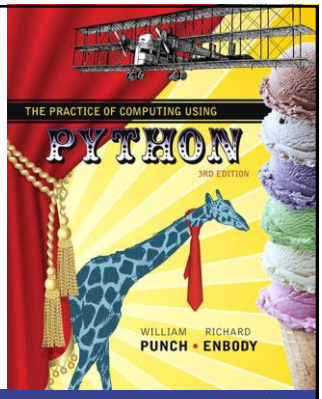
chapter 7

Lists and Tuples



Data Structures

Data Structures and Algorithms

- part of the "science" in computer science is the design and use of data structures and algorithms
- as you progress in CS, you will learn more about these two areas

Data Structures

- data structures are particular ways of storing data to make some operation easier or more efficient; i.e., they are tuned for certain tasks
- data structures are suited to solving certain problems, and they are often associated with algorithms

Kinds of Data Structures

two kinds of data structures:

- built-in data structures – so common as to be provided by default
- user-defined data structures (classes in object oriented programming) – designed for a particular task

Python Built-in Data Structures

- Python includes a general set of built-in data structures:
  - lists
  - tuples
  - string
  - dictionaries
  - sets
  - others...

Lists

Lists

- a list is an ordered sequence of items
- you have seen such a sequence before in a string
  - a string is just a particular kind of list (what kind)?

Creating Lists

- lists have a ***constructor***, with the same name as the data structure
  - the constructor receives an iterable data structure and ***adds each item*** to the list
- lists can use square brackets [ ] to include explicit items

Making Lists

```
>>> a_list = [1,2,'a',3.14159]
>>> week_days_list = ['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday']
>>> list_of_lists = [ [1,2,3], ['a','b','c']]
>>> list_from_collection = list('Hello')
>>> a_list
[1, 2, 'a', 3.1415899999999999]
>>> week_days_list
['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday']
>>> list_of_lists
[[1, 2, 3], ['a', 'b', 'c']]
>>> list_from_collection
['H', 'e', 'l', 'l', 'o']
>>> []
[]
>>>
```

Similarities with Strings

- concatenate/+ (but only of lists)
- repeat/*
- indexing (using the [ ] operator)
- slicing ([:])
- membership (using the in operator)
- len (the length operator)

Operators

`[1, 2, 3] + [4]` ⇒ `[1, 2, 3, 4]`

`[1, 2, 3] * 2` ⇒ `[1, 2, 3, 1, 2, 3]`

`1 in [1, 2, 3]` ⇒ `True`

`[1, 2, 3] < [1, 2, 4]` ⇒ `True`

compare index by index; first difference determines the result

Differences Between Lists and Strings

- lists can contain a mixture of any python objects; strings can only hold characters
  - e.g., **`[1,"bill",1.2345, True]`**
- lists are mutable, their values can be changed, while strings are immutable
- lists are designated with **`[]`**, with elements separated by commas; strings use **`""`** or **`''`**


```
myList = [1, 'a', 3.14159, True]
```

myList

1	'a'	3.14159	True	
0	1	2	3	Index forward
−4	−3	−2	−1	Index backward

```
myList[1] → 'a'
myList[:3] → [1, 'a', 3.14159]
```

FIGURE 7.1 The structure of a list.

Indexing

- indexing can be confusing, what does the **`[]`** mean, a list or an index?

  `[1, 2, 3][1]` ⇒ `2`

  - context solves the problem
  - an index always comes at the end of an expression, and is preceded by something (a variable or a sequence)

List of Lists

```
my_list = ['a', [1, 2, 3], 'z']
```

- what is the second element (index 1) of that list? another list

```
my_list[1][0] # apply left to right
my_list[1] ⇒ [1, 2, 3]
[1, 2, 3][0] ⇒ 1
```

List Functions

- **`len(lst)`**: number of elements in list (top level)

  `len([1, [1, 2], 3])` ⇒ `3`
- **`min(lst)`**: smallest element. Must all be the same type!
- **`max(lst)`**: largest element, again all must be the same type
- **`sum(lst)`**: sum of the elements, numeric only

Iteration

- you can iterate through the elements of a list like you did with a string:

```
>>> my_list = [1,3,4,8]
>>> for element in my_list:      # iterate through list elements
        print(element ,end=' ') # prints on one line

1 3 4 8
>>>
```

Mutability

Mutability

- strings are immutable; i.e., once created, the object's contents cannot be changed
- new objects can be created to reflect a change, but the object itself cannot be changed

```
my_str = 'abc'
my_str[0] = 'z'  # cannot do!
# instead, make new str
new_str = my_str.replace('a','z')
```

