CS303E: Elements of Computers and Programming

Lists

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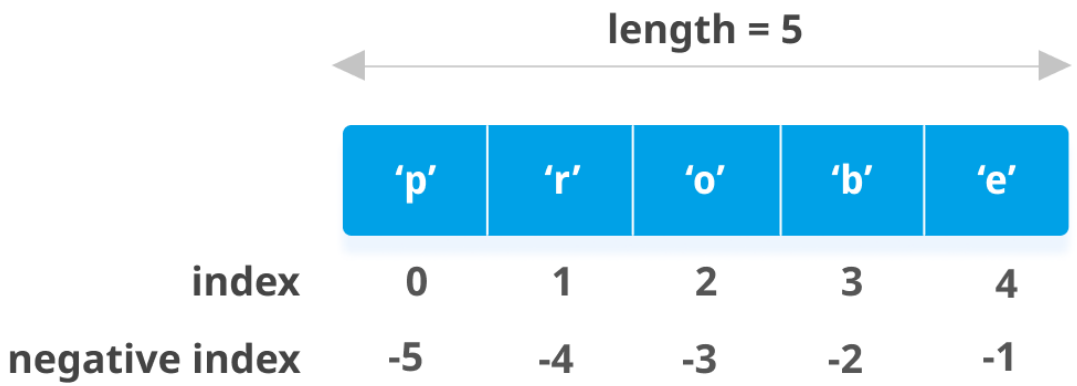
Lists

The `list` class is one of the most useful in Python.



Both strings and lists are sequence types in Python, so share many similar methods. Unlike strings, lists are *mutable*.

If you change a list, it doesn't create a new copy; *it changes the input list*.

Value of Lists

Suppose you have 30 different test grades to average. You could use 30 variables: grade1, grade2, ..., grade30. Or you could use one list with 30 elements: grades[0], grades[1], ..., grades[29].

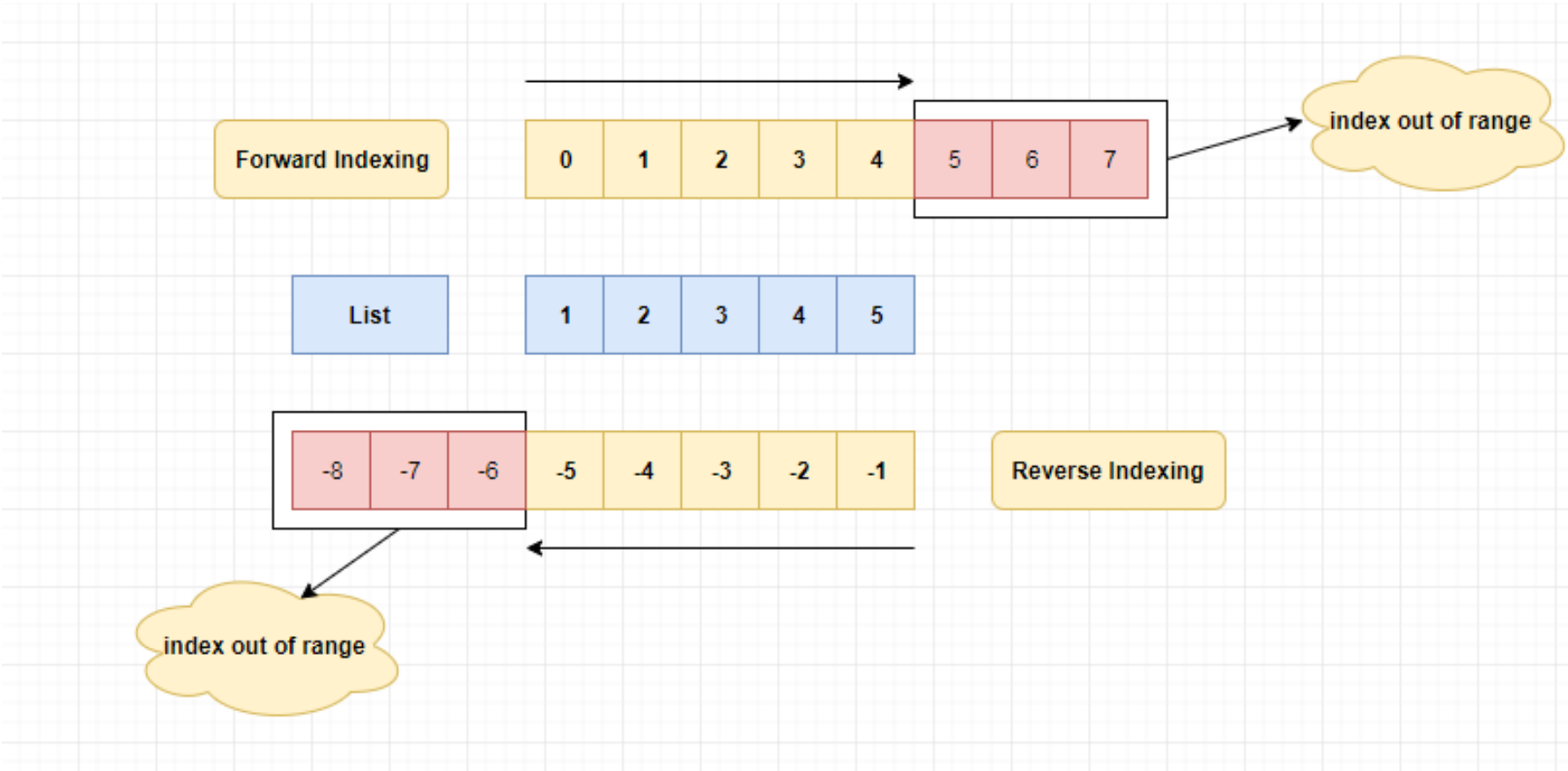
In file `AverageScores.py`:

```
grades = [ 67, 82, 56, 84, 66, 77, 64, 64, 85, 67, \
           73, 63, 98, 74, 81, 67, 93, 77, 97, 65, \
           77, 91, 91, 74, 93, 56, 96, 90, 91, 99 ]

sum = 0
for score in grades:
    sum += score
average = sum / len(grades)
print("Class average:", format(average, ".2f"))
```

```
> python AverageScores.py
Class average: 78.60
```

