Programming Principles in Python (CSCI 503/490)

Functions & Dictionaries

Dr. David Koop

(some slides adapted from Dr. Reva Freedman)

List methods

Method	**Meaning**
`<list>.append(d)`	Add element `d` to end of list.
`<list>.extend(s)`	Add **all** elements in `s` to end of list.
`<list>.insert(i, d)`	Insert `d` into list at index i.
`<list>.pop(i)`	Deletes `i`th element of the list and returns its value.
`<list>.sort()`	Sort the list.
`<list>.reverse()`	Reverse the list.
`<list>.remove(d)`	Deletes first occurrence of `d` in list.
`<list>.index(d)`	Returns index of first occurrence of `d`.
`<list>.count(d)`	Returns the number of occurrences of `d` in list.

List methods

Method	Meaning Mutate
`<list>.append(d)`	Add element `d` to end of list.
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Updating collections

- There are three ways to deal with operations that update collections:
  - Returns an **updated copy** of the collection
  - Updates the collection **in place**
  - Updates the collection in place **and returns it**
- `list.sort` and `list.reverse` work **in place** and **don't return** it
- `sorted` and `reversed` return an **updated copy**
  - `reversed` actually returns an iterator
  - these also work for immutable sequences like strings and tuples

enumerate

- Often you **do not** need the index when iterating through a sequence
- If you need an index while looping through a sequence, use `enumerate`
- ```
  for i, d in enumerate(my_list):
      print("index:", i, "element:", d)
  ```
- Each time through the loop, it yields **two** items, the **index** `i` & the **element** `d`
- `i, d` is actually a **tuple**
- Automatically **unpacked** above, can manually do this, but don't!
- ```
  for t in enumerate(my_list):
      i = t[0]
      d = t[1]
      print("index:", i, "element:", d)
  ```

enumerate

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- ```
  for t in enumerate(my_list):
      i = t[0]
      d = t[1]
      print("index:", i, "element:", d)
  ```

Tuple Packing and Unpacking

- ```
  def f(a, b):
      if a > 3:
          return a, b-a # tuple packing
      return a+b, b # tuple packing
  ```
- `c, d = f(4, 3) # tuple unpacking`

- Make sure to unpack the correct number of variables!
- `c, d = a+b, a-b, 2*a # ValueError: too many values to unpack`
- Sometimes, check return value before unpacking:
  - ```
    retval = f(42)
    if retval is not None:
        c, d = retval
    ```

Tuple Packing and Unpacking

- ```
  def f(a, b):
      if a > 3:
          return a, b-a # tuple packing
      return a+b, b # tuple packing
  ```

```
t = (a, b-a)
return t
```

- `c, d = f(4, 3) # tuple unpacking`

- Make sure to unpack the correct number of variables!
- `c, d = a+b, a-b, 2*a # ValueError: too many values to unpack`
- Sometimes, check return value before unpacking:
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    retval = f(42)
    if retval is not None:
        c, d = retval
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Tuple Packing and Unpacking

- ```
  def f(a, b):
      if a > 3:
          return a, b-a # tuple packing
      return a+b, b # tuple packing
  ```
- `c, d = f(4, 3) # tuple unpacking`

```
t = (a, b-a)
return t
```

```
t = f(4, 3)
(c, d) = t
```