Lists are Mutable

- unlike strings, lists are mutable – you ***can*** change the object's contents!

```
my_list = [1, 2, 3]
my_list[0] = 127
print(my_list) ⇒ [127, 2, 3]
```

List Methods

- remember, a function is a small program (such as **`len`**) that takes some arguments (in parentheses), and returns a value
- a method is a function called in a special way, the ***dot call***; it is called in the context of an object (or a variable associated with an object)

List Methods

```
my_list = ['a',1,True]
my_list.append('z')
```

arguments to the method

object that we are calling the method with

name of the method

Some New Methods

- list methods that change the list

```
my_list[0] = 'a' # index assignment
my_list.append() # append el to list
my_list.extend() # append list as els
my_list.pop()    # remove/return el
my_list.insert() # put el at loc
my_list.remove() # delete el
my_list.sort()
my_list.reverse()
```

List Methods

- most of these methods ***do not return a value***
- since lists are mutable, the methods modify the list directly; no need to return anything

Unusual Results

```
my_list = [4, 7, 1, 2]
my_list = my_list.sort()
my_list ⇒ None     # what happened?
```

- the sort operation changed the order of the list in place (right side of assignment)
- the sort method returned **`None`**, which was assigned to the variable
- the list was lost and **`None`** is now the value of the variable

The `split` Method

- the string method **`split`** generates a sequence of characters by splitting the string at certain split characters
- ***it returns a list*** (we didn't mention that before)

```
split_list = 'this is a test'.split()
split_list
     ⇒ ['this', 'is', 'a', 'test']
```

Sorting

- only lists have a built in sorting method
- thus, you often convert your data to a list if it needs sorting

```
my_list = list('xyzabc')
my_list →['x','y','z','a','b','c']
my_list.sort()   # no return
my_list →
  ['a', 'b', 'c', 'x', 'y', 'z']
```

Reverse Words in a String

- **`join`** method of string places the argument between every element of a list

```
>>> my_str = 'This is a test'
>>> string_elements = my_str.split()           # list of words
>>> string_elements
['This', 'is', 'a', 'test']
>>> reversed_elements = []
>>> for element in string_elements:            # for each word
...     reversed_elements.append(element[::-1]) # reverse, append
...
>>> reversed_elements
['sihT', 'si', 'a', 'tset']
>>> new_str = ' '.join(reversed_elements)  # join with space separator
>>> new_str
'sihT si a tset'                           # each words reversed
>>>
```

`sorted` Function

- the **`sorted`** function breaks a sequence into elements and sorts the sequence, placing the results in a list

```
sort_list = sorted('hi mom')
sort_list ⇒
[' ','h','i','m','m','o']
```

Examples

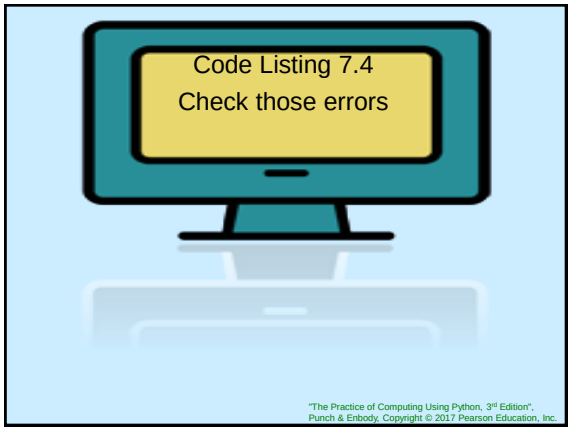
Anagram Example

- anagrams are words that contain the same letters arranged in a different order; e.g., 'iceman' and 'cinema'
- a strategy to identify anagrams is to take the letters of a word, sort those letters, then compare the sorted sequences; anagrams should have the same sorted sequence


```
def are_anagrams(word1, word2):
    """Return True, if words are anagrams."""
    #2. Sort the characters in the words
    word1_sorted = sorted(word1)    # sorted returns a sorted list
    word2_sorted = sorted(word2)

    #3. Check that the sorted words are identical.
    if word1_sorted == word2_sorted:  # compare sorted lists
        return True
    else:
        return False
```



```
def are_anagrams(word1, word2):
    """Return True, if words are anagrams."""
    #2. Sort the characters of the words.
    word1_sorted = sorted(word1)    # sorted returns a sorted list
    word2_sorted = sorted(word2)

    #3. Check that the sorted words are identical.
    return word1_sorted == word2_sorted

print("Anagram Test")

# 1. Input two words.
two_words = input("Enter two space separated words: ")
word1,word2 = two_words.split()  # split into a list of words

if are_anagrams(word1, word2):   # return True or False
    print("The words are anagrams.")
else:
    print("The words are not anagrams.")
```

