# CS303E: Elements of Computers and Programming
## Lists

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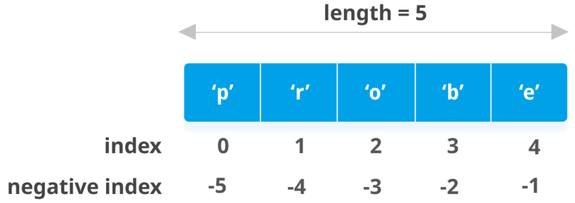
# Lists

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].

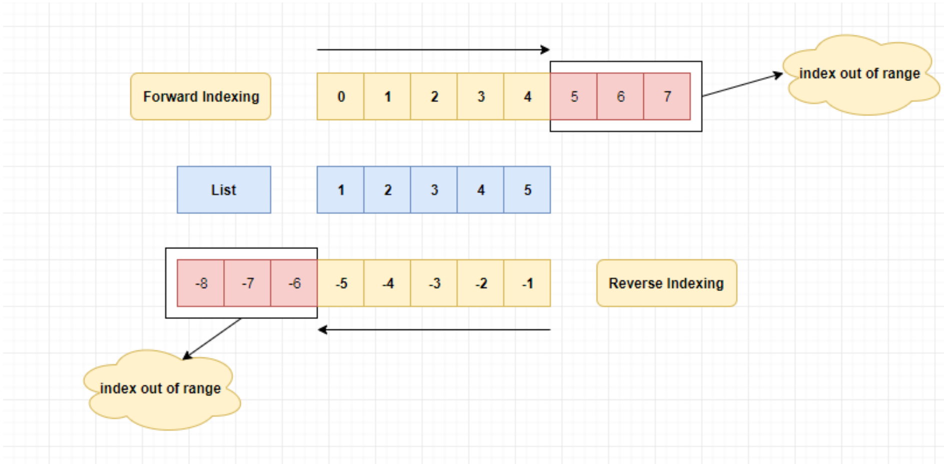
In file `AverageScores.py`:

```
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.



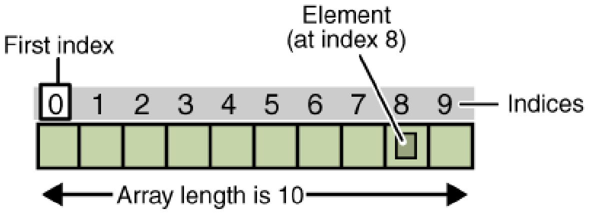
## Creating Lists

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, 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

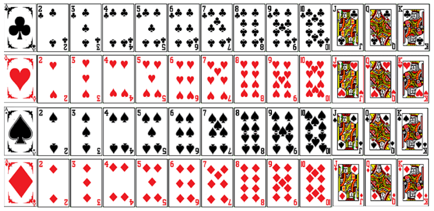
Like any other *mutable* object, when you pass a list to a function, you're really passing a reference (pointer) to the object in memory.

```
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.

```
    def show(self):
        print "{} of {}".format(self.value, self.suit)

class Deck(object):
    def __init__(self):
        self.cards = []
        self.build()

    def build(self):
        for s in ["Spades", "Clubs", "Diamonds", "Hearts"]:
```

```
Elis-MacBo
12 of Spade
5 of Diamonds
Elis-MacBook-Pro:Desktop elibyers$ python Deck_of_Cards.py
2 of Diamonds
```

**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.