- Make sure to unpack the correct number of variables!
- `c, d = a+b, a-b, 2*a # ValueError: too many values to unpack`
- Sometimes, check return value before unpacking:
  - ```
    retval = f(42)
    if retval is not None:
        c, d = retval
    ```

Assignment 3

- Out Soon
-

Functions

Functions

- Call a function `f`: `f(3)` or `f(3,4)` or … depending on number of parameters
-
```
def <function-name>(<parameter-names>):
    """Optional docstring documenting the function"""
    <function-body>
```
- `def` stands for function definition
- docstring is convention used for documentation
- Remember the **colon** and **indentation**
- Parameter list can be empty: `def f(): …`

Functions

- Use `return` to return a value
- ```
  def <function-name>(<parameter-names>):
      # do stuff
      return res
  ```
- Can return more than one value using commas
- ```
  def <function-name>(<parameter-names>):
      # do stuff
      return res1, res2
  ```
- Use **simultaneous assignment** when calling:
  - `a, b = do_something(1,2,5)`
- If there is no return value, the function returns `None` (a special value)

Return

- As many return statements as you want
- Always end the function and go back to the calling code
- Returns do not need to match one type/structure (generally not a good idea)
- ```
  def f(a,b):
      if a < 0:
          return -1
      while b > 10:
          b -= a
          if b < 0:
              return "BAD"
      return b
  ```
  ```

Scope

- The **scope** of a variable refers to where in a program it can be referenced
- Python has three scopes:
  - **global**: defined outside a function
  - **local**: in a function, only valid in the function
  - **nonlocal**: can be used with nested functions
- Python allows variables in different scopes to have the **same name**

Global read

- ```
  def f(): # no arguments
      print("x in function:", x)

  x = 1
  f()
  print("x in main:", x)
  ```
- Output:
  - ```
    x in function: 1
    x in main: 1
    ```
- Here, the `x` in `f` is read from the global scope

Try to modify global?

- ```
  def f(): # no arguments
      x = 2
      print("x in function:", x)

  x = 1
  f()
  print("x in main:", x)
  ```
- Output:
  - ```
    x in function: 2
    x in main: 1
    ```
- Here, the `x` in `f` is in the local scope

Global keyword

- ```
  def f(): # no arguments
      global x
      x = 2
      print("x in function:", x)

  x = 1
  f()
  print("x in main:", x)
  ```
- Output:
  - ```
    x in function: 2
    x in main: 2
    ```
- Here, the `x` in `f` is in the global scope because of the global declaration

What is the scope of a parameter of a function?

Depends on whether Python is
pass-by-value or pass-by-reference

Pass by value

- Detour to C++ land:
  - ```
    void f(int x) {
        x = 2;
        cout << "Value of x in f: " << x << endl;
    }

    main() {
        int x = 1;
        f(x);
        cout << "Value of x in main: " << x;
    }
    ```
    ```

Pass by value

- Detour to C++ land:
  - ```
    void f(int x) {
        x = 2;
        cout << "Value of x in f: " << x << endl;
    }

    main() {
        int x = 1;
        f(x);
        cout << "Value of x in main: " << x;
    }
    ```

Output:

```
Value of x in f: 2
Value of x in main: 1
```
```

Pass by reference

- Detour to C++ land:
  - ```
    void f(int & x) {
        x = 2;
        cout << "Value of x in f: " << x << endl;
    }

    main() {
        int x = 1;
        f(x);
        cout << "Value of x in main: " << x;
    }
    ```
    ```

Pass by reference

- Detour to C++ land:
  - ```
    void f(int & x) {
        x = 2;
        cout << "Value of x in f: " << x << endl;
    }

    main() {
        int x = 1;
        f(x);
        cout << "Value of x in main: " << x;
    }
    ```
    ```

Pass by reference

- Detour to C++ land:
  - ```
    void f(int & x) {
        x = 2;
        cout << "Value of x in f: " << x << endl;
    }

    main() {
        int x = 1;
        f(x);
        cout << "Value of x in main: " << x;
    }
    ```

Output:

```
Value of x in f: 2
Value of x in main: 2
```
```

Pass by reference

- Detour to C++ land:
  - ```
    void f(int & x) {
        x = 2;
        cout << "Value of x in f: " << x << endl;
    }

    main() {
        int x = 1;
        f(x);
        cout << "Value of x in main: " << x;
    }
    ```

Output:

```
Value of x in f: 2
Value of x in main: 2
```
```

Is Python pass-by-value or pass-by-reference?

