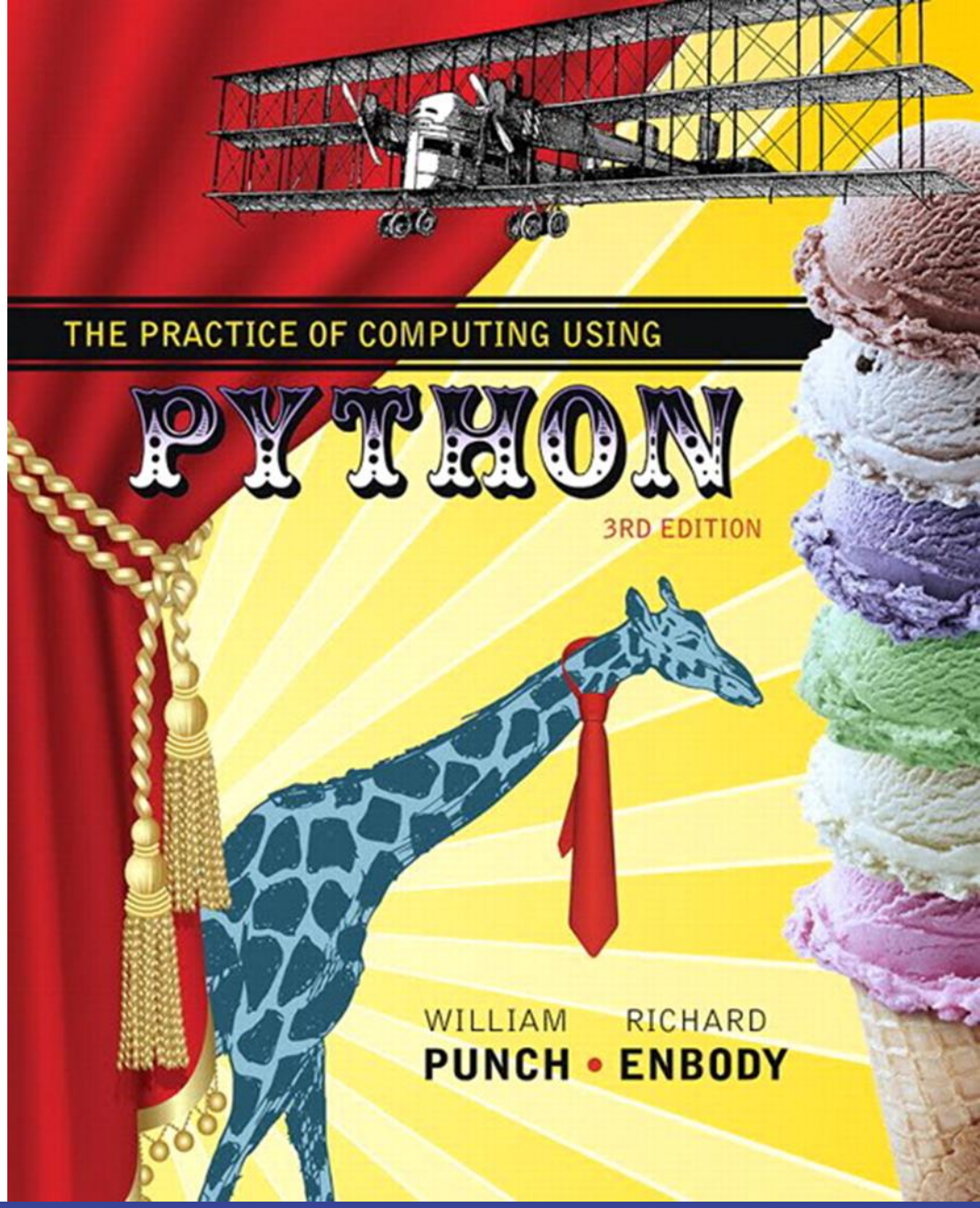
chapter 9

Dictionaries and Sets



More Data Structures

- we have seen the list data structure and what it can be used for
- we will now examine two more advanced data structures, the set and the dictionary
- in particular, the dictionary is an important, very useful part of Python, as well as generally useful to solve many problems

Dictionaries

What is a Dictionary?

- in data structure terms, a dictionary is better termed an *associative array, associative list* or a *map*
- you can think if it as a list of pairs, where the first element of the pair, the ***key***, is used to retrieve the second element, the ***value***
- thus, we ***map a key to a value***

Key/Value Pairs

- the key acts as an index to find the associated value
- just like a dictionary, you look up a word by its spelling to find the associated definition
- a dictionary can be searched to locate the value associated with a key

Python Dictionary

- Use the `{ }` marker to create a dictionary
- Use the `:` marker to indicate key:value pairs

```
contacts= {'bill': '353-1234',
 'rich': '269-1234', 'jane': '352-1234'}
print contacts
{'jane': '352-1234',
 'bill': '353-1234',
 'rich': '369-1234'}
```

