Lecture 17: Mutable Linked Lists

Brian Hou
July 20, 2016

Announcements

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  - May cover mutability, OOP I (Monday)

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- Project 3 is due 7/26 at 11:59pm
  - Earn 1 EC point for completing it by 7/25
- Quiz 5 tomorrow at the beginning of lecture
  - May cover mutability, OOP I (Monday)
- Project 1 revisions due 7/27 at 11:59pm

Roadmap

- Introduction
- Functions
- Data
- Mutability
- Objects
- Interpretation
- Paradigms
- Applications

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  - To learn the paradigm of *object-oriented programming*

Roadmap

- Introduction
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- Objects
- Interpretation
- Paradigms
- Applications

- This week (Objects), the goals are:
  - To learn the paradigm of *object-oriented programming*
  - To study applications of, and problems that be solved using, OOP

Practical OOP

Checking Types (and Accounts)

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>>> ch = CheckingAccount('Brian')
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```
>>> a = Account('Brian')
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>>> type(a) == Account
True
>>> type(ch) == Account
False
>>> type(ch) == CheckingAccount
True
```

Checking Types (and Accounts) (demo)

- We often check the type of an object to determine what operations it permits
- The **type** built-in function returns the class that its argument is an instance of
- The **isinstance** built-in function returns whether its first argument (object) is an instance of the second argument (class) *or a subclass*

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>>> a = Account('Brian')
>>> ch = CheckingAccount('Brian')

>>> type(a) == Account
True
>>> type(ch) == Account
False
>>> type(ch) == CheckingAccount
True

>>> isinstance(a, Account)
True
>>> isinstance(ch, Account)
True
>>> isinstance(a, CheckingAccount)
False
>>> isinstance(ch, CheckingAccount)
True
```

Checking Types (and Accounts) (demo)

- We often check the type of an object to determine what operations it permits
- The **type** built-in function returns the class that its argument is an instance of
- The **isinstance** built-in function returns whether its first argument (object) is an instance of the second argument (class) *or a subclass*
- isinstance(obj, cls) is usually preferred over type(obj) == cls

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>>> a = Account('Brian')
>>> ch = CheckingAccount('Brian')

>>> type(a) == Account
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>>> type(ch) == Account
False
>>> type(ch) == CheckingAccount
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Python's Magic Methods

Python's Magic Methods (demo)

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```
>>> x = Rational(3, 5)
>>> y = Rational(1, 3)
>>> y
Rational(1, 3)
```

Python's Magic Methods (demo)

- How does the Python interpreter display values?

```
>>> x = Rational(3, 5)
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  - First, it evaluates the expression to some value

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Python's Magic Methods (demo)

- How does the Python interpreter display values?
  - First, it evaluates the expression to some value
  - Then, it calls repr on that value and prints that string

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```
>>> x = Rational(3, 5)
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>>> y
Rational(1, 3)
>>> repr(y)
'Rational(1, 3)'
>>> print(repr(y))
Rational(1, 3)
```

Python's Magic Methods (demo)

- How does the Python interpreter display values?
  - First, it evaluates the expression to some value
  - Then, it calls repr on that value and prints that string
- How do magic methods work?

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Python's Magic Methods (demo)

- How does the Python interpreter display values?
  - First, it evaluates the expression to some value
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- How do magic methods work?

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>>> y
Rational(1, 3)
>>> repr(y)
'Rational(1, 3)'
>>> print(repr(y))
Rational(1, 3)
>>> x * y
Rational(1, 5)
>>> x.__mul__(y)
Rational(1, 5)
```

Python's Magic Methods (demo)

- How does the Python interpreter display values?
  - First, it evaluates the expression to some value
  - Then, it calls repr on that value and prints that string
- How do magic methods work?
- Are integers objects too? (Yep!)

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>>> y
Rational(1, 3)
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Python's Magic Methods (demo)

- How does the Python interpreter display values?
  - First, it evaluates the expression to some value
  - Then, it calls repr on that value and prints that string
- How do magic methods work?
- Are integers objects too? (Yep!)
- Are ____ objects too? (Yep!)

```
>>> x = Rational(3, 5)
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Rational(1, 3)
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```

Linked Lists

The Link Class

The Link Class

```
empty = 'X'

def link(first, rest=empty):
    return [first, rest]

def first(lnk):
    return lnk[0]

def rest(lnk):
    return lnk[1]
```

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>>> link_adt = link(1,
                    link(2,
                    link(3)))
>>> first(rest(link_adt))
2
```

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```
class Link:
    empty = ()
```

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empty = 'X'

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def first(lnk):
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>>> link_adt = link(1,
                    link(2,
                    link(3)))
>>> first(rest(link_adt))
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```