Example 1

- ```
  def change_list(inner_list):
      inner_list = [10,9,8,7,6]

  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4]
  ```

- Looks like pass by value!
  ```

Example 2

- ```
  def change_list(inner_list):
      inner_list.append(5)

  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4,5]
  ```

- Looks like pass by reference!
  ```

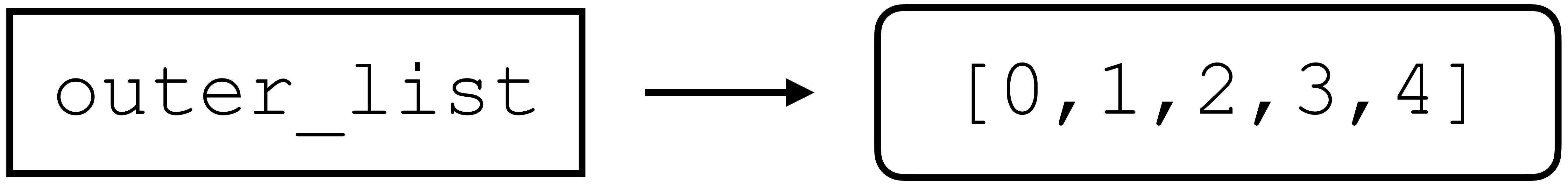
What's going on?

Think about how assignment works in Python
Different than C++

Example 1

- ```
  def change_list(inner_list):
      inner_list = [10,9,8,7,6]

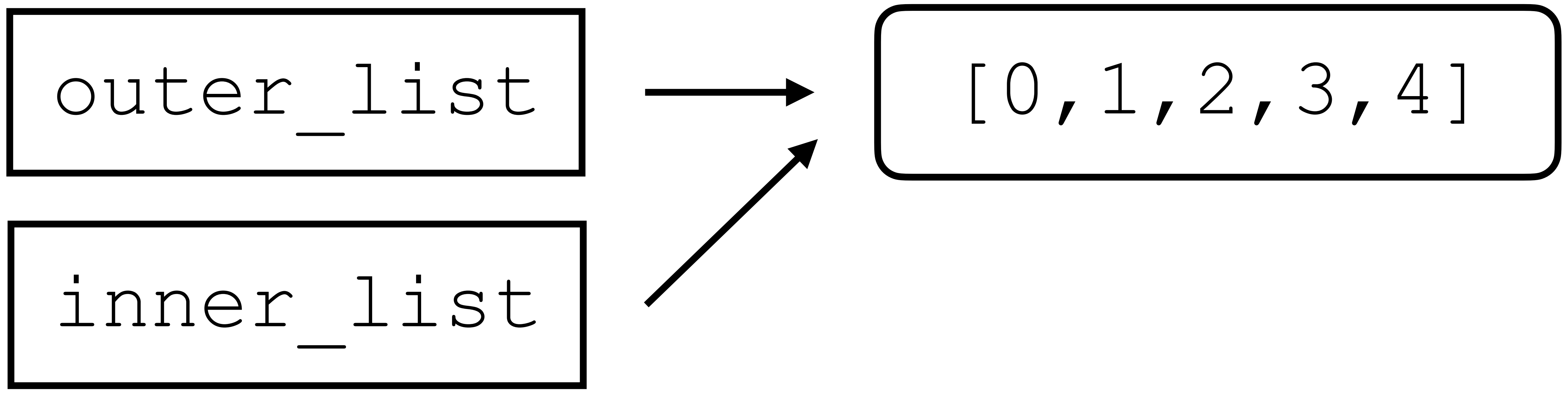
  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4]
  ```


  ```

Example 1

- **`def change_list(inner_list):`**
```
      inner_list = [10,9,8,7,6]