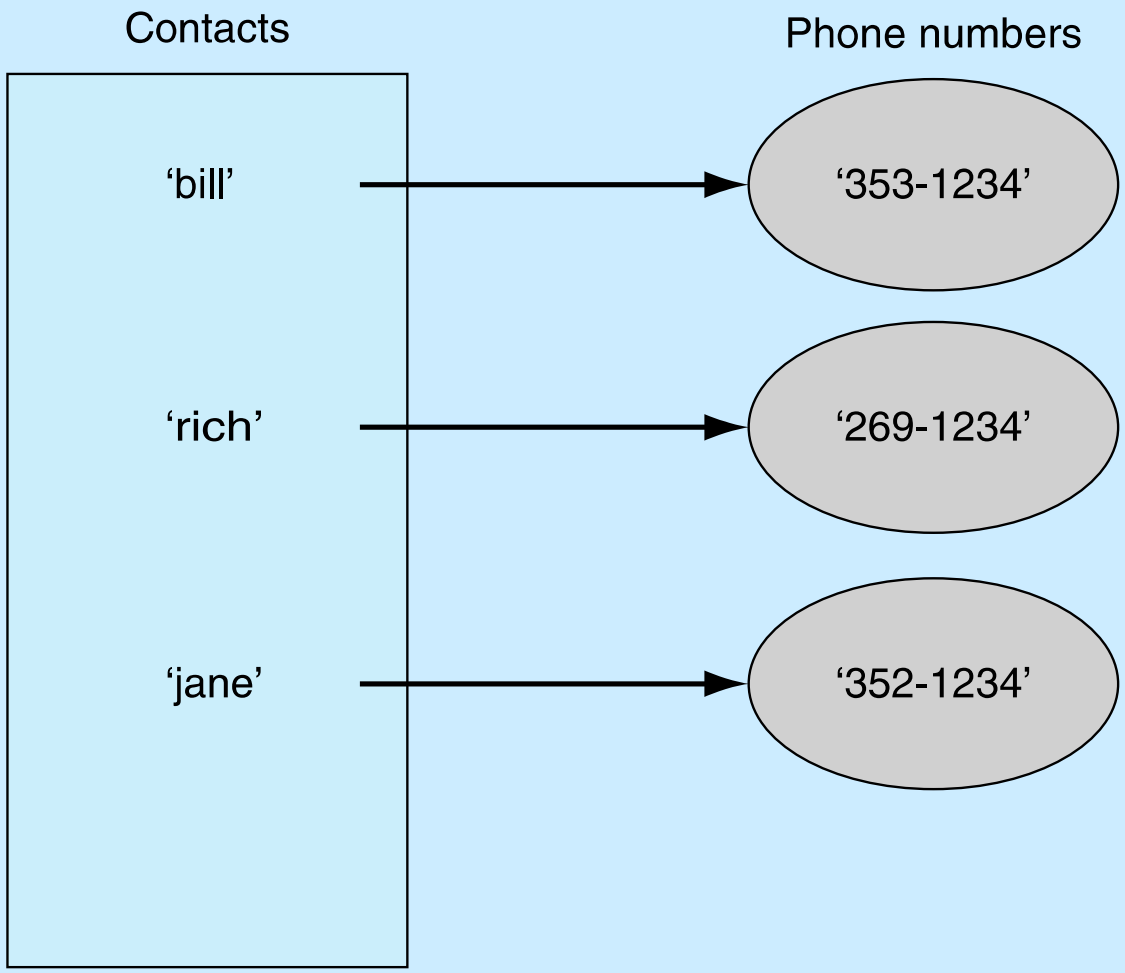


FIGURE 9.1 Phone contact list: names and phone numbers.

Keys and Values

- key must be immutable
  - strings, integers, tuples are fine
  - lists are NOT
- value can be anything

Collection But Not a Sequence

- dictionaries are collections but they are not sequences, such as lists, strings or tuples
  - there is no order to the elements of a dictionary
  - in fact, the order (for example, when printed) might change as elements are added or deleted.
- So how to access dictionary elements?

Access Dictionary Elements

- access requires `[ ]`, but the *key* is the index!

  `my_dict={}`

  – an empty dictionary

  `my_dict['bill']=25`

  – added the pair 'bill':25

  `print(my_dict['bill'])`

  – prints `25`

Dictionaries are Mutable

- like a list, a dictionary is a mutable data structure
  - you can change the object via various operations, such as index assignment

```
my_dict = {'bill':3, 'rich':10}
print(my_dict['bill'])    # prints 3
my_dict['bill'] = 100
print(my_dict['bill'])    # prints 100
```

Again, Common Operators

- like others, dictionaries respond to these
  - **`len(my_dict)`**
    - number of key:value **pairs** in the dictionary
  - **`element in my_dict`**
    - boolean, is **`element`** a **`key`** in the dictionary
  - **`for key in my_dict:`**
    - iterates through the **keys** of a dictionary

Fewer Methods

- only nine methods in total; here are some:
  - **`key in my_dict`**

    does the key exist in the dictionary
  - **`my_dict.clear()`** – empty the dictionary
  - **`my_dict.update(yourDict)`** – for each key in **`yourDict`**, **updates `my_dict` with that key/value pair**
  - **`my_dict.copy`** - shallow copy
  - **`my_dict.pop(key)`** – remove key, return value

Dictionary Content Methods

- **`my_dict.items()`** – all the key/value pairs
- **`my_dict.keys()`** – all the keys
- **`my_dict.values()`** – all the values

- these return what is called a *dictionary view*.
  - the order of the views corresponds
  - are dynamically updated with changes
  - are iterable

Views are Iterable

```
for key in my_dict:
    print key
```

- prints all the keys

```
for key,value in my_dict.items():
    print key,value
```

- prints all the key/value pairs

```
for value in my_dict.values():
    print value
```

- prints all the values

my_dict = {'a':2, 3:['x', 'y'], 'joe':'smith}

```
>>> dict_value_view = my_dict.values()
>>> dict_value_view                                    # a view
dict_values([2, ['x', 'y'], 'smith'])
>>> type(dict_value_view)                              # view type
<class 'dict_values'>
>>> for val in dict_value_view:                        # view iteration
        print(val)

2
['x', 'y']
smith
>>> my_dict['new_key'] = 'new_value'
>>> dict_value_view                                    # view updated
dict_values([2, 'new_value', ['x', 'y'], 'smith'])
>>> dict_key_view = my_dict.keys()
dict_keys(['a', 'new_key', 3, 'joe'])
>>> dict_value_view
dict_values([2, 'new_value', ['x', 'y'], 'smith']) # same order
>>>
```

Frequency of Words in List 3 Ways

Membership Test

```
count_dict = {}
for word in word_list:
    if word in count_dict:
        count_dict[word] += 1
    else:
        count_dict[word] = 1
```