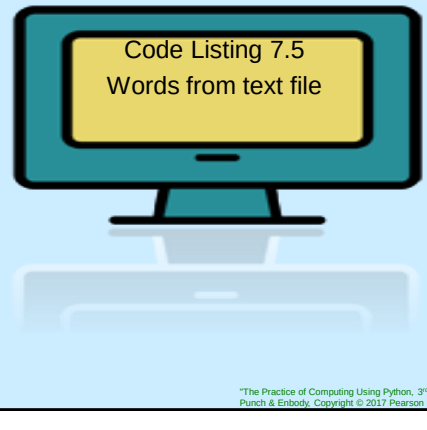


Checking Valid Input

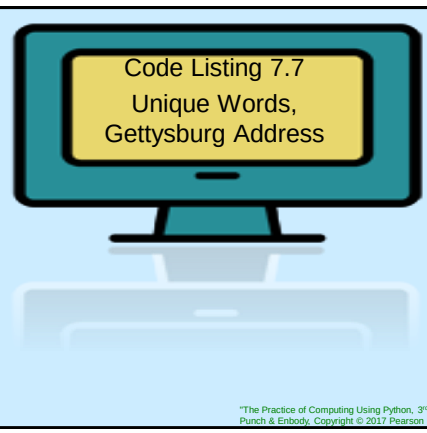
```
valid_input_bool = False
while not valid_input_bool:
    try:
        two_words = input("Enter two …")
     word1, word2 = two_words.split()
     valid_input_bool = True
    except ValueError:
        print("Bad Input")
```

only runs when no error; otherwise, try again


```
def are_anagrams(word1, word2):
    """Return True, if words are anagrams."""
    #2. Sort the characters of the words.
    word1_sorted = sorted(word1)    # sorted returns a sorted list
    word2_sorted = sorted(word2)

    #3. Check that the sorted words are identical.
    return word1_sorted == word2_sorted

print("Anagram Test")

# 1. Input two words, checking for errors now
valid_input_bool = False
while not valid_input_bool:
    try:
        two_words = input("Enter two space separated words: ")
        word1,word2 = two_words.split()  # split the input string into a list
                                         of words
        valid_input_bool = True
    except ValueError:
        print("Bad Input")

if are_anagrams(word1, word2):   # function returned True or False
    print("The words {} and {} are anagrams.".format(word1, word2))
else:
    print("The words {} and {} are not anagrams.".format(word1, word2))
```


```
def make_word_list(a_file):
    """Create a list of words from the file."""
    word_list = []      # list of speech words: initialized to be empty

    for line_str in a_file:          # read file line by line
        line_list = line_str.split()  # split each line into a list of words
        for word in line_list:        # get words one at a time from list
            if word != "--":          # if the word is not "--"
                word_list.append(word)   # add the word to the speech list
    return word_list
```

```
# Gettysburg address analysis
# count words, unique words

def make_word_list(a_file):
    """Create a list of words from the file."""
    word_list = []      # list of speech words: initialized to be empty

    for line_str in a_file:           # read file line by line
        line_list = line_str.split()  # split each line into a list of words
        for word in line_list:        # get words one at a time from list
            if word != "--":          # if the word is not "--"
                word_list.append(word)    # add the word to the speech list
    return word_list

def make_unique(word_list):
    """Create a list of unique words."""
    unique_list = []  # list of unique words: initialized to be empty

    for word in word_list:        # get words one at a time from speech
        if word not in unique_list: # if word is not already in unique list,
            unique_list.append(word)# add word to unique list

    return unique_list

################################

gba_file = open("gettysburg.txt", "r")
speech_list = make_word_list(gba_file)

# print the speech and its lengths
print(speech_list)
print("Speech Length: ", len(speech_list))
print("Unique Length: ", len(make_unique(speech_list)))
```


More about Mutables

Assignment

- assignment takes an object (the final object after all operations) from the RHS and associates it with a variable on the LHS
- when you assign one variable to another, you ***share the association*** with the same object

my_int = 27
your_int = my_int

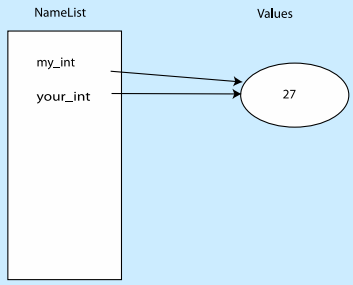


FIGURE 7.2 Namespace snapshot #1.