  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4]
```



Example 1

- ```
  def change_list(inner_list):
      inner_list = [10,9,8,7,6]

  outer_list = [0,1,2,3,4]
  change_list(outer_list)
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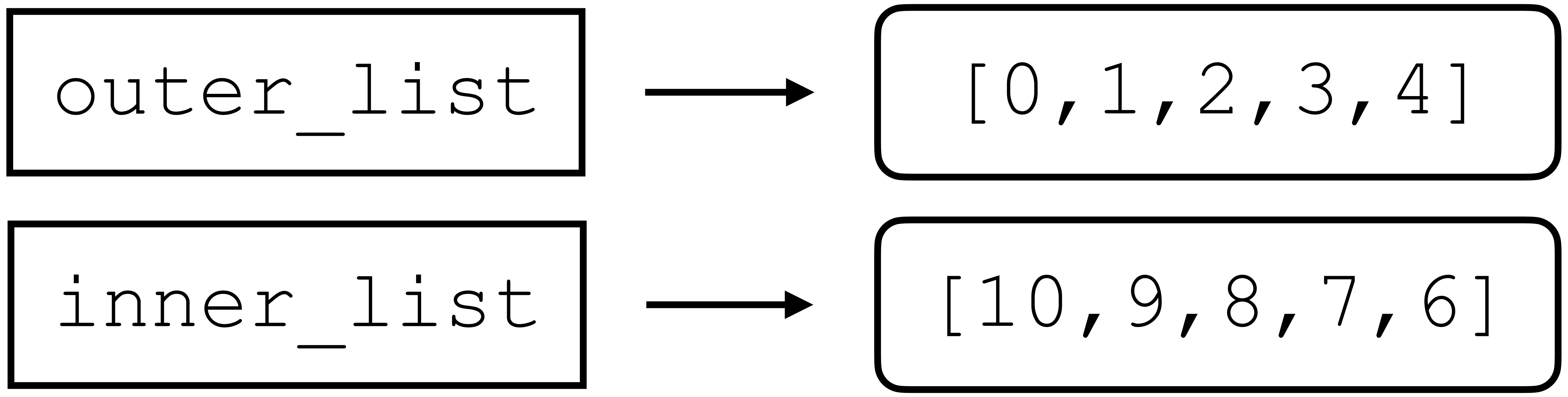
  ```


  ```

Example 1

```
def change_list(inner_list):
    inner_list = [10,9,8,7,6]

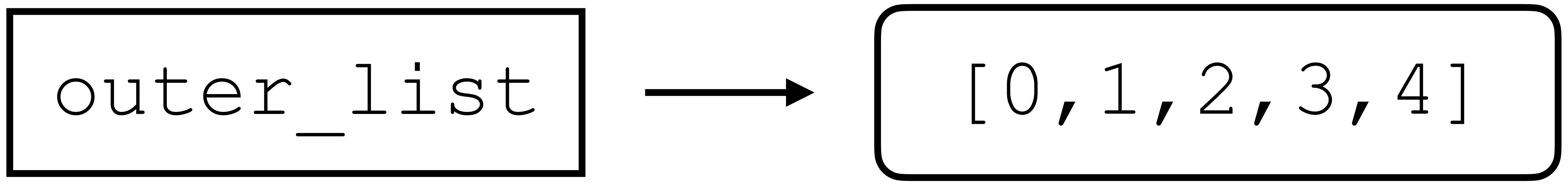
outer_list = [0,1,2,3,4]
change_list(outer_list)
outer_list # [0,1,2,3,4]
```

outer_list → [0,1,2,3,4]