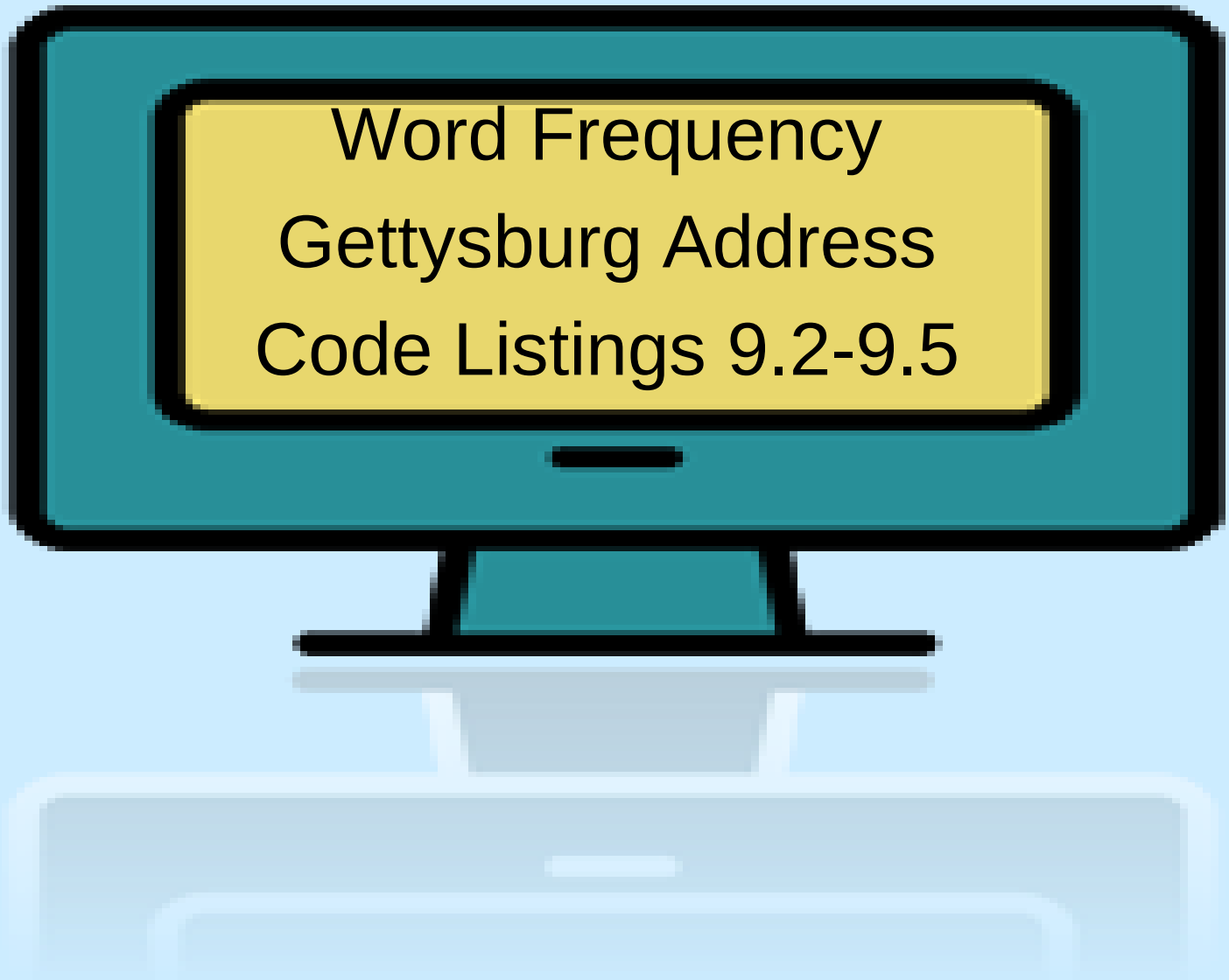
Exceptions

```
count_dict = {}
for word in word_list:
    try:
        count_dict[word] += 1
    except KeyError:
        count_dict[word] = 1
```

`get` Method

- the **`get`** method returns the value associated with a dictionary key or a default value provided as second argument. Below, the default is 0

```
count_dict = {}
for word in word_list:
    count_dict[word] = count_dict.get(word,0) + 1
```



Four Dictionary Functions

- **`add_word(word, word_dict)`** adds word to the dictionary; no return
- **`process_line(line, word_dict).`** processes line and identifies words; calls **`add_word`** ; no return.
- **`pretty_print(word_dict)`**. nice printing of the dictionary contents; no return
- **`main()`** function to start the program

Passing Mutables

- because we are passing a mutable data structure, a dictionary, we do not have to return the dictionary when the function ends
- if all we do is update the dictionary (change the object), then the argument will be associated with the changed object

```
1 def add_word(word, word_count_dict):
2     '''Update the word frequency: word is the key, frequency is the value.'''
3     if word in word_count_dict:
4         word_count_dict[word] += 1
5     else:
6         word_count_dict[word] = 1
```

```
1  import string
2  def process_line(line, word_count_dict):
3      '''Process the line to get lowercase words to add to the dictionary.'''
4      line = line.strip()
5      word_list = line.split()
6      for word in word_list:
7          # ignore the '--' that is in the file
8          if word != '--':
9              word = word.lower()
10             word = word.strip()
11             # get commas, periods and other punctuation out as well
12             word = word.strip(string.punctuation)
13             add_word(word, word_count_dict)
```

Sorting in Pretty Print

- the **`sort`** method works on lists, so if we sort we must sort a list
- for complex elements (like a tuple), the sort compares the first element of each complex element:

```
(1, 3) < (2, 1)       # True
(3,0) < (1,2,3)       # False
```

- a list comprehension (commented out) is the equivalent of the code below it

```
1  def pretty_print(word_count_dict):
2      '''Print nicely from highest to lowest frequency.'''
3      # create a list of tuples, (value, key)
4      # value_key_list = [(val,key) for key,val in d.items()]
5      value_key_list=[]
6      for key,val in word_count_dict.items():
7          value_key_list.append((val,key))
8      # sort method sorts on list's first element, the frequency.
9      # Reverse to get biggest first
10     value_key_list.sort(reverse=True)
11     # value_key_list = sorted([(v,k) for k,v in value_key_list.items()],
   reverse=True)
12     print('{:11s}{:11s}'.format('Word', 'Count'))
13     print('_'*21)
14     for val,key in value_key_list:
15         print('{:12s}  {:<3d}'.format(key,val))
```

```
1 def main ():
2     word_count_dict={}
3     gba_file = open('gettysburg.txt','r')
4     for line in gba_file:
5         process_line(line, word_count_dict)
6     print('Length of the dictionary:',len(word_count_dict))
7     pretty_print(word_count_dict)
```

Periodic Table Example

Comma Separated Values (csv)

- ***csv*** files are a text format that are used by many applications (especially spreadsheets) to exchange data as text
- row-oriented representation where each line is a row, and elements of the row (columns) are separated by a comma
- despite the simplicity, there are variations and we'd like Python to help

csv Module

- **`csv.reader`** takes an opened file object as an argument and reads one line at a time from that file
- Each line is formatted as a list with the elements (the columns, the comma separated elements) found in the file