Indexing and Slicing

Indexing and slicing on lists are as for strings, including negative indexes.



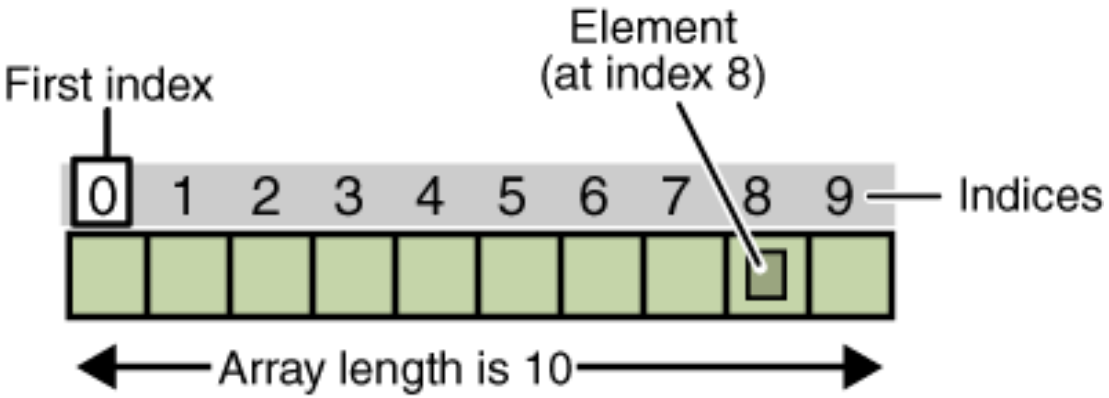
Creating Lists

Lists can be created with the `list` class constructor or using special syntax.

```
>>> list()                  # create empty list, with constructor
[]
>>> list([1, 2, 3])        # create list [1, 2, 3]
[1, 2, 3]
>>> list(["red", 3, 2.5])  # create heterogeneous list
['red', 3, 2.5]
>>> ["red", 3, 2.5]        # create list, no explicit constructor
['red', 3, 2.5]
>>> range(4)                # not an actual list
range(0, 4)
>>> list(range(4))          # create list using range
[0, 1, 2, 3]
>>> list("abcd")            # create character list from string
['a', 'b', 'c', 'd']
```

Lists vs. Arrays

Many programming languages have an **array** type. Python doesn't have native arrays (though some Python libraries add arrays).



Arrays are:

- homogeneous (all elements are of the same type)
- fixed size
- permit very fast access time

Python lists are:

- heterogeneous (can contain elements of different types)
- variable size
- permit fast access time

Sequence Operations

Like strings, lists are sequences and inherit various functions from sequences.