Example 2

- ```
  def change_list(inner_list):
      inner_list.append(5)

  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4,5]
  ```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- ```
  def change_list(inner_list):
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  outer_list # [0,1,2,3,4,5]
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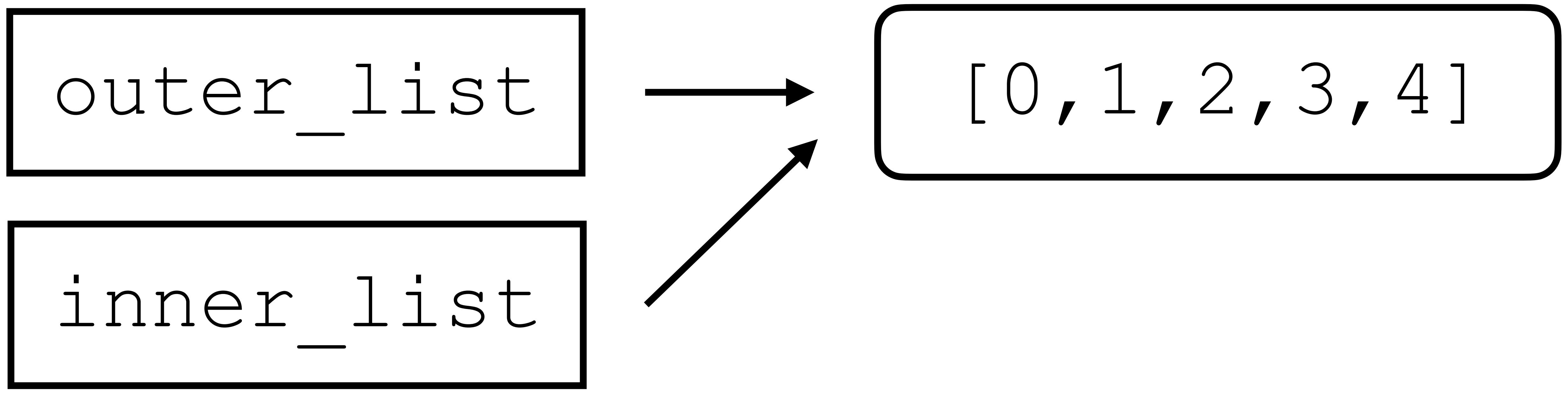
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  def change_list(inner_list):
      inner_list.append(5)

  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4,5]
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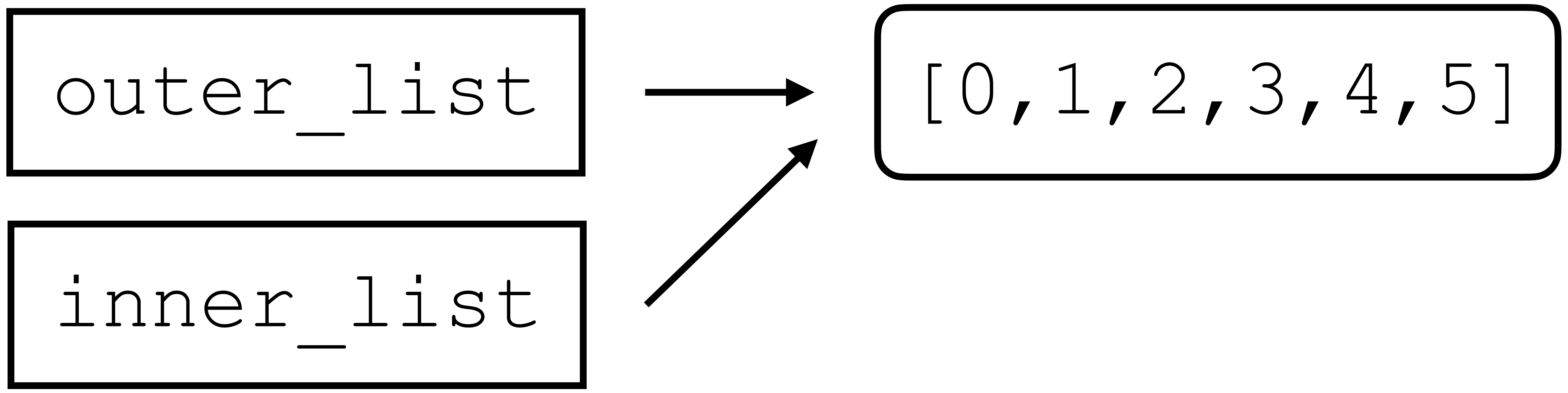
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Example 2

- ```
  def change_list(inner_list):
      inner_list.append(5)

  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4,5]
  ```