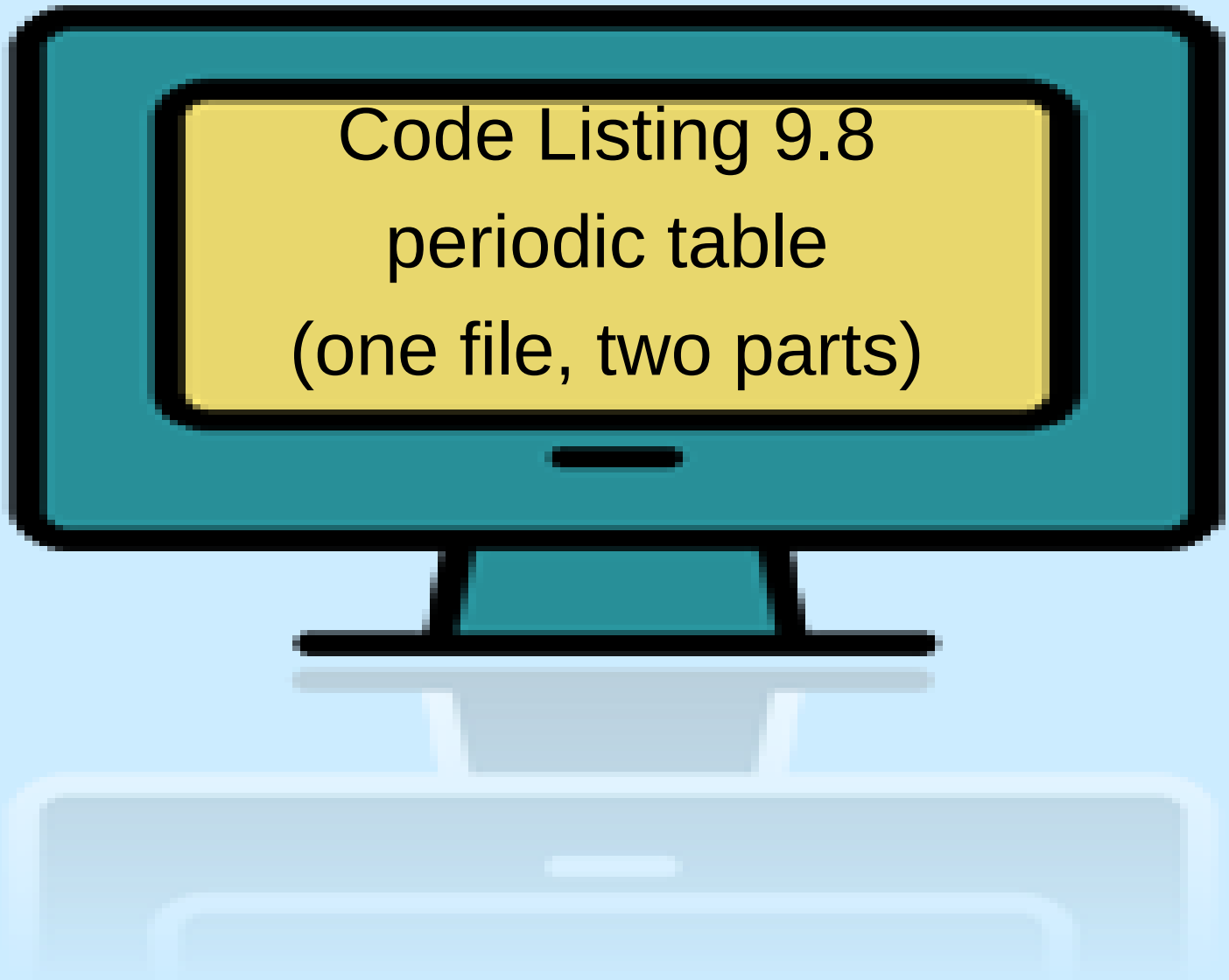
Encodings Other Than UTF-8

- this example uses a csv file encoded with characters other than UTF-8 (our default)
  - in particular, the symbol **±** occurs
- can solve by opening the file with the correct encoding, in this case **`windows-1252`**

Example

```
>>> import csv
>>> periodic_file = open("Periodic-Table.csv", "r",encoding="windows-1252")
>>> reader = csv.reader(periodic_file)
>>> for row in reader:
        print(row)

# some of the output data
['2', 'He', '18', 'VIII A', '1', 'helium', '4.003', '0', '', '', ...]
['3', 'Li', '1', 'I A', '2', 'lithium', '6.941', '+1', '', '', ... ]
['4', 'Be', '2', 'II A', '2', 'beryllium', '9.012', '+2', '', '', ...]
['5', 'B', '13', 'III A', '2', 'boron', '10.81', '+3', '', '', ...]
# etc. etc.
```



```
import csv

def read_table(a_file, a_dict):
    """Read Periodic Table file into a dict. with element symbol as key.
       periodic_file is a file object opened for reading """
    data_reader = csv.reader(a_file)

    for row in data_reader:
        # ignore header rows: elements begin with a number
        if row[0].isdigit():
            symbol_str = row[1]
            a_dict[symbol_str] = row[:8]  # ignore end of row

def parse_element(element_str):
    """Parse element string into symbol and quantity,
       e.g. Si2 returns ('Si',2)"""
    symbol_str=""
    quantity_str = ""
    for ch in element_str:
        if ch.isalpha():
            symbol_str = symbol_str + ch
        else:
            quantity_str = quantity_str + ch
    if quantity_str == "":                    # if no number, default is 1
        quantity_str = "1"
    return symbol_str, int(quantity_str)
```

```
# 1. Read File
periodic_file = open("Periodic-Table.csv", "r",encoding="windows-1252")

# 2. Create Dictionary of Periodic Table using element symbols as keys
periodic_dict={}
read_table(periodic_file, periodic_dict)

# 3. Prompt for input and convert compound into a list of elements
compound_str = input("Input a chemical compound, hyphenated, e.g. C-O2: ")
compound_list = compound_str.split("-")

# 4. Initialize atomic mass
mass_float = 0.0
print("The compound is composed of: ", end=' ')

# 5. Parse compound list into symbol-quantity pairs, print name, and add mass
for c in compound_list:
    symbol_str, quantity_int = parse_element(c)
    print(periodic_dict[symbol_str][5], end=' ')  # print element name
    mass_float = mass_float + quantity_int *\
                 float(periodic_dict[symbol_str][6]) # add atomic mass

print("\n\nThe atomic mass of the compound is", mass_float)

periodic_file.close()
```