Function	Description
`x in s`	x is in sequence s
`x not in s`	x is not in sequence s
`s1 + s2`	concatenates two sequences
`s * n`	repeat sequence s n times
`s[i]`	ith element of sequence (0-based)
`s[i:j]`	slice of sequence s from i to j-1
`len(s)`	number of elements in s
`min(s)`	minimum element of s
`max(s)`	maximum element of s
`sum(s)`	sum of elements in s
`for loop`	traverse elements of sequence
`<, <=, >, >=`	compares two sequences
`==, !=`	compares two sequences

Calling Functions on Lists

```
>>> l1 = [1, 2, 3, 4, 5]
>>> len(l1)
5
>>> min(l1)      # assumes elements are comparable
1
>>> max(l1)      # assumes elements are comparable
5
>>> sum(l1)      # assumes summing makes sense
15
>>> l2 = [1, 2, "red"]
>>> sum(l2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for +: 'int' and 'str
    '
>>> min(l2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: '<' not supported between instances of 'str' and
    'int'
>>>
```

Aside: Functions vs. Methods

Since lists are actual objects in class `lst`, shouldn't `len`, `max`, etc. be *methods* instead of functions? Yes and no!

Remember from earlier that `len` is actually syntactic sugar for the method `__len__`.

```
>>> len([1, 2, 3])
3
>>> [1, 2, 3].__len__()
3
```

The others (`sum, max, min`) are actually functions defined on the class, for user convenience.

You just have to remember which operators are functions and which are methods.

Using Functions

We could rewrite AverageScores.py as follows:

```
grades = [ 67, 82, 56, 84, 66, 77, 64, 64, 85, 67, \
           73, 63, 98, 74, 81, 67, 93, 77, 97, 65, \
           77, 91, 91, 74, 93, 56, 96, 90, 91, 99 ]
average = sum(grades) / len(grades)
print("Class average:", format(average, ".2f"))
```

```
> python AverageScores.py
Class average: 78.60
```

Traversing Elements with a For Loop

General Form:

```
for u in list:
    body
```

In file `test.py`:

```
for u in range(3):                  # not really a list
    print(u, end=" ")
print()

for u in [2, 3, 5, 7]:
    print(u, end=" ")
print()

for u in range(15, 1, -3):  # not really a list
    print(u, end=" ")
print()
```

```
> python test.py
0 1 2
2 3 5 7
15 12 9 6 3
```

Comparing Lists

Compare lists using the operators: `>`, `>=`, `<`, `<=`, `==`, `!=`. Uses *lexicographic* ordering: Compare the first elements of the two lists; if they match, compare the second elements, and so on. The corresponding elements must be of *comparable* classes.

```
>>> list1 = ["red", 3, "green"]
>>> list2 = ["red", 3, "grey"]
>>> list1 < list2
True
>>> list3 = ["red", 5, "green"]
>>> list3 > list1
True
>>> list4 = [5, "red", "green"]
>>> list3 < list4
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: '<' not supported between instances of 'str' and
    'int'
>>> ["red", 5, "green"] == [5, "red", "green"]
False
```

BTW: the book's comparisons in 10.2.8 seem wrong.

List Comprehension

List comprehension gives a compact syntax for building lists.

```
>>> range(4)                          # not actually a list
range(0, 4)
>>> [ x for x in range(4) ]           # create list from range
[0, 1, 2, 3]
>>> [ x ** 2 for x in range(4) ]
[0, 1, 4, 9]
>>> lst = [ 2, 3, 5, 7, 11, 13 ]
>>> [ x ** 3 for x in lst ]
[8, 27, 125, 343, 1331, 2197]
>>> [ x for x in lst if x > 2 ]
[3, 5, 7, 11, 13]
>>> [s[0] for s in ["red", "green", "blue"] if s <= "green"]
['g', 'b']
>>> from IsPrime3 import *
>>> [ x for x in range(100) if isPrime(x) ]
[2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53,
     59, 61, 67, 71, 73, 79, 83, 89, 97]
```

Let's Take a Break

More List Methods

These are methods from class `list`. Since lists are mutable, these actually change `l`.