```
class Link:
    empty = ()

    def __init__(self, first,
                 rest=empty):
```

The Link Class

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```
class Link:
    empty = ()

    def __init__(self, first,
                 rest=empty):
        self.first = first
```

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class Link:
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        self.first = first
        self.rest = rest
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class Link:
    empty = ()

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>>> link_cls = Link(1,
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>>> link_cls = Link(1,
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>>> link_cls.rest.first
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Mutable Linked Lists

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- Instances of user-defined classes are mutable *by default*

Mutable Linked Lists (demo)

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Mutable Linked Lists (demo)

- Instances of user-defined classes are mutable *by default*

```
class Link:
    empty = ()

    def __init__(self, first, rest=empty):
        self.first = first
        self.rest = rest

    def __repr__(self):
        if self.rest is Link.empty:
            return 'Link({0})'.format(
                self.first)
        else:
            return 'Link({0}, {1})'.format(
                self.first, repr(self.rest))
```

Linked Lists are Sequences

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```
class Link:
```

Linked Lists are Sequences

```
class Link:
    empty = ()

    ...
```

Linked Lists are Sequences

```
class Link:
    empty = ()

    ...

    def __getitem__(self, i):
```

Linked Lists are Sequences

```
class Link:
    empty = ()

    ...

    def __getitem__(self, i):
        if i == 0:
```

Linked Lists are Sequences

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class Link:
    empty = ()

    ...

    def __getitem__(self, i):
        if i == 0:
            return self.first
```

Linked Lists are Sequences

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class Link:
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    ...

    def __getitem__(self, i):
        if i == 0:
            return self.first
        elif self.rest is Link.empty:
```

Linked Lists are Sequences

```
class Link:
    empty = ()

    ...

    def __getitem__(self, i):
        if i == 0:
            return self.first
        elif self.rest is Link.empty:
            raise IndexError('...')
```

Linked Lists are Sequences

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Linked Lists are Sequences

Sneaky recursive call: equivalent to self.rest.__getitem__(i-1)

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    def __len__(self):
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        else:
            return self.rest[i - 1]

    def __len__(self):
        return 1 + len(self.rest)
```

Linked Lists are Sequences

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Sneaky recursive call: equivalent to self.rest.__getitem__(i-1)

Another sneaky recursive call: equivalent to self.rest.__len__()

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Sneaky recursive call: equivalent to self.rest.__getitem__(i-1)

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Where's the base case??

Linked Lists are Sequences

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Linked Lists are Sequences (demo)

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    empty = ()

    ...

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Where's the base case??

The __setitem__ Magic Method

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```
>>> s = Link(1, Link(2, Link(3)))
```

The __setitem__ Magic Method

```
>>> s = Link(1, Link(2, Link(3)))
>>> s[1] = 3
```

The __setitem__ Magic Method

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>>> s = Link(1, Link(2, Link(3)))
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```

The __setitem__ Magic Method

```
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Link(1, Link(3, Link(3)))
```

The __setitem__ Magic Method

```
>>> s = Link(1, Link(2, Link(3)))
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>>> s
Link(1, Link(3, Link(3)))
```

```
class Link:
```

The __setitem__ Magic Method

```
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```

```
class Link:
    ...
```

The __setitem__ Magic Method

```
>>> s = Link(1, Link(2, Link(3)))
>>> s[1] = 3
>>> s
Link(1, Link(3, Link(3)))
```

```
class Link:
    ...
    def __setitem__(self, i, val):
```

The __setitem__ Magic Method

```
>>> s = Link(1, Link(2, Link(3)))
>>> s[1] = 3
>>> s
Link(1, Link(3, Link(3)))
```

```
class Link:
    ...
    def __setitem__(self, i, val):
        if i == 0:
```

The __setitem__ Magic Method

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class Link:
    ...
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Link(1, Link(3, Link(3)))
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class Link:
    ...
    def __setitem__(self, i, val):
        if i == 0:
            self.first = val
        elif self.rest is Link.empty:
```

The __setitem__ Magic Method

```
>>> s = Link(1, Link(2, Link(3)))
>>> s[1] = 3
>>> s
Link(1, Link(3, Link(3)))
```

```
class Link:
    ...
    def __setitem__(self, i, val):
        if i == 0:
            self.first = val
        elif self.rest is Link.empty:
            raise IndexError('...')
```

The __setitem__ Magic Method

```
>>> s = Link(1, Link(2, Link(3)))
>>> s[1] = 3
>>> s
Link(1, Link(3, Link(3)))
```

```
class Link:
    ...
    def __setitem__(self, i, val):
        if i == 0:
            self.first = val
        elif self.rest is Link.empty:
            raise IndexError('...')
        else:
```

The __setitem__ Magic Method