Sets

Sets, as in Mathematical Sets

- in mathematics, a set is a collection of objects, potentially of many different types
- in a set, no two elements are identical
  - that is, a set consists of elements each of which is unique compared to the other elements
- there is no order to the elements of a set
- a set with no elements is the empty set

Creating a Set

- a set can be created in one of two ways:
  - constructor: **`set(iterable)`** where the argument is iterable

```
my_set = set('abc')
my_set → {'a', 'b', 'c'}
```

- shortcut: **`{}`**, braces where the elements have no colons (to distinguish them from dicts)

```
my_set = {'a', 'b','c'}
```

Diverse Elements

- a set can consist of a mixture of different types of elements

```
my_set = {'a',1,3.14159,True}
```

- as long as the single argument can be iterated through, you can make a set of it

No Duplicates

- duplicates are automatically removed

```
my_set = set("aabbccdd")
print(my_set)
```

→ `{'a', 'c', 'b', 'd'}`

Example

```
>>> null_set = set()          # set() creates the empty set
>>> null_set
set()
>>> a_set = {1,2,3,4}         # no colons means set
>>> a_set
{1, 2, 3, 4}
>>> b_set = {1,1,2,2,2}       # duplicates are ignored
>>> b_set
{1, 2}
>>> c_set = {'a', 1, 2.5, (5,6)} # different types is OK
>>> c_set
{(5, 6), 1, 2.5, 'a'}
>>> a_set = set("abcd")       # set constructed from iterable
>>> a_set
{'a', 'c', 'b', 'd'}          # order not maintained!
```

Common Operators

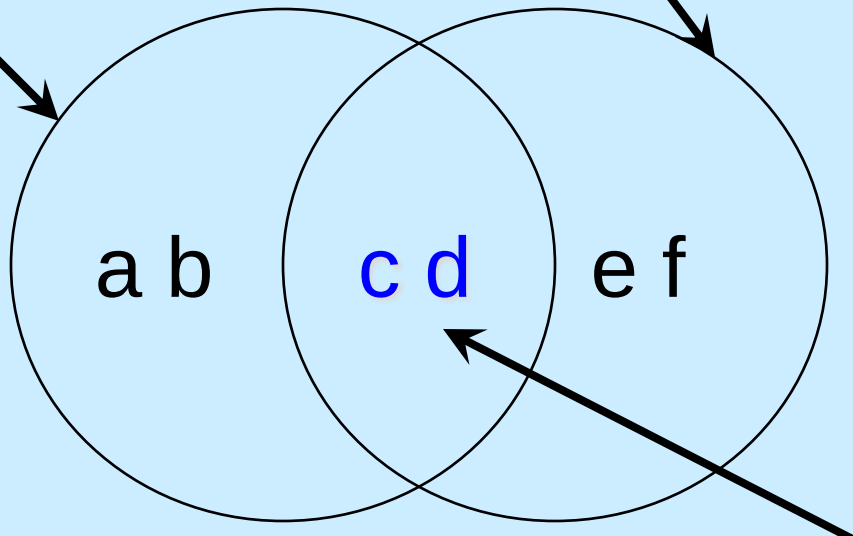
- most data structures respond to these:
  - **`len(my_set)`**
    - the number of elements in a set
  - **`element in my_set`**
  - boolean indicating whether element is in the set
  - **`for element in my_set:`**
  - iterate through the elements in **`my_set`**

Set Operators

- the set data structure provides some special operators that correspond to the operators you learned in middle school
- these are various combinations of set contents
- these operations have both a method name and a shortcut binary operator

Method: `intersection`, Op: `&`

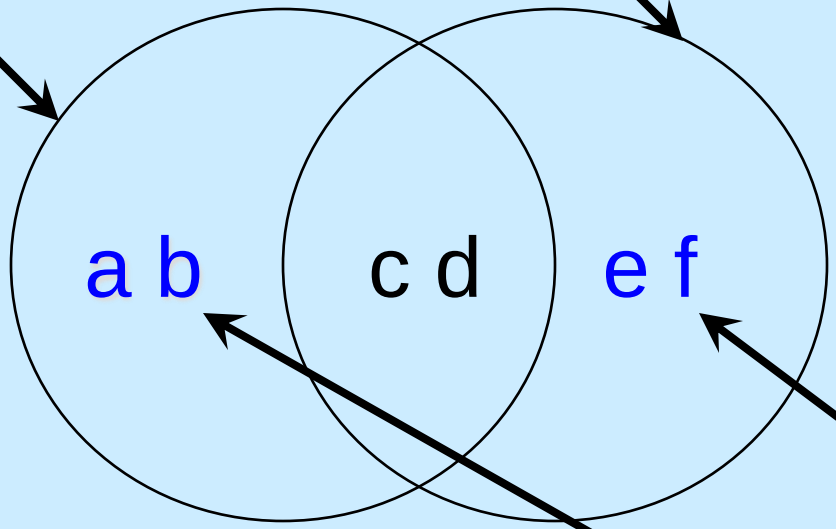
```
a_set=set("abcd")   b_set=set("cdef")
```




```
a_set & b_set → {'c', 'd'}
b_set.intersection(a_set) → {'c', 'd'}
```