`outer_list` → `[0,1,2,3,4,5]`
  ```

Pass by object reference

- AKA passing object references by value
- Python doesn't allocate space for a variable, it just links identifier to a value
- **Mutability** of the object determines whether other references see the change
- Any immutable object will act like pass by value
- Any mutable object acts like pass by reference unless it is reassigned to a new value

Remember: global allows assignment in functions

- ```
  def change_list():
      global a_list
      a_list = [10,9,8,7,6]

  a_list = [0,1,2,3,4]
  change_list()
  a_list # [10,9,8,7,6]
  ```
  ```

Default Parameter Values

- Can add `=<value>` to parameters
- ```
  def rectangle_area(width=30, height=20):
      return width * height
  ```
- All of these work:
  - `rectangle_area() # 600`
  - `rectangle_area(10) # 200`
  - `rectangle_area(10,50) # 500`
- If the user does not pass an argument for that parameter, the parameter is set to the default value
- Cannot add non-default parameters after a defaulted parameter
  - ~~`def rectangle_area(width=30, height)`~~

[Deitel & Deitel]
  ```

Don't use mutable values as defaults!

- ```
  def append_to(element, to=[]):
      to.append(element)
      return to
  ```
- ```
  my_list = append_to(12)
  my_list # [12]
  ```
- ```
  my_other_list = append_to(42)
  my_other_list # [12, 42]
  ```

[K. Reitz and T. Schlusser]
  ```

Use None as a default instead

- ```
  def append_to(element, to=None):
      if to is None:
          to = []
      to.append(element)
      return to
  ```
- ```
  my_list = append_to(12)
  my_list # [12]
  ```
- ```
  my_other_list = append_to(42)
  my_other_list # [42]
  ```

- If you're not mutating, this isn't an issue

[K. Reitz and T. Schlusser]
  ```

Keyword Arguments

- Keyword arguments allow someone calling a function to specify exactly which values they wish to specify without specifying all the values
- This helps with long parameter lists where the caller wants to only change a few arguments from the defaults
- ```
  def f(alpha=3, beta=4, gamma=1, delta=7, epsilon=8, zeta=2,
        eta=0.3, theta=0.5, iota=0.24, kappa=0.134):
      # …
  ```
- `f(beta=12, iota=0.7)`
  ```

Positional & Keyword Arguments

- Generally, any argument can be passed as a keyword argument
- ```
  def f(alpha, beta, gamma=1, delta=7, epsilon=8, zeta=2,
           eta=0.3, theta=0.5, iota=0.24, kappa=0.134):
      # …
  ```
- `f(5,6)`
- `f(alpha=7, beta=12, iota=0.7)`
  ```

Position-Only Arguments

- PEP 570 introduced position-only arguments
- Sometimes it makes sense that certain arguments must be position-only
- Certain functions (those implemented in C) only allow position-only: `pow`
- Add a slash (`/`) to delineate where keyword arguments start
-
```
def f(alpha, beta, /, gamma=1, delta=7, epsilon=8, zeta=2,
          eta=0.3, theta=0.5, iota=0.24, kappa=0.134):
      # …
```
  - `f(alpha=7, beta=12, iota=0.7) # ERROR`
  - `f(7, 12, iota=0.7) # WORKS`

Arbitrary Argument Containers

- ```
  def f(*args, **kwargs):
      # ...
  ```
- `args`: a list of arguments
- `kwargs`: a key-value dictionary of arguments
- Stars in function signature, not in use
- Can have named arguments before these arbitrary containers
- Any values set by position will not be in kwargs:
- ```
  def f(a, *args, **kwargs):
      print(args)
      print(kwargs)
  f(a=3, b=5) # args is empty, kwargs has only b
  ```

Programming Principles: Defining Functions

- List arguments in an order that makes sense
  - May be convention => `pow(x,y)` means x^y
  - May be in order of expected frequency used
- Use default parameters when meaningful defaults are known
- Use position-only arguments when there is no meaningful name or the syntax might change in the future

Calling module functions

- Some functions exist in modules (we will discuss these more later)
- Import module
- Call functions by prepending the module name plus a dot
- ```
  import math
  math.log10(100)
  math.sqrt(196)
  ```
  ```

