Programming Principles in Python (CSCI 503)

Functions

Dr. David Koop

(some slides adapted from Dr. Reva Freedman)

Sequences

- Strings `"abcde"`, Lists `[1, 2, 3, 4, 5]`, and Tuples `(1, 2, 3, 4, 5)`

- Defining a list: `my_list = [0, 1, 2, 3, 4]`
- But lists can store different types:
  - `my_list = [0, "a", 1.34]`
- Including other lists:
  - `my_list = [0, "a", 1.34, [1, 2, 3]]`
- Others are similar: tuples use parenthesis, strings are delineated by quotes (single or double)

Sequence Operations

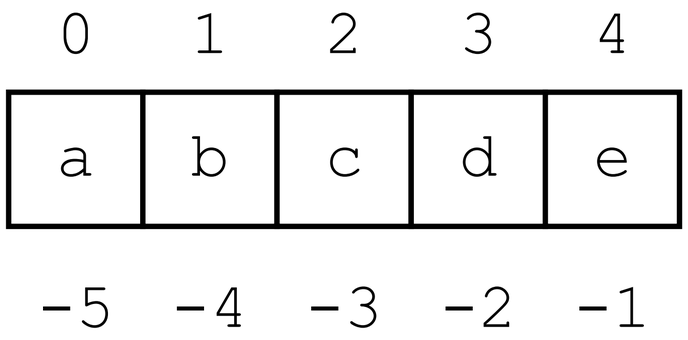
- Concatenate: `[1, 2] + [3, 4] # [1,2,3,4]`
- Repeat: `[1,2] * 3 # [1,2,1,2,1,2]`
- Length: `my_list = [1,2]; len(my_list) # 2`

- Concatenate: `(1, 2) + (3, 4) # (1,2,3,4)`
- Repeat: `(1,2) * 3 # (1,2,1,2,1,2)`
- Length: `my_tuple = (1,2); len(my_tuple) # 2`

- Concatenate: `"ab" + "cd" # "abcd"`
- Repeat: `"ab" * 3 # "ababab"`
- Length: `my_str = "ab"; len(my_str) # 2`

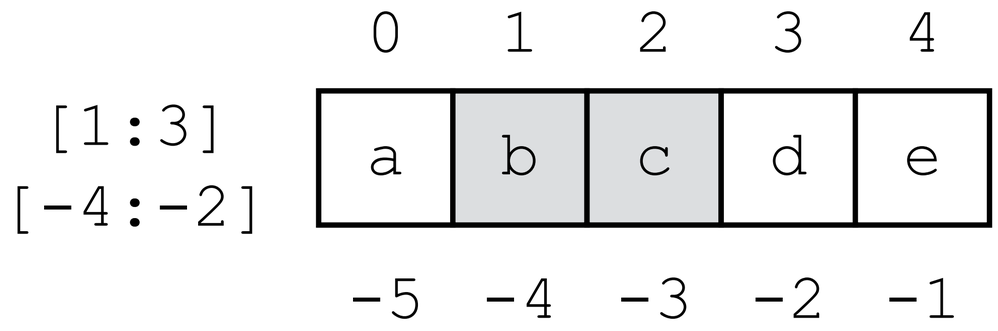
Indexing (Positive and Negative)

- Positive indices start at zero, negative at -1
- `my_str = "abcde"; my_str[1] # "b"`
- `my_list = [1,2,3,4,5]; my_list[-3] # 3`
- `my_tuple = (1,2,3,4,5); my_tuple[-5] # 1`



Slicing

- Positive or negative indices can be used at any step
- `my_str = "abcde"; my_str[1:3] # ["b", c"]`
- `my_list = [1,2,3,4,5]; my_list[3:-1] # [4]`
- Implicit indices
  - `my_tuple = (1,2,3,4,5); my_tuple[-2:] # (4,5)`
  - `my_tuple[:3] # (1,2,3)`



Iteration

- `for d in sequence:`
  `    # do stuff`
- **Important**: `d` is a **data** item, **not** an **index**!
- `sequence = "abcdef"`
  `for d in sequence:`
  `    print(d, end=" ")  # a b c d e f`
- `sequence = [1,2,3,4,5]`
  `for d in sequence:`
  `    print(d, end=" ")  # 1 2 3 4 5`
- `sequence = (1,2,3,4,5)`
  `for d in sequence:`
  `    print(d, end=" ")  # 1 2 3 4 5`