Method: **difference**, Op: -

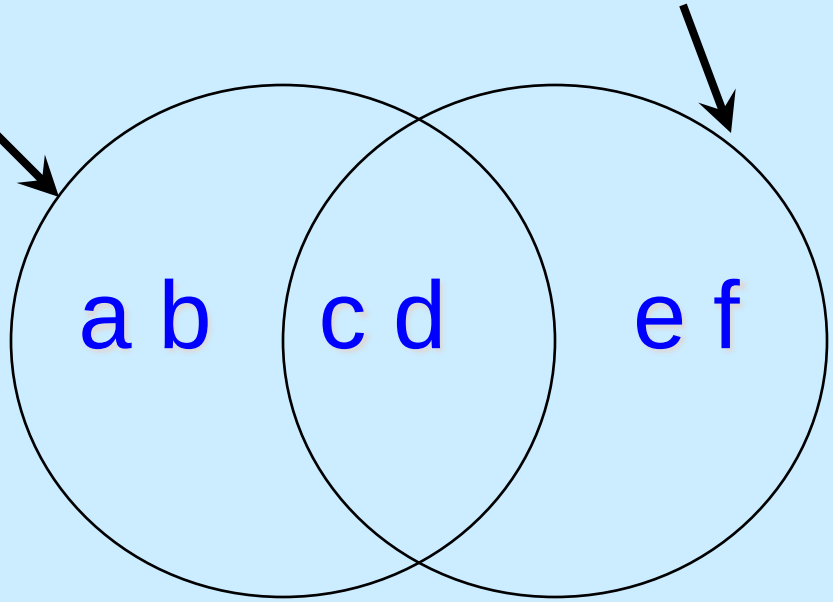
```
a_set=set("abcd")   b_set=set("cdef")
```




```
a_set - b_set → {'a', 'b'}
b_set.difference(a_set) → {'e', 'f'}
```

Method: **union**, Op: |

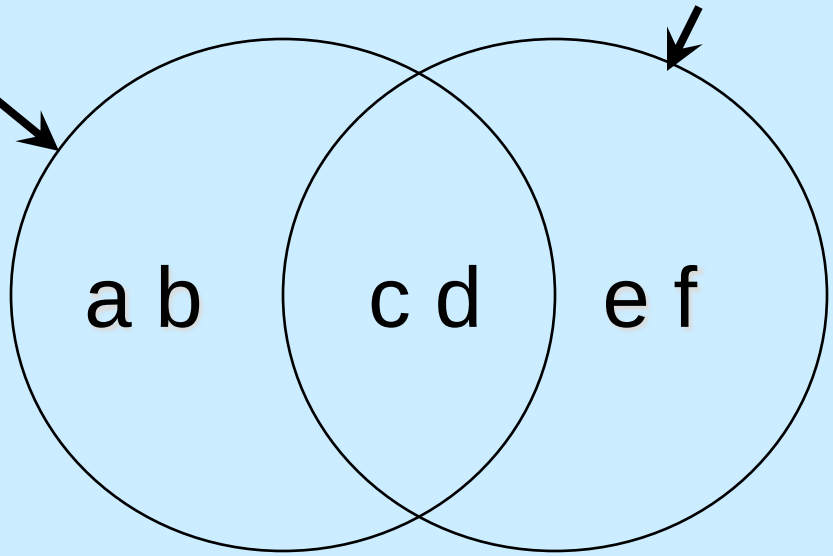
```
a_set=set("abcd")  b_set=set("cdef")
```




```
a_set | b_set → {'a', 'b', 'c', 'd', 'e', 'f'}
b_set.union(a_set) → {'a', 'b', 'c', 'd', 'e',
'f'}
```

Method: **symmetric_difference**, Op: **^**

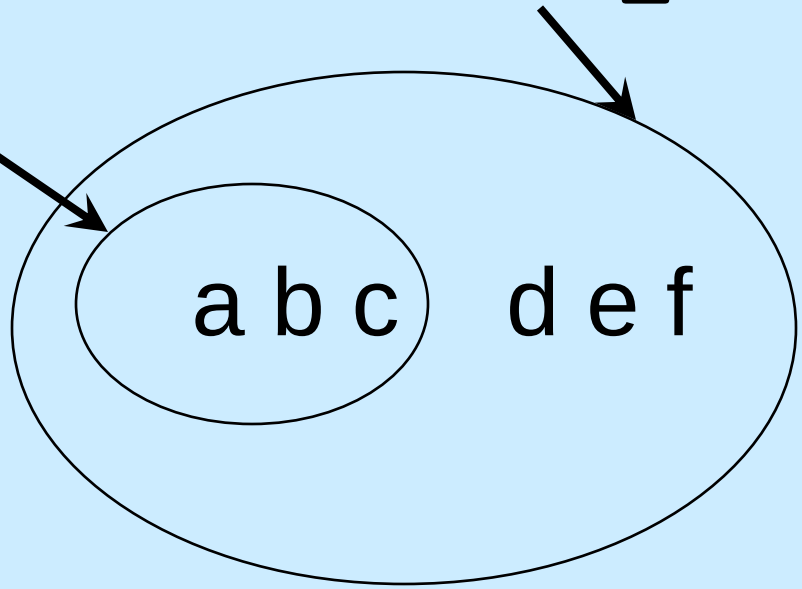
```
a_set=set("abcd");  b_set=set("cdef")
```




```
a_set ^ b_set → {'a', 'b', 'e', 'f'}
b_set.symmetric_difference(a_set) → {'a', 'b',
'e', 'f'}
```

Method: `issubset`, Op: `<=`
Method: `issuperset`, Op: `>=`

```
small_set=set("abc"); big_set=set("abcdef")
```



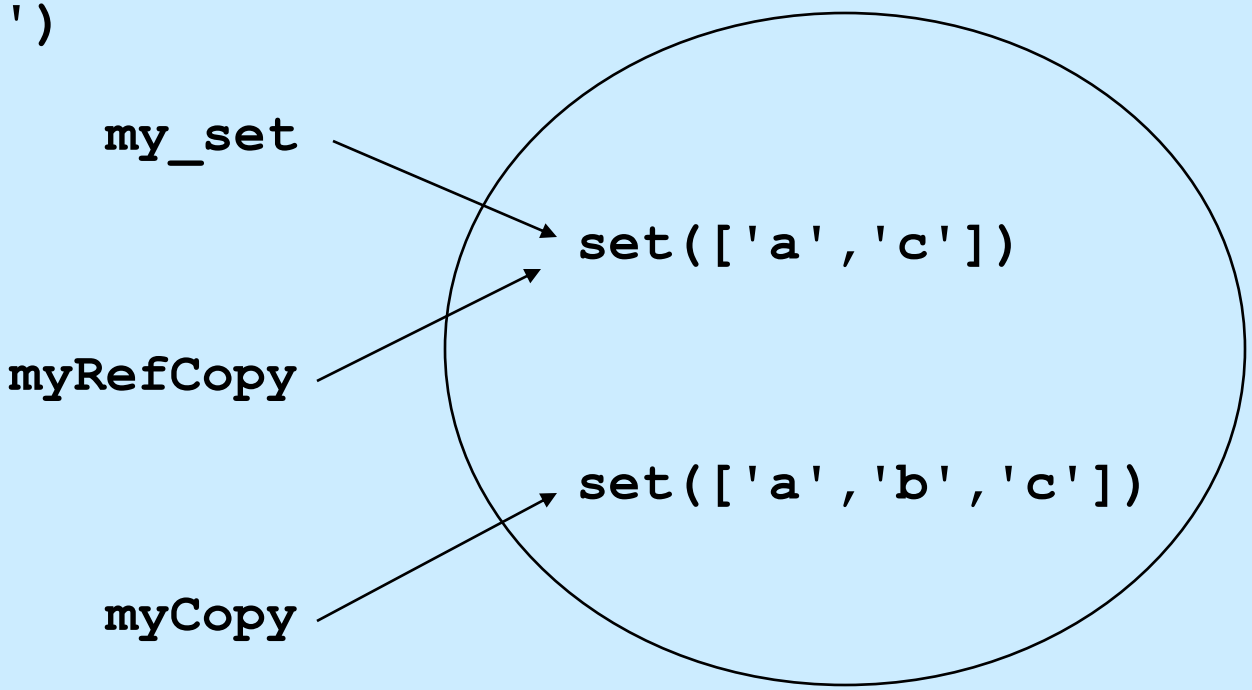

```
small_set <= big_set → True
big_set >= small_set → True
```

