the `Person` constructor. The second arrow originates from the `p.lname` attribute access in the `print` statement and points to the `lname="Anderson"` argument in the `Person` constructor.

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
- namedtuple

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

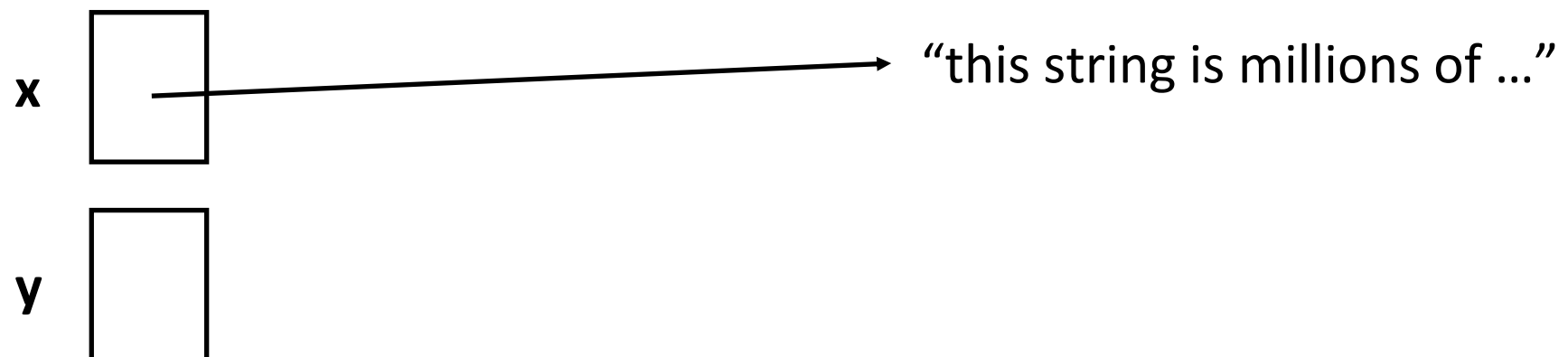
Code:

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

State:

references

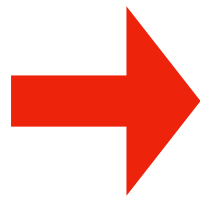
objects



Reason 1: Performance

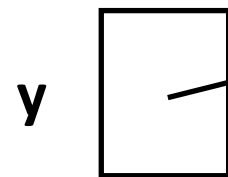
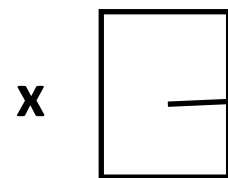
Code:

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



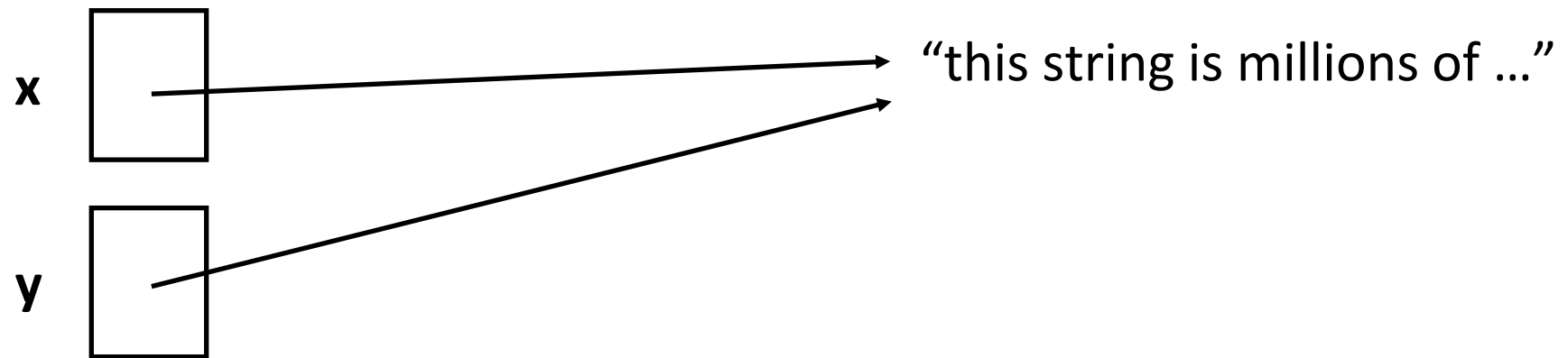
State:

references



objects

"this string is millions of ..."