Sequence Operations

Operator	Meaning
`<seq> + <seq>`	Concatenation
`<seq> * <int-expr>`	Repetition
`<seq>[<int-expr>]`	Indexing
`len(<seq>)`	Length
`<seq>[<int-expr?>:<int-expr?>]`	Slicing
`for <var> in <seq>:`	Iteration
`<expr> in <seq>`	Membership (Boolean)

Sequence Operations

Operator	Meaning
`<seq> + <seq>`	Concatenation
`<seq> * <int-expr>`	Repetition
`<seq>[<int-expr>]`	Indexing
`len(<seq>)`	Length
`<seq>[<int-expr?>:<int-expr?>]`	Slicing
`for <var> in <seq>:`	Iteration
`<expr> in <seq>`	Membership (Boolean)

`<int-expr?>`: may be `<int-expr>` but also can be empty

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.	
`<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.	

Assignment 2

- Due Monday
- Python control flow and functions
- Do not use containers like lists (except for the extra credit)!
- Simple FRACTRAN programs
- Make sure to follow instructions
  - Name the submitted file a2.ipynb
  - Put your name and z-id in the first cell
  - Label each part of the assignment using markdown
  - Make sure to produce output according to specifications

The del statement

- `pop` works well for removing an element by index plus it **returns** the element
- Can also remove an element at index i using
  - `del my_list[i]`
- Note this is very different syntax so I prefer pop
- But del can **delete slices**
  - `del my_list[i:j]`
- Also, can delete **identifier** names completely
  -
```
a = 32
del a
a # NameError
```
- This is different than `a = None`

Updating collections

- There are three ways to deal with operations that update collections:
  - Returns an updated **copy** of the list
  - 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** the list
- Common error:

```
- sorted_list = my_list.sort() # sorted_list = None
```

- Instead:

```
- sorted_list = sorted(my_list)
```

sorted and reversed

- For both sort and reverse, have `sorted` & `reversed` which are **not** in place
- Called with the sequence as the argument
- ```
  my_list = [7, 3, 2, 5, 1]
  for d in sorted(my_list):
      print(d, end=" ")                    # 1 2 3 5 7
  ```
- ```
  my_list = [7, 3, 2, 5, 1]
  for d in reversed(my_list):
      print(d, end=" ")                    # 1 5 2 3 7
  ```
- But this doesn't work:
  - `reversed_list = reversed(my_list)`
- If you need a new list (same as with `range`):
  - `reversed_list = list(reversed(my_list))`

Reversed sort

- Both sort and sorted have a boolean parameter `reverse` that will sort the list in reverse
- ```
  my_list = [7, 3, 2, 5, 1]
  my_list.sort(reverse=True) # my_list now [7, 5, 3, 2, 1]
  ```
- ```
  for i in sorted(my_list, reverse=True):
      print(i, end = " ")    # prints 7 5 3 2 1
  ```
- There is also a `key` parameter that should be a **function** that will be called on each element before comparisons—the outputs will be used to sort
  - Example: convert to lowercase

Nested Sort

- By default, sorts by comparing inner elements in order
- `sorted([[4,2],[1,5],[1,3],[3,5]])`
  - 1st element: `1 == 1 < 3 < 4`
  - 2nd element for equal: `3 < 5`
  - Result: `[[1,3],[1,5],[3,5],[4,2]]`
- Longer lists after shorter lists:
  - `sorted([[1,2],[1]]) # [[1],[1,2]]`

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

- 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)
```

Tuples

- Tuples are **immutable** sequences
- We've actually seen tuples a couple of times already
  - Simultaneous Assignment
  - Returning Multiple Values from a Function
- Python allows us to omit parentheses when it's clear
  - `b, a = a, b` `# same as (b, a) = (a, b)`
  - `t1 = a, b` `# don't normally do this`
  - `c, d = f(2, 5, 8)` `# same as (c, d) = f(2, 5, 8)`
  - `t2 = f(2, 5, 8)` `# don't normally do this`

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
    ```

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
```

- 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
    ```

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
```

Unpacking other sequences

- You can unpack other sequences, too
  - `a, b = 'ab'`
  - `a, b = ['a', 'b']`
- Why is list unpacking rare?

Other sequence methods

- `my_list = [7, 2, 1, 12]`
- Math methods:
  - `max(my_list) # 12`
  - `min(my_list) # 1`
  - `sum(my_list) # 22`
- `zip`: combine two sequences into a single sequence of tuples
  - ```
    zip_list = list(zip(my_list, "abcd"))
    zip_list # [(1, 'a'), (2, 'b'), (7, 'c'), (12, 'd')]
    ```
  - Use this instead of using indices to count through both
    ```

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?

