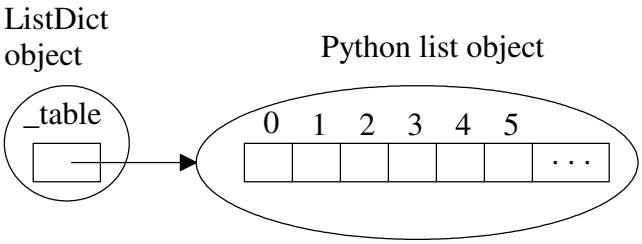
METHOD	WHAT IT DOES
`d = ListDict()`	Creates and returns an empty dictionary.
`d.__getitem__(key)`	Same as `d[key]`. Returns the value associated with `key` if `key` exists, or returns `None` otherwise.
`d.__setitem__(key, value)`	Same as `d[key] = value`. If `key` exists, replaces its associated value with `value`; otherwise, inserts a new `key/value` entry.
`d.pop(key)`	Removes the `key`/value entry and returns the associated value if `key` exists, or returns `None` otherwise.
`d.__contains__(key)`	Same as `key in d`. Returns `True` if `key` is a key in `d`, or returns `False` otherwise.
`d.__len__()`	Same as `len(d)`. Returns the number of entries currently in `d`.
`d.__iter__()`	Returns an iterator on the keys of `d`. Supports a `for` loop with `d`. Keys are visited in an unspecified order.
`d.__str__()`	Same as `str(d)`. Returns a string containing the string representations of the key/value pairs in `d`.

[TABLE 19.3] The interface of the `ListDict` class



1. Consider the following `ListDict` class implementation.

```
""" File: dictionary.py """

class Entry(object):
    """A key/value pair."""

    def __init__(self, key, value):
        self.key = key
        self.value = value

    def __eq__(self, other):
        return self.key == other.key

    def __str__(self):
        return str(self.key) + ":" + str(self.value)
```

```
class ListDict(object):
    """A list-based implementation of a dictionary."""

    def __init__(self):
        self._table = []

    def __getitem__(self, key):
        """Returns the value associated with key or
        returns None if key does not exist."""
        entry = Entry(key, None)
        try:
            index = self._table.index(entry)
            return self._table[index].value
        except:
            return None

    def pop(self, key):
        """Removes the entry associated with key and
        returns its value or returns None if key
        does not exist."""
        entry = Entry(key, None)
        try:
            index = self._table.index(entry)
            return self._table.pop(index).value
        except:
            return None

    def __setitem__(self, key, value):
        """Inserts an entry with key/value if key
        does not exist or replaces the existing value
        with value if key exists."""
        entry = Entry(key, value)
        try:
            index = self._table.index(entry)
            self._table[index] = entry
        except:
            self._table.append(entry)

    # The methods __len__(), __str__(), keys(),
    #     contains    , and values() are exercises
```

a) Explain how the __getitem__ method looks up a key?

b) What is the average-case theta notation of each operation?

__getitem__(self, key):

pop(self, key):

__setitem__(self, key, value):

__contains__(key):

2. Consider the following `HashDict` class implementation.

```
from arrays import Array

class HashEntry(Entry):

    def __init__(self, key, value, next):
        Entry.__init__(self, key, value)
        self.next = next

class HashDict(object):
    """A hashing implementation of a dictionary."""

    DEFAULT_CAPACITY = 3

    def __init__(self, capacity = None):
        if capacity is None:
            self._capacity = HashDict.DEFAULT_CAPACITY
        else:
            self._capacity = capacity
        self._table = Array(self._capacity)
        self._size = 0
        self._priorEntry = None
        self._foundEntry = None
        self._index = None

    def __contains__(self, key):
        """Returns True if key is in the dictionary or
           False otherwise."""
        self._index = abs(hash(key)) % self._capacity
        self._priorEntry = None
        self._foundEntry = self._table[self._index]
        while self._foundEntry != None:
            if self._foundEntry.key == key:
                return True
            else:
                self._priorEntry = self._foundEntry
                self._foundEntry = self._foundEntry.next
        return False

    def __getitem__(self, key):
        """Returns the value associated with key or
           returns None if key does not exist."""
        if key in self:
            return self._foundEntry.value
        else:
            return None

    def pop(self, key):
        """Removes the entry associated with key and
           returns its value or returns None if key
        does not exist."""
        if not key in self:
            return None
        else:
            if self._priorEntry is None:
                self._table[self._index] = self._foundEntry.next
            else:
                self._priorEntry.next = self._foundEntry.next
            self._size -= 1
            return self._foundEntry.value
```

a) Explain how the __getitem__ method looks up a key?

b) What is the average-case theta notation of each operation? (Let α be *load factor* (n/Array size))

__getitem__(self, key):

pop(self, key):