Reason 2: Centralized Updates

alice = {"name": "Alice", "score": 10, "age": 30}

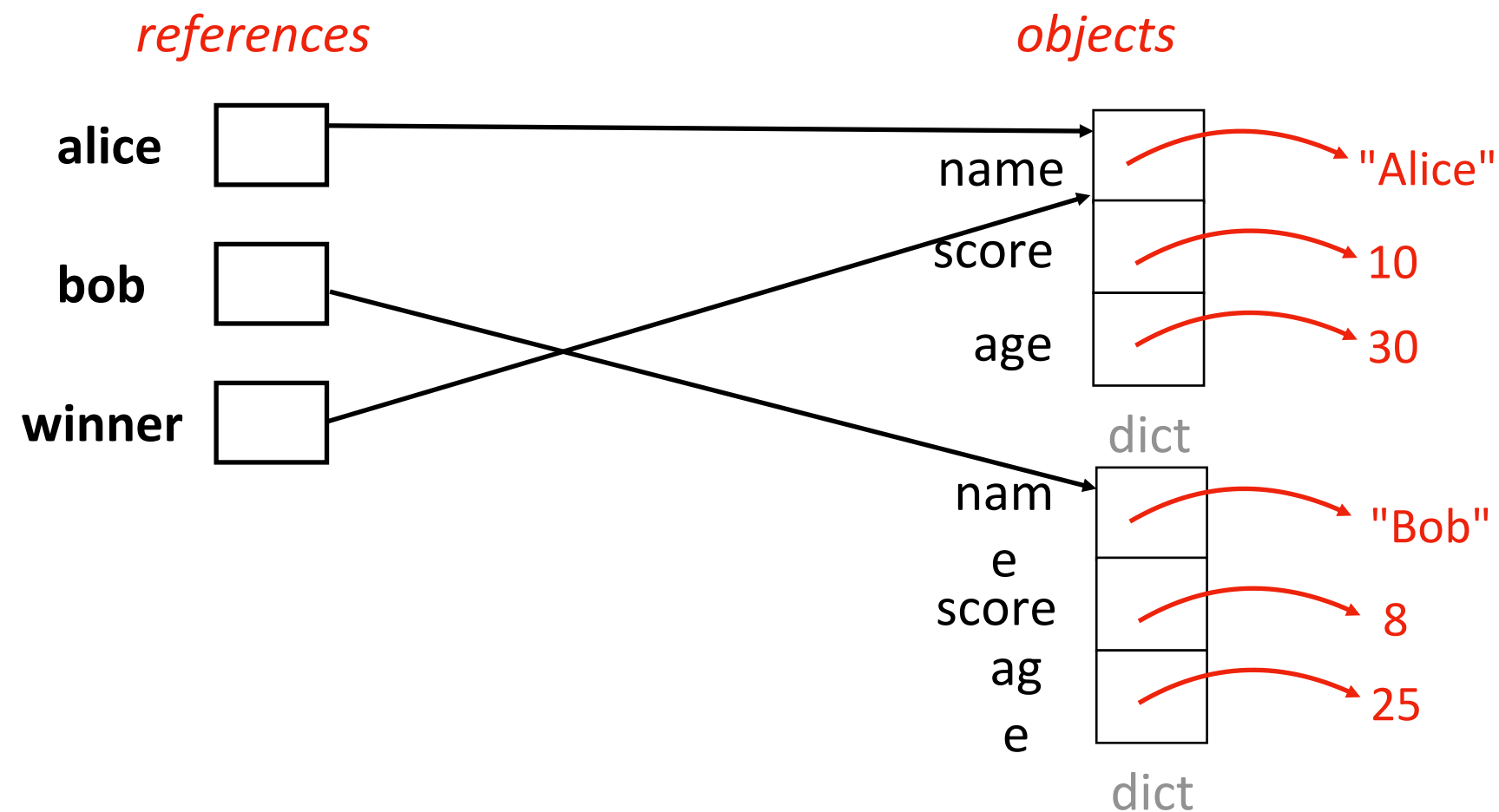
bob = {"name": "Bob", "score": 8, "age": 25}

winner = alice

alice["age"] += 1

print("Winner age:", winner["age"])