Neither

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!
  ```

Python lists

- Lists are **mutable**: we can change them in place:
  - ```
    my_list = [0,1,2,3,4]
    my_list.append(5)
    my_list # [0,1,2,3,4,5]
    ```
- Remember that integers, strings, floats are not mutable (immutable)
    ```

Example 2

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

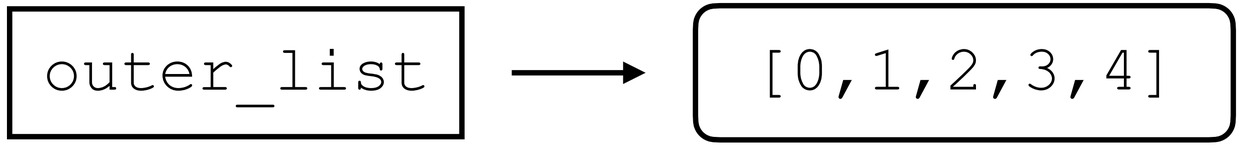
  outer_list = [0,1,2,3,4]
  change_list(outer_list)
  outer_list # [0,1,2,3,4,5]
  ```

- Looks like pass by reference!
  ```

What's going on?

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

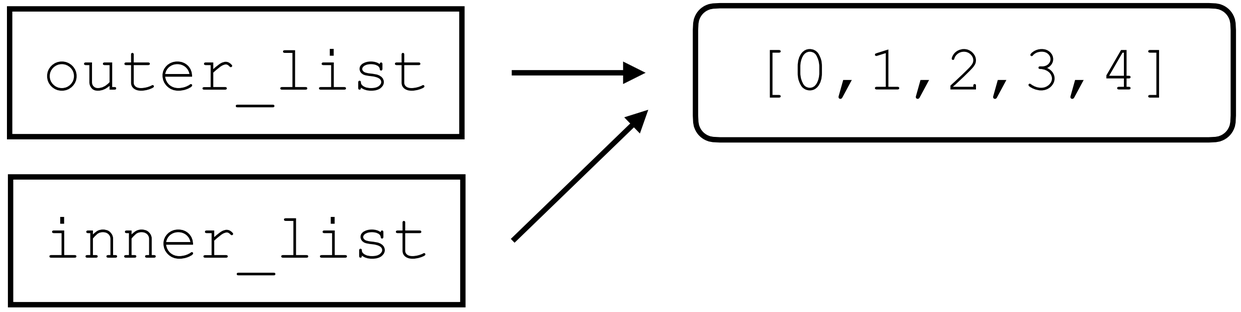
Example 1

```
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]
```