```
>>> s = Link(1, Link(2, Link(3)))
>>> s[1] = 3
>>> s
Link(1, Link(3, Link(3)))
```

```
class Link:
    ...
    def __setitem__(self, i, val):
        if i == 0:
            self.first = val
        elif self.rest is Link.empty:
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            self.rest[i - 1] = val
```

The __setitem__ Magic Method (demo)

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>>> s = Link(1, Link(2, Link(3)))
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class Link:
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```

Mutating Map

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```
>>> s = Link(1, Link(2, Link(3)))
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Mutating Map

```
>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
```

Mutating Map

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```

Mutating Map

```
>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
>>> s
Link(1, Link(4, Link(9)))
```

Mutating Map

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>>> s = Link(1, Link(2, Link(3)))
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>>> s
Link(1, Link(4, Link(9)))
```

```
class Link:
    ...
```

Mutating Map

```
>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
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Link(1, Link(4, Link(9)))
```

```
class Link:
    ...
    def map(self, f):
```

Mutating Map

```
>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
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Link(1, Link(4, Link(9)))
```

```
class Link:
    ...
    def map(self, f):
        for i in range(len(self)):
```

Mutating Map

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>>> s.map(lambda x: x * x)
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Link(1, Link(4, Link(9)))
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```
class Link:
    ...
    def map(self, f):
        for i in range(len(self)):
            self[i] = f(self[i])
```

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class Link:
    ...
    def map(self, f):
        for i in range(len(self)):
            self[i] = f(self[i])
```

Runtime?

Mutating Map

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>>> s = Link(1, Link(2, Link(3)))
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>>> s
Link(1, Link(4, Link(9)))

class Link:
    ...
    def __getitem__(self, i):
        if i == 0:
            return self.first
        else:
            return self.rest[i - 1]

    def map(self, f):
        for i in range(len(self)):
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Mutating Map

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>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
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self[0] = f(self[0])
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```
class Link:
    ...
    def __getitem__(self, i):
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$\Theta(n^2)$

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contains and in (demo)

```
class Link:
    ...
    def __contains__(self, e):
        return self.first == e or e in self.rest
```

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>>> s = Link(1, Link(2, Link(3)))
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Break!

Environments

Environment Frames

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The Call Stack

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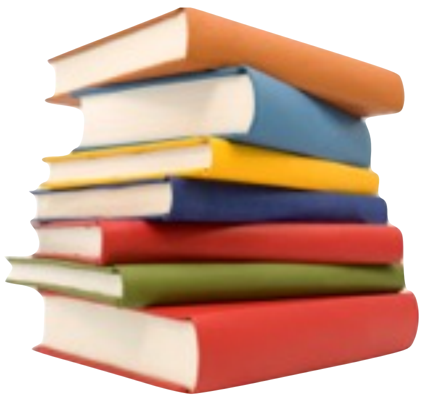

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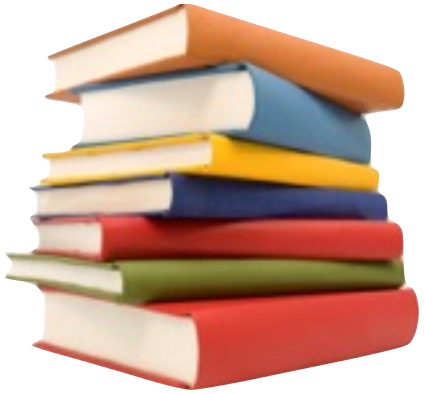

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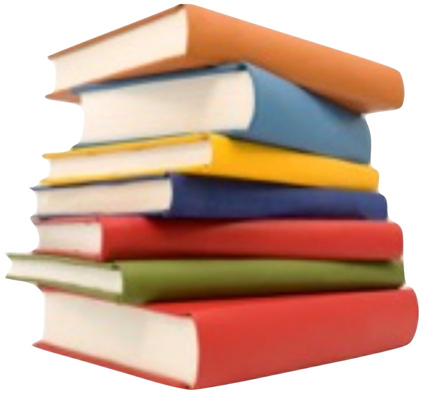

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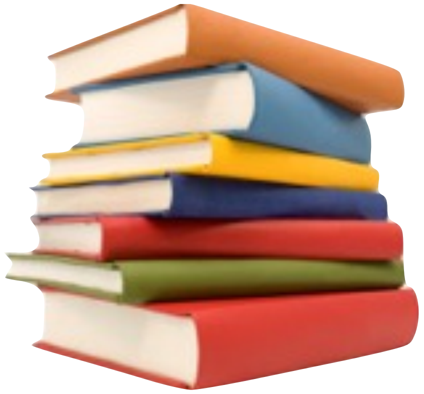