State:

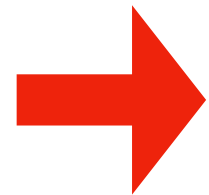


Reason 2: Centralized Updates

```
alice = {"name": "Alice", "score": 10, "age": 30}
```

```
bob = {"name": "Bob", "score": 8, "age": 25}
```

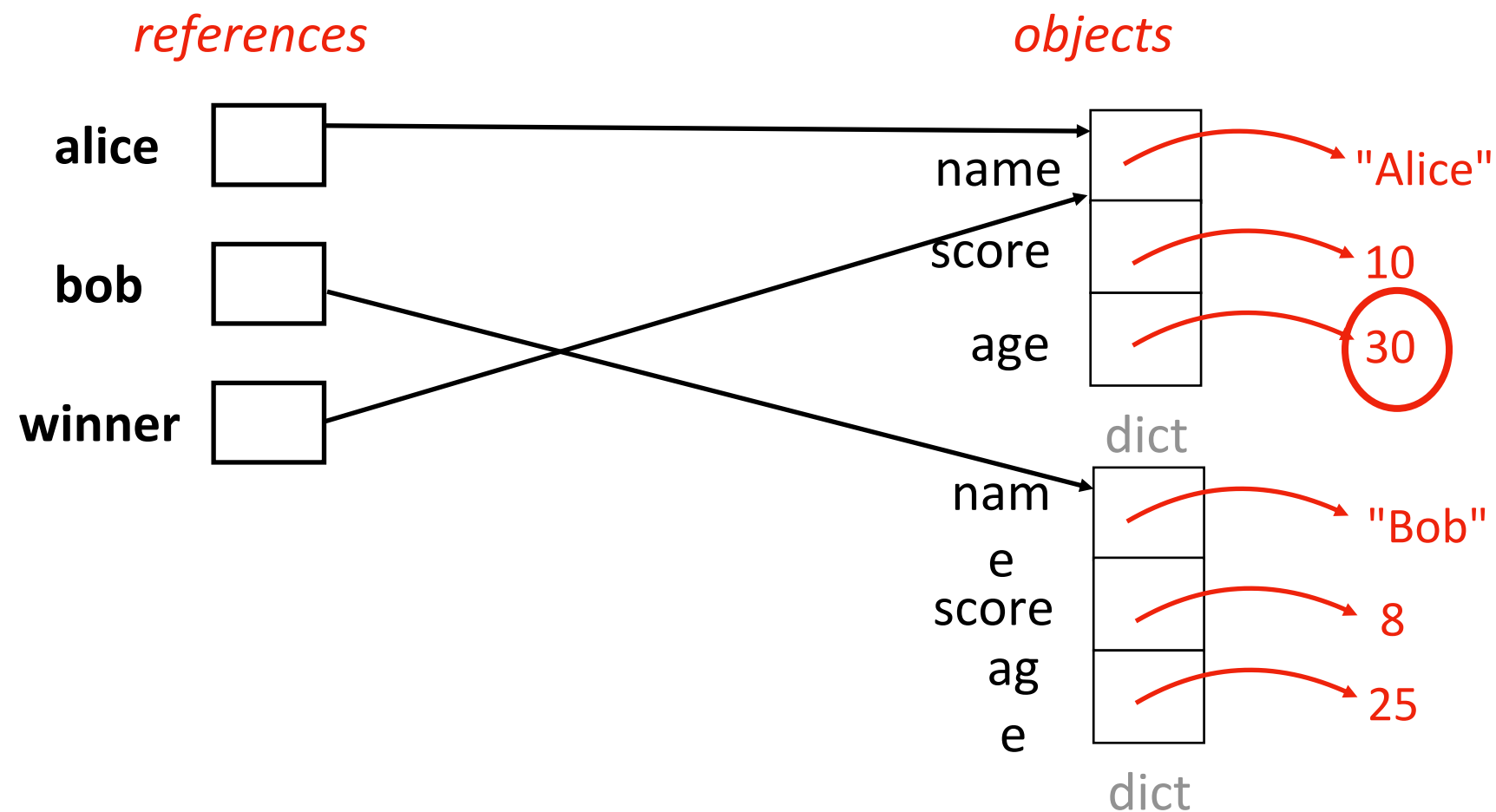
```
winner = alice
```



```
alice["age"] += 1
```

```
print("Winner age:", winner["age"])
```