Function	Description
`l.append(x)`	add x to the end of l
`l.extend(l2)`	append elements of l2 to l
`l.insert(i, x)`	insert x into l at position i
`l.pop()`	remove and return the last element of l
`l.pop(i)`	remove and return the ith element of l
`l.remove(x)`	remove the first occurence of x from l
`l.reverse()`	reverse the elements of l
`l.sort()`	order the elements of l
`l.count(x)`	number of times x appears in l
`l.index(x)`	index of first occurence of x in l

List Examples

```
>>> l1 = [1, 2, 3]
>>> l1.append(4)              # add 4 to the end of l1
>>> l1                        # note: changes l1
[1, 2, 3, 4]
>>> l1.count(4)               # count occurrences of 4 in l1
1
>>> l2 = [5, 6, 7]
>>> l1.extend(l2)             # add elements of l2 to l1
>>> l1
[1, 2, 3, 4, 5, 6, 7]
>>> l1.index(5)               # where does 5 occur in l1?
4
>>> l1.insert(0, 0)           # add 0 at the start of l1
>>> l1                        # note new value of l1
[0, 1, 2, 3, 4, 5, 6, 7]
>>> l1.insert(3, 'a')         # lists are heterogenous
>>> l1
[0, 1, 2, 'a', 3, 4, 5, 6, 7]
>>> l1.remove('a')            # what goes in can come out
>>> l1
[0, 1, 2, 3, 4, 5, 6, 7]
```

List Examples

```
>>> l1.pop()                    # remove and return last element
7
>>> l1
[0, 1, 2, 3, 4, 5, 6]
>>> l1.reverse()                # reverse order of elements
>>> l1
[6, 5, 4, 3, 2, 1, 0]
>>> l1.sort()                   # elements must be comparable
>>> l1
[0, 1, 2, 3, 4, 5, 6]
>>> l2 = [4, 1.3, "dog"]
>>> l2.sort()                   # elements must be comparable
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: '<' not supported between instances of 'str' and
    'float'
>>> l2.pop()                    # put the dog out
'dog'
>>> l2
[4, 1.3]
>>> l2.sort()                   # int and float are comparable
>>> l2
[1.3, 4]
```

Random Shuffle

A useful method on lists is `random.shuffle()` from the `random` module.

```
>>> import random
>>> list1 = [ x for x in range(9) ]
>>> list1
[0, 1, 2, 3, 4, 5, 6, 7, 8]
>>> random.shuffle( list1 )
>>> list1
[7, 4, 0, 8, 1, 6, 5, 2, 3]
>>> random.shuffle( list1 )
>>> list1
[4, 1, 5, 0, 7, 8, 3, 2, 6]
>>> random.shuffle( list1 )
>>> list1
[7, 5, 2, 6, 0, 4, 3, 1, 8]
```

Splitting a String into a List

Recall our `SplitFields` function from Slideset 8 to split up a comma separated value (csv) string. Python provides an easier approach with the `split` method on strings.

```
>>> str1 = "abc, def , ghi"
>>> str1.split(",")                    # split on comma
['abc', ' def ', ' ghi']               # keeps whitespace
>>> strs = " abc def ghi "
strs.split()                           # split on whitespace
['abc', 'def', 'ghi']
>>> str3 = "\tabc\ndef\r ghi\n"
>>> str3.split()                       # split on whitespace
['abc', 'def', 'ghi']
>>> str4 = "abc / def / ghi"
>>> str4.split("/")                    # split on slash
['abc ', ' def ', ' ghi']
```

Note `split` with no arguments splits on whitespace.

Processing CSV Lines

Suppose grades for a class were stored in a list of csv strings, such as:

```
studentData = ["Charlie,90,75",
               "Frank,8,77",
               "Susie,60,80"]
```

Here the fields are: Name, Midterm grade, Final Exam grade.

Compute the average for each student and print a nice table of results. *Remember that we solved a version of this problem in Slideset 3, where the data was entered by the user.*

Processing CSV Lines

```
def ProcessStudentData ( studentData ):
    """ Process list of csv student records. """
    # Print header line:
    print( "Name           MT   FN   Avg")
    print( "-----------------------------")

    for line in studentData:
        fields = line.split(',')
        if (len(fields) < 3):
            print( "Bad student record for ", fields[0] )
            continue
        else:
            name, midterm, final = fields[0].strip(), \
                                   int(fields[1].strip()), \
                                   int(fields[2].strip())
            avg = (midterm + final) / 2
            print( format(name, "10s"), \
                   format(midterm, "4d"), \
                   format(final, "4d"), \
                   format(avg, "7.2f") )
```