Immutables

- object sharing, two variables associated with the same object, is not a problem since the object cannot be changed
- any changes that occur generate a ***new*** object

my_int = 27
your_int = my_int
your_int = your_int + 1

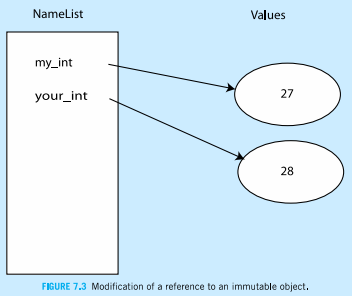


FIGURE 7.3 Modification of a reference to an immutable object.

Mutability

- if two variables associate with the same object, then ***both reflect*** any change to that object


```
a_list = [1,2,3]
b_list = a_list
```

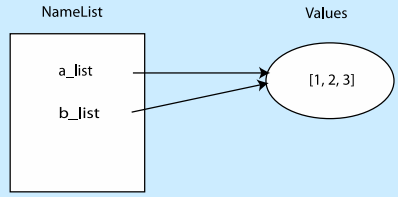


FIGURE 7.4 Namespace snapshot after assigning mutable objects.


```
a_list = [1,2,3]
b_list = a_list
a_list.append(27)
```

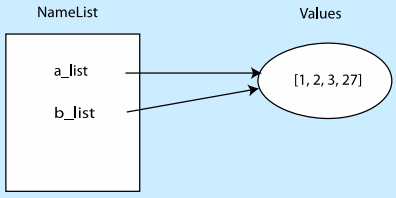


FIGURE 7.5 Modification of shared, mutable objects.

Copy

- if we copy, does that solve the problem?

```
my_list = [1, 2, 3]
newLst = my_list[:]
```


```
a_list = [1,2,3]
b_list = a_list[:]    # explicitly make a distinct copy
a_list.append(27)
```

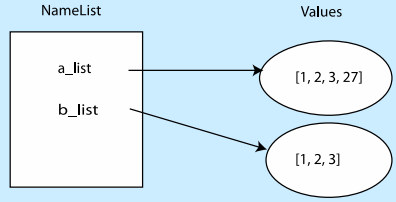


FIGURE 7.6 Making a distinct copy of a mutable object.

Copy

- the big question is – what gets copied?
  - what actually gets copied is the top level reference
  - if the list has nested lists or uses other associations, only the association gets copied (a ***shallow copy***)

a_list = [1,2,3]
a_list.append(a_list)
print(a_list) → [1, 2, 3, [...]]

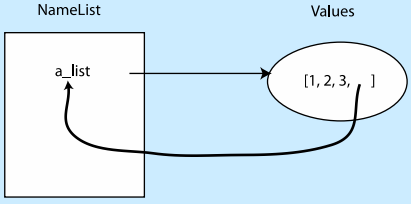


FIGURE 7.7 Self-referencing.

a_list = [1,2,3]
b_list = [5,6,7]

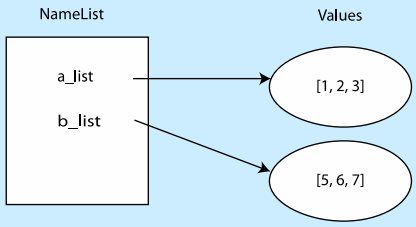


FIGURE 7.8 Simple lists before append.

a_list = [1,2,3]
b_list = [5,6,7]
a_list.append(b_list)

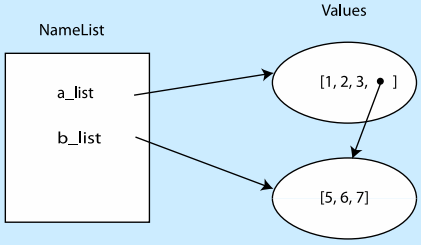


FIGURE 7.9 Lists after append.

a_list = [1,2,3]
b_list = [5,6,7]
a_list.append(b_list)
c_list = b_list
c_list[2] = 88

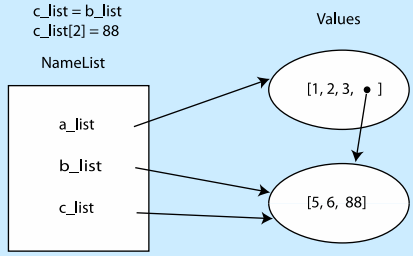


FIGURE 7.10 Final state of copying example.