Calling object methods

- Some functions are defined for objects like strings
- These are **instance methods**
- Call these using a similar dot-notation
- Can take arguments
- ```
  s = 'Mary'
  s.upper() # 'MARY'
  ```
- ```
  t = '   extra spaces  '
  t.strip() # 'extra spaces'
  ```
- ```
  u = '1+2+3+4'
  u.split(sep='+') # ['1','2','3','4']
  ```
  ```

Dictionaries

Dictionary

- AKA associative array or map
- Collection of key-value pairs
  - Keys are unique (repeats clobber existing)
  - Values need not be unique
- Syntax:
  - Curly brackets `{}` delineate start and end
  - Colons separate keys from values, commas separate pairs
  - `d = {'DeKalb': 783, 'Kane': 134, 'Cook': 1274, 'Will': 546}`
- No type constraints
  - `d = {'abc': 25, 12: 'abc', ('Kane', 'IL'): 123.54}`

Dictionary Examples

Keys	Key type	Values	Value type
Country names	`str`	Internet country	`str`
Decimal numbers	`int`	Roman numerals	`str`
States	`str`	Agricultural	`list of str`
Hospital patients	`str`	Vital signs	`tuple of floats`
Baseball players	`str`	Batting averages	`float`
Metric	`str`	Abbreviations	`str`
Inventory codes	`str`	Quantity in stock	`int`

[Deitel & Deitel]

Collections

- A dictionary is **not** a sequence
- Sequences are **ordered**
- Conceptually, dictionaries need no order
- A dictionary is a **collection**
- Sequences are also collections
- All collections have length (`len`), membership (`in`), and iteration (loop over values)
- Length for dictionaries counts number of key-value **pairs**
  - Pass dictionary to the `len` function
  - ```
    d = {'abc': 25, 12: 'abc', ('Kane', 'IL'): 123.54}
    len(d) # 3
    ```
    ```

Mutability

- Dictionaries are **mutable**, key-value pairs can be added, removed, updated
- (Each key must be immutable)
- Accessing elements parallels lists but with different "indices" possible
- Index → Key
- `d = {'DeKalb': 783, 'Kane': 134, 'Cook': 1274, 'Will': 546}`
- `d['Winnebago'] = 1023 # add a new key-value pair`
- `d['Kane'] = 342        # update an existing key-value pair`
- `d.pop('Will')          # remove an existing key-value pair`
- `del d['Winnebago']     # remove an existing key-value pair`

Key Restrictions

- Many types can be keys… including tuples
  - `d = {'abc': 25, 12: 'abc', ('Kane', 'IL'): 123.54}`
- …but the type must be immutable—lists cannot be keys
  - ~~`d = {['Kane', 'IL']: 2348.35, [1, 2, 3]: "apple"}`~~
- Why?

Key Restrictions

- Many types can be keys… including tuples
  - `d = {'abc': 25, 12: 'abc', ('Kane', 'IL'): 123.54}`
- …but the type must be **immutable***—lists cannot be keys
  - ~~`d = {['Kane', 'IL']: 2348.35, [1, 2, 3]: "apple"}`~~
- *technically, the type must be hashable, but having a mutable and still hashable type almost always causes problems
- Why?
  - Dictionaries are fast in Python because are implemented as hash tables
  - No matter how long the key, python hashes it stores values by hash
  - Given a key to lookup, Python hashes it and finds the value quickly (O(1))
  - If the key can mutate, the hash will not match the key!

Principle

- Be careful using floats for keys
- Why?