__setitem__(self, key, value):

__contains__(key):

```
    def __setitem__(self, key, value):
        """Inserts an entry with key/value if key
           does not exist or replaces the existing value
           with value if key exists."""
        if not key in self:
            newEntry = HashEntry(key, value,
                                 self._table[self._index])
            self._table[self._index] = newEntry
            self._size += 1
            return None
        else:
            returnValue = self._foundEntry.value
            self._foundEntry.value = value
            return returnValue

    def __len__(self):
        return self._size

    def __str__(self):
        result = "HashDict: capacity = " + \
                 str(self._capacity) + ", load factor = " + \
                 str(len(self) / float(self._capacity))
        for i in xrange(self._capacity):
            rowStr = ""
            entry = self._table[i]
            while entry != None:
                rowStr += str(entry) + " "
                entry = entry.next
            if rowStr != "":
                result += "\nRow " + str(i) + ": " + rowStr
        return result
    # The methods keys() and values() are exercises
```

3. Consider the following `HashTable` class implementation.

```
""" File: hashtable.py  Case study for Chapter 19.  """

from arrays import Array

class HashTable(object):
    "Represents a hash table."""

    EMPTY = None
    DELETED = True

    def __init__(self, capacity = 29,
                 hashFunction = hash,
                 linear = True):
        self._table = Array(capacity, HashTable.EMPTY)
        self._size = 0
        self._hash = hashFunction
        self._homeIndex = -1
        self._actualIndex = -1
        self._linear = linear
        self._probeCount = 0

    def insert(self, item):
        """Inserts item into the table
        Preconditions: There is at least one empty cell or
        one previously occupied cell.
        There is not a duplicate item."""
        self._probeCount = 0
        # Get the home index
        self._homeIndex = abs(self._hash(item)) % len(self._table)
        distance = 1
        index = self._homeIndex

        # Stop searching when an empty cell is encountered
        while not self._table[index] in (HashTable.EMPTY,
                                         HashTable.DELETED):

            # Increment the index and wrap around to first
            # position if necessary
            if self._linear:
                increment = index + 1
            else:
                # Quadratic probing
                increment = self._homeIndex + distance ** 2
                distance += 1
            index = increment % len(self._table)
            self._probeCount += 1

        # An empty cell is found, so store the item
        self._table[index] = item
        self._size += 1
        self._actualIndex = index
```

Let α be the load factor. The average probes with **linear probing** for insertion or unsuccessful search is:

$$\left(\tfrac{1}{2}\right)\left(1+\left(\frac{1}{(1-\alpha)^2}\right)\right)$$

The average probes with linear probing for successful search is:

$$\left(\tfrac{1}{2}\right)\left(1+\left(\frac{1}{(1-\alpha)}\right)\right)$$

If $\alpha = 0.8$, what is the average probes for:

a) unsuccessful search?

b) successful search?

c) Why is unsuccessful worse than successful search?

```
def search(self, item):
    """Search for item in the table."""
    self._probeCount = 0
    # Get the home index
    self._homeIndex = abs(self._hash(item)) % len(self._table)
    distance = 1
    index = self._homeIndex

    # Stop searching when an empty cell is encountered
    while not self._table[index] in (HashTable.EMPTY,  item):

        # Increment the index and wrap around to first
        # position if necessary
        if self._linear:
            increment = index + 1
        else:
            # Quadratic probing
            increment = self._homeIndex + distance ** 2
            distance += 1
        index = increment % len(self._table)
        self._probeCount += 1

    # An empty cell is found, so return None
    if self._table[index] == HashTable.EMPTY:
        return None
    else:
        self._actualIndex = index
        return self._table[index]

# Methods __len__(), __str__(), loadFactor(), homeIndex(),
# actualIndex(), and probeCount() are exercises.
```

4. Let α be the load factor. The average probes with **quadratic probing** for insertion or unsuccessful search is:

$$\left(\frac{1}{1-\alpha}\right) - \alpha - \log_e(1-\alpha)$$

The average probes with quadratic probing for successful search is:

$$1 - \left(\frac{\alpha}{2}\right) - \log_e(1-\alpha)$$

Consider the following table containing the average number probes for various load factors:

Probing Type	**Search outcome**	**Load Factor**				
		0.25	**0.5**	**0.67**	**0.8**	**0.99**
Linear Probing	unsuccessful	1.39	2.50	5.09	13.00	5000.50
	successful	1.17	1.50	2.02	3.00	50.50
Quadratic Probing	unsuccessful	1.37	2.19	3.47	5.81	103.62
	successful	1.16	1.44	1.77	2.21	5.11

a) Why do you suppose the "general rule of thumb" in hashing tries to keep the load factor between 0.5 and 0.67?

5. Allowing deletions from an open-address hash table complicates the implementation. Assuming linear probing we might have the following

Set of Keys	Hash function
John Doe	hash(John Doe) = 6
Philip East	hash(Philip East) = 3
Mark Fienup	hash(Mark Fienup) = 5
Ben Schafer	hash(Ben Schafer) = 8
Paul Gray	hash(Paul Gray) = 3
Kevin O'Kane	hash(Kevin O'Kane) = 4

Hash Table Array

0		
1		
2		
3	Philip East	3-2939
4	Paul Gray	3-5917
5	Mark Fienup	3-5918
6	John Doe	3-4567
7	Kevin O'Kane	3-7322
8	Ben Schafer	3-2187
9		
10		

a) If "Mark Fienup" is deleted, how will we find Kevin O'Kane?

b) How might we fix this problem?