Other Set Ops

- **`my_set.add("g")`**
  - adds to the set, no effect if item is in set already
- **`my_set.clear()`**
  - empties the set
- **`my_set.remove("g")`** versus **`my_set.discard("g")`**
  - **`remove`** throws an error if "**`g`**" isn't there
  - **`discard`** doesn't care
  - both remove "**`g`**" from the set
- **`my_set.copy()`**
  - returns a shallow copy of **`my_set`**

Copy vs. Assignment

```
my_set=set {'a', 'b', 'c'}
my_copy=my_set.copy()
my_ref_copy=my_set
my_set.remove('b')
```



Common words in the Gettysburg Address and the Declaration of Independence

- can reuse or only slightly modify much of the code for document frequency
- the overall outline remains much the same
- for clarity, we will ignore any word that has three characters or less (typically stop words)

Four Set Functions

- **`add_word(word, word_set)`** add word to the set (instead of dict); no return
- **`process_line(line, word_set)`** process line and identify words; calls **`add_word`**; no return (no change except for parameters)
- **`pretty_print(word_set)`** nice printing of the various set operations; no return
- **`main()`** function to start the program

```
1 def add_word(word, word_set):
2     '''Add the word to the set. No word smaller than length 3.'''
3     if len(word) > 3:
4         word_set.add(word)
```

```
1  import string
2  def process_line(line, word_set):
3      '''Process the line to get lowercase words to be added to the set.'''
4      line = line.strip()
5      word_list = line.split()
6      for word in word_list:
7          # ignore the '--' that is in the file
8          if word != '--':
9              word = word.strip()
10             # get commas, periods and other punctuation out as well
11             word = word.strip(string.punctuation)
12             word = word.lower()
13             add_word(word, word_set)
```

More Complicated Pretty Print

- the **`pretty_print`** function applies the various set operators to the two resulting sets
- prints, in particular, the intersection in a nice format
- should this have been broken up into two functions??

```
def pretty_print(ga_set, doi_set):
    # print some stats about the two sets
    print('Count of unique words of length 4 or greater')
    print('Gettysburg Addr: {}, Decl of Ind: {}\n'.format(len(ga_set),len(
doi_set)))
    print('{:15s} {:15s}'.format('Operation', 'Count'))
    print('-'*35)
    print('{:15s} {:15d}'.format('Union', len(ga_set.union(doi_set))))
    print('{:15s} {:15d}'.format('Intersection', len(ga_set.intersection(
doi_set))))
    print('{:15s} {:15d}'.format('Sym Diff', len(ga_set.symmetric_difference(
doi_set))))
    print('{:15s} {:15d}'.format('GA-DoI', len(ga_set.difference(doi_set))))
    print('{:15s} {:15d}'.format('DoI-GA', len(doi_set.difference(ga_set))))

    # list the intersection words, 5 to a line, alphabetical order
    intersection_set = ga_set.intersection(doi_set)
    word_list = list(intersection_set)
    word_list.sort()
    print('\n Common words to both')
    print('-'*20)
    count = 0
    for w in word_list:
        if count % 5 == 0:
            print()
        print('{:13s}'.format(w), end=' ')
        count += 1
```

More on Scope

Namespace Review

- a namespace is an association of a name and a value
- it looks like a dictionary, and for the most part it is (at least for modules and classes)

Scope

- the namespace you might be using is part of identifying the scope of the variables and function you are using
- by "scope" we mean the context, the part of the code, where we can make a reference to a variable or function

Multiple Scopes

- often, there can be multiple scopes that are candidates for determining a reference.
- knowing which one is the right one (or more importantly, knowing the order of scopes) is important

Two Kinds of Namespaces

- ***unqualified namespaces:*** what we have pretty much seen so far – functions, assignments etc.
- ***qualified namespaces:*** modules and classes (we'll talk more about this one later in the classes section)

Unqualified

- this is the standard assignment and def we have seen so far
- determining the scope of a reference identifies what its true 'value' is

LEGB Rule for Unqualified

- ***local*** – inside the function in which it was defined
- ***enclosing/encompassing*** – is it defined in an enclosing function?
- ***global***
- ***built-in*** – finally, defined as part of the special built-in scope
- else ERROR

Code Listing 9.13

`locals()` Function

- returns a dictionary of the current (presently in play) local namespace
- useful for looking at what is defined where