Principle

- Be careful using floats for keys
- ```
  a = 0.123456
  b = 0.567890

  values = [a, b, (a / b) * b, (b / a) * a]
  found = {}
  for d in values:
      found[d] = True
  len(found) # 3 !!!
  found.keys() # [0.123456, 0.56789, 0.12345599999999998]
  ```
  ```

Accessing Values by Key

- To get a value, we start with a key
- Things work as expected
  - `d['Kane'] + d['Cook']`
- If a value does not exist, get KeyError
  - `d['Boone'] > 12 # KeyError`

Membership

- The membership operator (`in`) applies to **keys**
  - `'Boone' in d # False`
  - `'Cook' in d # True`
- To check the negation (if a key doesn't exist), use `not in`
  - `'Boone' not in d # True`
  - `not 'Boone' in d # True (equivalent but less readable)`
- Membership testing is much **faster** than for a list
- Checking and accessing at once
  - `d.get('Boone')    # no error, evaluates to None`
  - `d.get('Boone', 0) # no error, evaluates to 0 (default)`

Updating multiple key-value pairs

- Update adds or replaces key-value pairs
- Update from another dictionary:
  - `d.update({'Winnebago': 1023, 'Kane': 324})`
- Update from a list of key-value tuples
  - `d.update([('Winnebago', 1023), ('Kane', 324)])`
- Update from keyword arguments
  - `d.update(Winnebago=1023, Kane=324)`
  - Only works for strings!
- Syntax for update also works for constructing a **new** dictionary
  - `d = dict([('Winnebago', 1023), ('Kane', 324)])`
  - `d = dict(Winnebago=1023, Kane=324)`

Dictionary Methods

Method	Meaning
`<dict>.clear()`	Remove all key-value pairs
`<dict>.update(other)`	Updates the dictionary with values from `other`
`<dict>.pop(k, d=None)`	Removes the pair with key `k` and returns value or default `d` if no key
`<dict>.get(k, d=None)`	Returns the value for the key `k` or default `d` if no key
`<dict>.items()`	Returns iterable view over all pairs as (key, value) tuples
`<dict>.keys()`	Returns iterable view over all keys
`<dict>.values()`	Returns iterable view over all values

Dictionary Methods

Method	**Meaning** **Mutate**
<dict>.clear()	Remove all key-value pairs
<dict>.update(other)	Updates the dictionary with values from other
<dict>.pop(k, d=None)	Removes the pair with key k and returns value or default d if no key
<dict>.get(k, d=None)	Returns the value for the key k or default d if no key
<dict>.items()	Returns iterable view over all pairs as (key, value) tuples
<dict>.keys()	Returns iterable view over all keys
<dict>.values()	Returns iterable view over all values

Iteration

- Even though dictionaries are not sequences, we can still iterate through them
- Principle: Don't depend on order
- ```
  for k in d:
      print(k, end=" ")
  ```
- This only iterates through the **keys**!
- We could get the values:
- ```
  for k in d:
      print('key:', k, 'value:', d[k], end=" ")
  ```
- …but this is kind of like counting through a sequence (not pythonic)

Dictionary Views

- ```
  for k in d.keys():      # iterate through keys
      print('key:', k)
  ```
- ```
  for v in d.values():    # iterate through values
      print('value:', v)
  ```
- ```
  for k, v in d.items(): # iterate through key-value pairs
      print('key:', k, 'value:', v)
  ```
- `keys()` is superfluous but is a bit clearer
- `items()` is the enumerate-like method
  ```

Sorting

- Order doesn't really mean anything in a dictionary
- There is **not** a `.sort` or `.reverse` method
- We can iterate through items in sorted order using `sorted`
- ```
  d = count_letters('illinois')
  for k, v in sorted(d.items()):
      print(k, ':', v)
  ```
- `reversed` also works on dictionary views
- `sorted` and `reversed` work on any iterable (thus all collections)
  ```