Processing CSV Lines

```
def main():
    studentData = ["Charlie,90,75",
                   "Frank,8,77",
                   "Johnnie,40",
                   "Susie,60,80"]
    ProcessStudentData( studentData )

main()
```

```
> python ExamExample2.py
Name            MT    FN    Avg
-----------------------------
Charlie         90    75    82.50
Frank            8    77    42.50
Bad student record for  Johnnie
Susie           60    80    70.00
```

Copying Lists

Suppose you want to make a copy of a list. *The following won't work!*

```
>>> lst1 = [1, 2, 3, 4]
>>> lst2 = lst1
>>> lst1 is lst2      # there's only one list here
True
>>> print(lst1)
[1, 2, 3, 4]
>>> print(lst2)
[1, 2, 3, 4]
>>> lst1.append(5)    # changes to lst1 also change lst2
>>> print(lst2)
[1, 2, 3, 4, 5]
```

But you can do the following:

```
>>> lst2 = [x for x in lst1]    # creates a new copy
>>> lst3 = list(lst1)           # this also works
```

Passing Lists to Functions

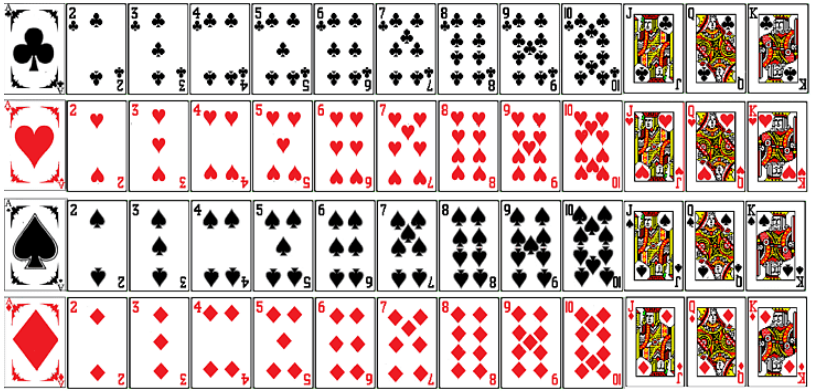
Like any other *mutable* object, when you pass a list to a function, you're really passing a reference (pointer) to the object in memory.

```
def alter( lst ):
    lst.pop()

def main():
    lst = [1, 2, 3, 4]
    print( "Before call: ", lst )
    alter( lst )
    print( "After call: ", lst )

main()
```

```
> python ListArg.py
Before call:  [1, 2, 3, 4]
After call:  [1, 2, 3]
```

Let's Take a Break

Classes Using Lists: Card Deck Example



In Slideset 7 we introduced the Card class. Let's now define a Deck of Cards. Remember we defined some functions: `isRank`, `isSuit`, `cardRankToIndex`, `cardIndexToRank`, etc.

It would be much easier to just add the following constant definitions to `Card.py`.

```
RANKS = ['Ace', '2', '3', '4', '5', '6', '7', '8', \
         '9', '10', 'Jack', 'Queen', 'King']
SUITS = ['Spades', 'Diamonds', 'Hearts', 'Clubs']
```

Think of how you'd redefine the functions listed above with those lists available.

Card Auxiliary Functions

```
RANKS = ['Ace', '2', '3', '4', '5', '6', '7', '8', '9', \
         '10', 'Jack', 'Queen', 'King']
SUITS = ['Spades', 'Diamonds', 'Hearts', 'Clubs']

def isRank( r ):
    return r in RANKS

def isSuit( s ):
    return s in SUITS

def cardRankToIndex( r ):
    return RANKS.index( r )

def cardSuitToIndex( s ):
    return SUITS.index( s )
```

Designing the Deck Class

A deck of cards "is" a list of Card objects, one for each combination of rank and suit.

Data: a list of Card objects, initially all possible combinations of rank and suit.

Methods:

- Print the deck in order.
- Shuffle the deck.
- Deal a card from deck.
- How many cards are left in the deck (after dealing)?

Create a Card Deck

In file Deck.py:

```
import random
from Card import *

class Deck:
    """ Defines the Deck class.  Each Deck contains
    a list of cards, one for each rank and suit """

    def __init__(self):
        """Return a new deck of cards."""
        self.__cards = []
        for suit in Card.SUITS:
            for rank in Card.RANKS:
                c = Card(rank, suit)
                self.__cards.append(c)
```

Card Deck Example

Other things we might want to do with a deck are:

1. shuffle the deck
2. deal a card from the deck
3. ask how many cards are left in the deck
4. print the deck in order

Since the deck "is" a list, shuffling just means calling the `random.shuffle` function.

```
    def shuffle(self):
        """Shuffle the cards."""
        random.shuffle(self.__cards)
```

Since lists are mutable, this shuffles *in place*, i.e., it doesn't create a new deck.