Function Local Values

- if a reference is assigned in a function, then that reference is only available within that function
- if a reference with the same name is provided outside the function, the reference is reassigned

```
global_X = 27

def my_function(param1=123, param2='hi mom'):
    local_X = 654.321
    print('\n=== local namespace ===')
    for key,val in locals().items():
        print('key:{}, object:{}'.format(key, str(val)))
    print('local_X:',local_X)
    print('global_X:',global_X)

my_function()
```

```
=== local namespace ===
key:local_X, object:654.321
key:param1, object:123
key:param2, object:hi mom
local_X: 654.321
global_X: 27
```

global is still found because of the sequence of namespace search

`globals()` Function

- like the **`locals()`** function, the **`globals()`** function will return as a dictionary the values in the global namespace

```
import math
global_X = 27

def my_function(param1=123, param2='hi mom'):
    local_X = 654.321
    print('\n=== local namespace ===')
    for key,val in locals().items():
        print('key: {}, object: {}'.format(key, str(val)))
    print('local_X:',local_X)
    print('global_X:',global_X)

my_function()

key,val = 0,0  # add to the global namespace. Used below
print('\n--- global namespace ---')

for key,val in globals().items():
    print('key: {:15s} object: {}'.format(key, str(val)))

print('\n-----------------------')
#print 'Local_X:', local_X
print('Global_X:', global_X)
print('Math.pi:',math.pi)
print('Pi:',pi)
```

```
=== local namespace ===
key: local_X, object: 654.321
key: param1, object: 123
key: param2, object: hi mom
local_X: 654.321
global_X: 27

--- global namespace ---
key: my_function     object: <function my_function at 0xe15a30>
key: __builtins__    object: <module '__builtin__' (built-in)>
key: __package__     object: None
key: global_X        object: 27
key: __name__        object: __main__
key: __doc__         object: None
key: math            object: <module 'math' from '/Library/Frameworks/Python.
framework/Versions/3.2/lib/python3.2/lib-dynload/math.so'>

-----------------------
Global_X: 27
Math.pi: 3.14159265359
Pi:

Traceback (most recent call last):
  File "/Volumes/Admin/Book/chapterDictionaries/localsAndGlobals.py", line 22, in
<module>
    print('Pi:',pi)
NameError: name 'pi' is not defined
```

Global Assignment Rule

- a quirk of Python
- if an assignment occurs ***anywhere*** in the suite of a function, Python adds that variable to the local namespace
- even if the variable is assigned later in the suite, the variable is still local

```
my_var = 27

def my_function(param1=123, param2='Python'):
    for key,val in locals().items():
        print('key {}: {}'.format(key, str(val)))
    my_var = my_var + 1      # causes an error!

my_function(123456, 765432.0)
```

```
key param2: 765432.0
key param1: 123456
Traceback (most recent call last):
  File "localAssignment1.py", line 9, in <module>
    my_function(123456, 765432.0)
  File "localAssignment1.py", line 7, in my_function
    my_var = my_var + 1      # causes an error!
UnboundLocalError: local variable 'my_var' referenced before assignment
```

my_var is local (is in the local namespace) because it is assigned in the suite

The `global` Statement

- you can tell Python that you want the object associated with the global, not local namespace, using the **`global`** statement
- avoids the local assignment rule
- should be used carefully as it is an over-ride of normal behavior

```
my_var = 27

def my_function(param1=123, param2='Python'):
    for key,val in locals().items():
        print('key {}: {}'.format(key, str(val)))
    my_var = my_var + 1      # causes an error!

def better_function(param1=123, param2='Python'):
    global my_var
    for key,val in locals().items():
        print('key {}: {}'.format(key, str(val)))
    my_var = my_var + 1
    print('my_var:',my_var)



# my_function(123456, 765432.0)
better_function()
```

```
key param2: Python
key param1: 123
my_var: 28
```

my_var is not in the local namespace

built-in

- just the standard library of Python
- to see what is there, look at

```
import __builtin__
dir(__builtin__)
```

Enclosed

- functions which define other functions in a function suite are ***enclosed***, defined only in the enclosing function
- the inner/enclosed function is then part of the local namespace of the outer/enclosing function
- remember, a function is an object too!

```
global_var = 27

def outer_function(param_outer = 123):
    outer_var = global_var + param_outer

    def inner_function(param_inner = 0):
        # get inner, enclosed and global
        inner_var = param_inner + outer_var + global_var

        # print inner namespace
        print('\n--- inner local namespace ---')
        for key,val in locals().items():
            print('{}:{}'.format(key,str(val)))
        return inner_var

    result = inner_function(outer_var)
    # print outer namespace
    print('\n--- outer local namespace ---')
    for key,val in locals().items():
        print('{}:{}'.format(key,str(val)))
    return result

result  = outer_function(7)
print('\n--- result ---')
print('Result:',result)
```

```
--- inner local namespace ---
outer_var:34
inner_var:95
param_Inner:34

--- outer local namespace ---
outer_var:34
param_Outer:7
result:95
inner_function:<function inner_function at 0xe2ba30>

--- result ---
Result: 95
```

Building Dictionaries Faster

- **`zip`** creates pairs from two parallel lists

  `zip("abc",[1,2,3])` yields

  `[('a',1),('b',2),('c',3)]`

- good for building dictionaries
- also call the **`dict`** function which takes a list of pairs to make a dictionary

  `dict(zip("abc",[1,2,3]))` yields

  `{'a': 1, 'c': 3, 'b': 2}`

Dictionary and Set Comprehensions

- like list comprehensions, you can write shortcuts that generate either a dictionary or a set, with the same control you had with list comprehensions
- both are enclosed with `{}` (remember, list comprehensions were in `[]`)
- difference is if the collected item is a `:` separated pair or not

Dictionary Comprehension

```
>>> a_dict = {k:v for k,v in enumerate('abcdefg')}
>>> a_dict
{0: 'a', 1: 'b', 2: 'c', 3: 'd', 4: 'e', 5: 'f', 6: 'g'}
>>> b_dict = {v:k for k,v in a_dict.items()} # reverse key—value pairs
>>> b_dict
{'a': 0, 'c': 2, 'b': 1, 'e': 4, 'd': 3, 'g': 6, 'f': 5}
>>> sorted(b_dict)     # only sorts keys
['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> b_list = [(v,k) for v,k in b_dict.items()]   # create list
>>> sorted(b_list)                               # then sort
[('a', 0), ('b', 1), ('c', 2), ('d', 3), ('e', 4), ('f', 5), ('g', 6)]
```

Set Comprehension

```
>>> a_set = {ch for ch in 'to be or not to be'}
>>> a_set
{' ', 'b', 'e', 'o', 'n', 'r', 't'}  # set of unique characters
>>> sorted(a_set)
[' ', 'b', 'e', 'n', 'o', 'r', 't']
```

Reminder, rules so far

1. Think before you program!
2. A program is a human-readable essay on problem solving that 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.