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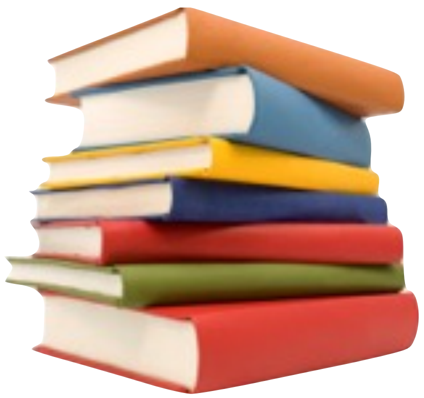

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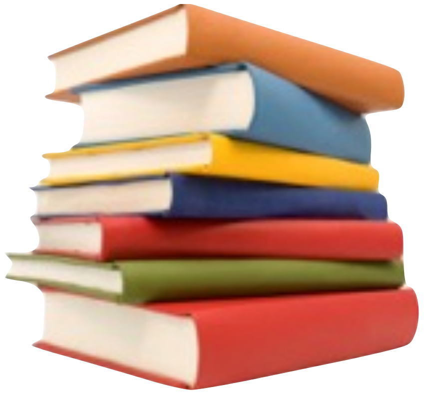

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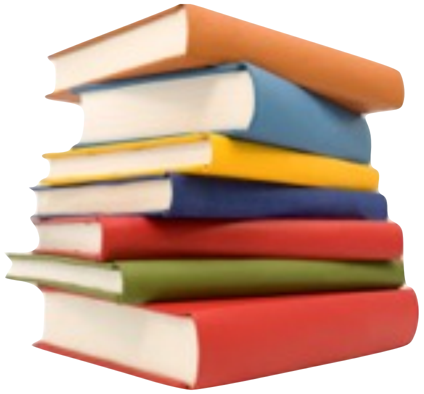

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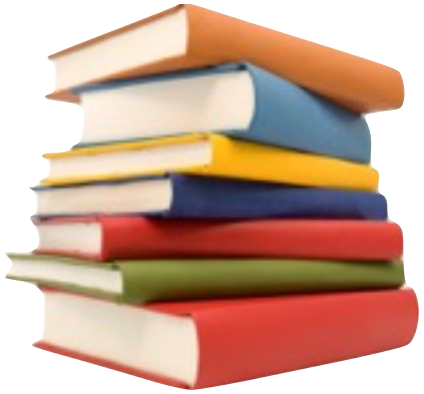

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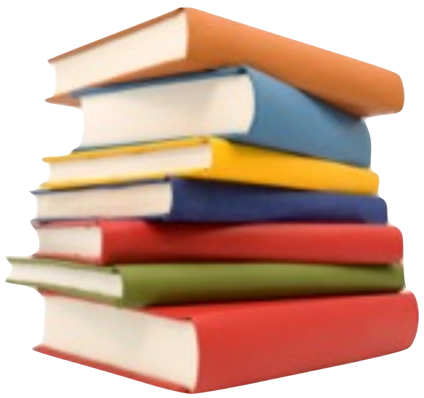

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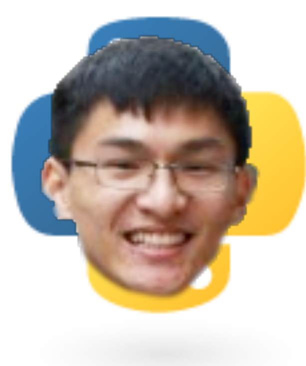

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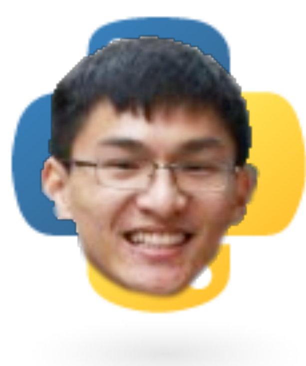

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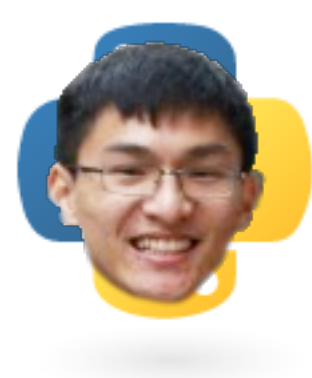

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A different Brython: http://brython.info/

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- An object-based implementation of the linked list abstraction allows for easy mutability
  - No more crazy nonlocal stuff!
- Implementing magic methods lets us hook into convenient Python syntax and built-in functions
- Linked lists can be used to implement some of the core ideas of this course!