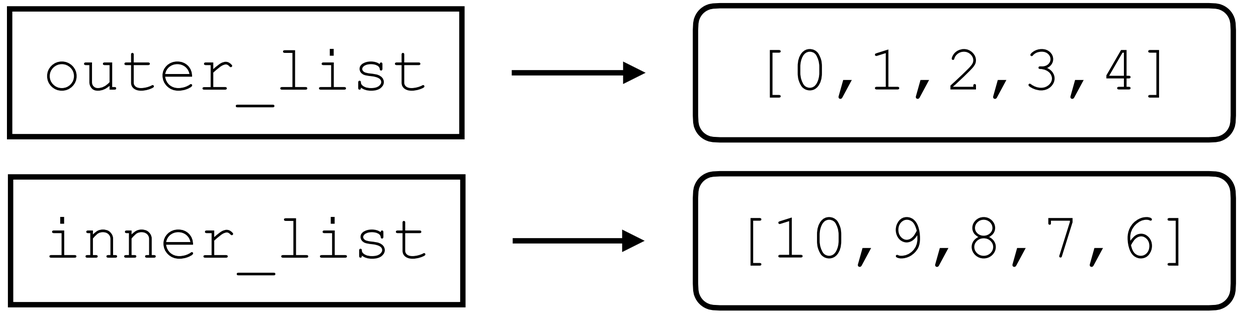
Example 1

- **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]
  ```



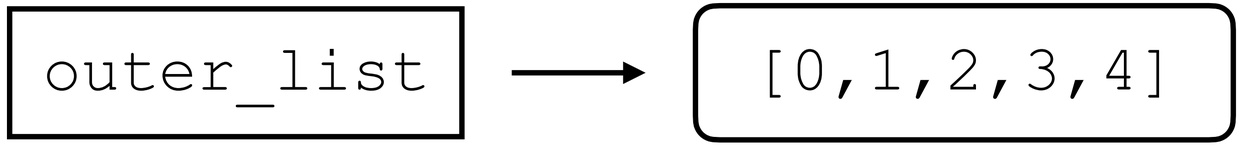
Example 1

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

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



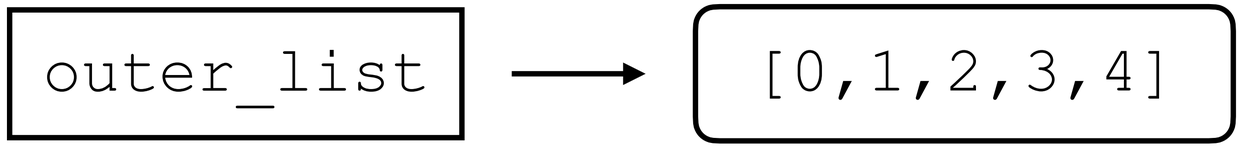
Example 1

```
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 2

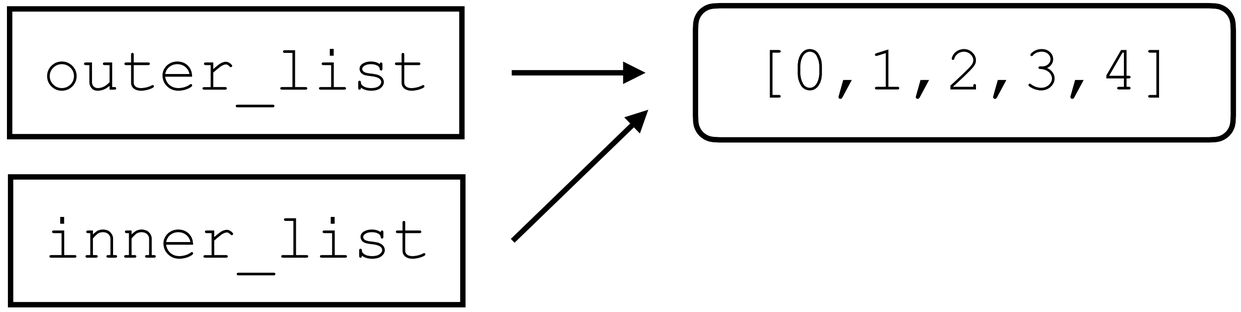
```
def change_list(inner_list):
    inner_list.append(5)

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



Example 2

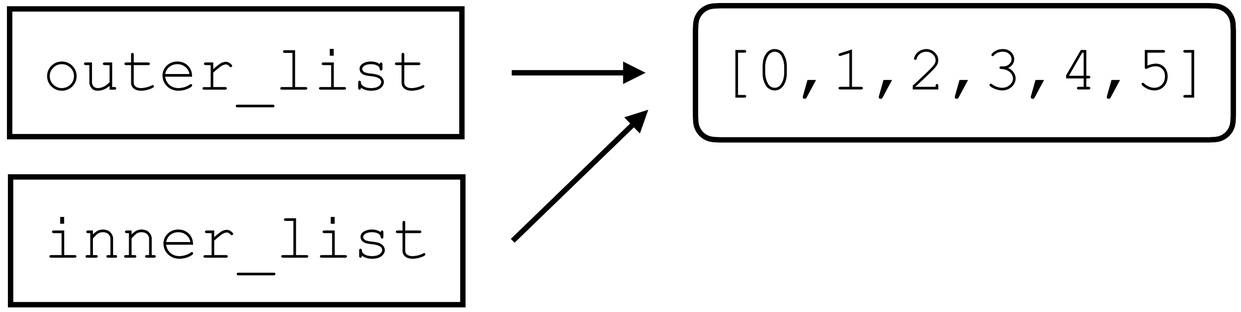
- **def change_list(inner_list):**
  inner_list.append(5)

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



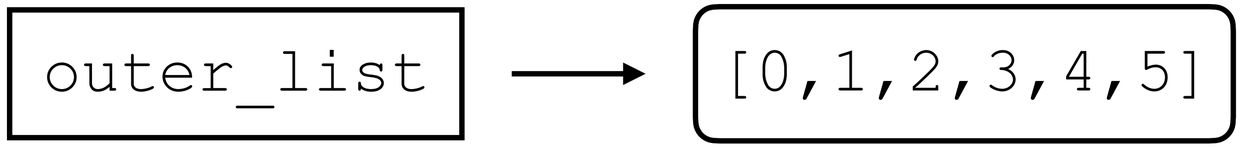
Example 2

```
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]
```



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]
```



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']
  ```
  ```