Shallow vs. Deep Copy

- regular copy, using `[:]`, only copies the top level reference/association
- if you want a full copy, you can use deepcopy

```
>>> a_list = [1, 2, 3]
>>> b_list = [5, 6, 7]
>>> a_list.append(b_list)
>>> import copy
>>> c_list = copy.deepcopy(a_list)
>>> b_list[0]=1000
>>> a_list
[1, 2, 3, [1000, 6, 7]]
>>> c_list
[1, 2, 3, [5, 6, 7]]
>>>
```

a_list = [1,2,3]
b_list = [5,6,7]
a_list.append(b_list)
c_list = copy.deepcopy(a_list)
b_list[0] = 1000

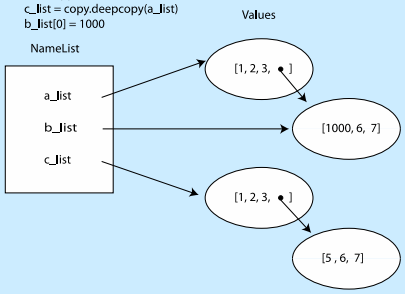


FIGURE 7.12 Using the copy module for a deep copy.

Tuples

Tuples

- tuples are simply immutable lists
- they are printed with **(,)**

```
>>> 10,12          # Python creats a tuple
(10, 12)
>>> tup = 2,3      # assigning a tuple to a variable
>>> tup
(2, 3)
>>> (1)            # not a tuple, a grouping
1
>>> (1,)           # comma makes it a tuple
(1,)
>>> x,y = 'a',3.14159     # from on right, multiple assignments
>>> x
'a'
>>> y
3.14159
>>> x,y            # create a tuple
('a', 3.14159)
```

Tuples

- why have an immutable list, a tuple, as a separate type?
- because an immutable list gives you a data structure with some integrity, some permanent-ness if you will
- you know you cannot accidentally change it

Lists and Tuples

- everything that works with a list also works with a tuple, ***except*** methods that modify the tuple
- thus, indexing, slicing, len, print all work as expected
- however, ***none*** of the mutable methods work: **`append, extend, del`**

Commas Create a Tuple

- for tuples, you can think of a comma as the operator that creates a tuple, where the ( ) simply acts as a grouping

```
myTuple = 1,2    # creates (1,2)
myTuple = (1,)   # creates (1)
myTuple = (1)    # creates 1 not (1)
myTuple = 1,     # creates (1)
```

Data Structures in General

Organization of Data

- so far, we have seen strings, lists and tuples
- each is an organization of data that is useful for some things, but not as useful for others

Marks of Good Data Structures

- efficient with respect to us (some algorithm)
- efficient with respect to the amount of space used
- efficient with respect to the time it takes to perform some operations

EPA Example

List Comprehensions

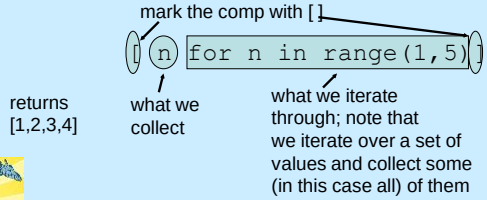
Lists are a Big Deal!

- the use of lists in Python is a major part of its power
- lists are very useful and can be used to accomplish many tasks
- Python therefore provides some pretty powerful support to make common list tasks easier

Constructing Lists

- one way is a "list comprehension"

```
[n for n in range(1,5)]
```



Modifying the Collected Items

```
[n**2 for n in range(1,6)]
```

- returns **[1,4,9,16,25]**
- note that we can only change the values we are iterating over, in this case **n**

Multiple Collects

```
[x+y for x in range(1,4) for y in range (1,4)]
```

- it is as if we had done the following:

```
my_list = [ ]
for x in range (1,4):
  for y in range (1,4):
    my_list.append(x+y)
```

⇒ **[2,3,4,3,4,5,4,5,6]**

Modifying What Gets Collected

```
[c for c in "Hi There Mom" if c.isupper()]
```

- the **if** part of the comprehensive controls which of the iterated values is collected
- only those values which make the if part true will be collected

⇒ **['H','T','M']**

Rules

1. Think before you program!
2. A program is a human-readable essay on problem solving that also executes on a computer.
3. The best way to improve your programming and problem solving skills is to practice!
4. A foolish consistency is the hobgoblin of little minds
5. Test your code, often and thoroughly
6. If it was hard to write, it is probably hard to read. Add a comment.
7. All input is evil, unless proven otherwise.
8. A function should do one thing.