Dealing a Card and Deck Length

Dealing a Card means removing the top card from the Deck and returning that card:

```
    def deal(self):
        """Remove and return the top card, or None
        if the deck is empty."""
        if len(self) == 0:
            print("Deck is empty.")
            return None
        else:
            return self.__cards.pop(0)
```

Notice that we're calling `len(self)` to check whether the Deck is empty. This only works if we define the `__len__` method for the class:

```
    def __len__(self):
        """Returns the number of cards left in the deck."""
        return len(self.__cards)
```

Printing a Deck

Finally, we can use the `print` method for Deck class instances only if we've defined a `__str__` method to generate an appropriate string value:

```
    def __str__(self):
        result = ""
        for c in self.__cards:
            # Here we ask each card how it
            # wants to be printed.
            result = result + str(c) + "\n"
        return result
```

Notice that `str(c)` only works because we defined the `__str__` method within class `Card`.

Using the Deck Class

```
>>> from Deck import *
>>> d = Deck()                    # create a new deck
>>> print( d )                    # print, notice order
Ace of Spades
2 of Spades
   ...
Jack of Clubs
Queen of Clubs
King of Clubs

>>> d.shuffle()                  # randomly shuffle deck
>>> print( d )
Queen of Spades
5 of Diamonds
4 of Clubs
  ...
Jack of Diamonds
8 of Clubs
```

Using the Deck Class

```
>>> c1 = d.deal()                    # deal top card
>>> print( c1 )
Queen of Spades
>>> c2 = d.deal()                    # deal next card
>>> print( c2 )
5 of Diamonds
>>> len( c1 )                        # didn't define len for Card
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object of type 'Card' has no len()
>>> len( d )                         # deck now 50 cards
50
>>> d.__len__()                      # len same as __len__
50
>>> d.__cards                        # can't access private field
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: 'Deck' object has no attribute '__cards'
```

Designing the Hand Class

Recall that our initial goal (from the Object slideset) was playing Poker. Now that we have Cards and Decks, we can define Hands; a poker hand is five cards.

Data: a list of five Card objects, dealt from a Deck object.

Methods:

- Print the hand in order.
- (Later) evaluate the hand as a poker hand.

The Hand Class

From file Hand.py:

```
import Card
from Deck import *

class Hand:
    """ Five cards dealt from a Deck object. """
    def __init__(self, deck):
        """ A hand is simply a list of 5 cards, dealt
            from the deck. """
        if ( len(deck) < 5 ):
            print ( "Not enough cards left!" )
            return None
        self.__cards = []
        for i in range(5):
            card = deck.deal()           # deal next card
            self.__cards.append(card)    # append to hand

    def __str__(self):
        result = ""
        for card in self.__cards:
            result = result + str(card) + "\n"
        return result
```

The Hand Class

Finally, we allow looking at the cards in the Hand object:

```
    def getCard( self, i ):
        """ Get the ith card from the hand, where
            i in [0..4]. """
        if (0 <= i <= 4):
            return self.__cards[i]
        else:
            return None
```

Using the Hand Class

```
>>> from Hand import *
>>> h1 = Hand()                  # can't deal without a deck
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: __init__() missing 1 required positional argument
    : 'deck'
>>> d = Deck()                   # so create a new deck
>>> d.shuffle()                  # shuffle it
>>> print( d )
7 of Clubs
King of Diamonds
6 of Diamonds
Queen of Spades
8 of Clubs
Jack of Hearts
8 of Hearts
 ...
7 of Spades
10 of Clubs
```

Using the Hand Class

```
>>> h1 = Hand( d )          # deal a hand from Deck d
>>> print( h1 )
7 of Clubs
King of Diamonds
6 of Diamonds
Queen of Spades
8 of Clubs

>>> h2 = Hand( d )          # deal another hand
>>> print( h2 )
Jack of Hearts
8 of Hearts
Jack of Clubs
9 of Clubs
8 of Diamonds

>>> len( d )
42
>>> len( h1 )              # we didn't define len on Hand
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object of type 'Hand' has no len()
```

Future Work

It would be nice to be able to evaluate a hand as a poker hand, and perhaps compare two hands.

That would be a pretty good project!

Next stop: More on Lists.