State:



Reason 2: Centralized Updates

```
alice = {"name": "Alice", "score": 10, "age": 30}
```

```
bob = {"name": "Bob", "score": 8, "age": 25}
```

```
winner = alice
```

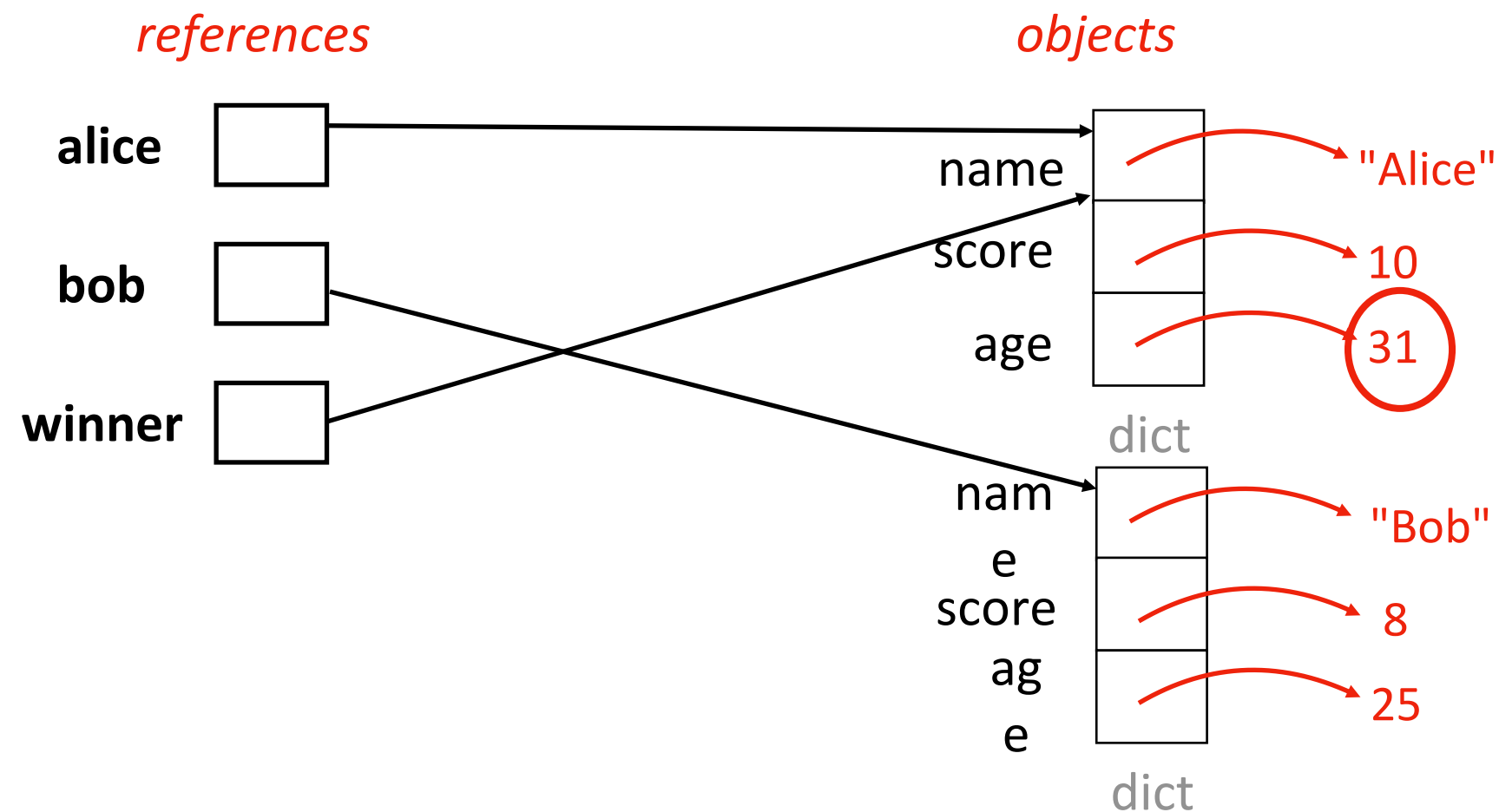


```
alice["age"] += 1
```

```
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