Composition

Announcements

List Efficiency

List Efficiency

Appending, assigning, and list comprehensions are fast:

Inserting (beginning/middle), slicing, and adding lists are slow:

Example: building long lists of perfect squares (numbers that are an integer times itself)

```
def using_list_comprehension(n):
    return [k * k for k in range(n)]

def using_append(n):
    s = []
    for k in range(n):
        s.append(k * k)
    return s

def using_assign(n):
    s = [0 for k in range(n)]
    for k in range(n):
        s[k] = k * k
    return s
```

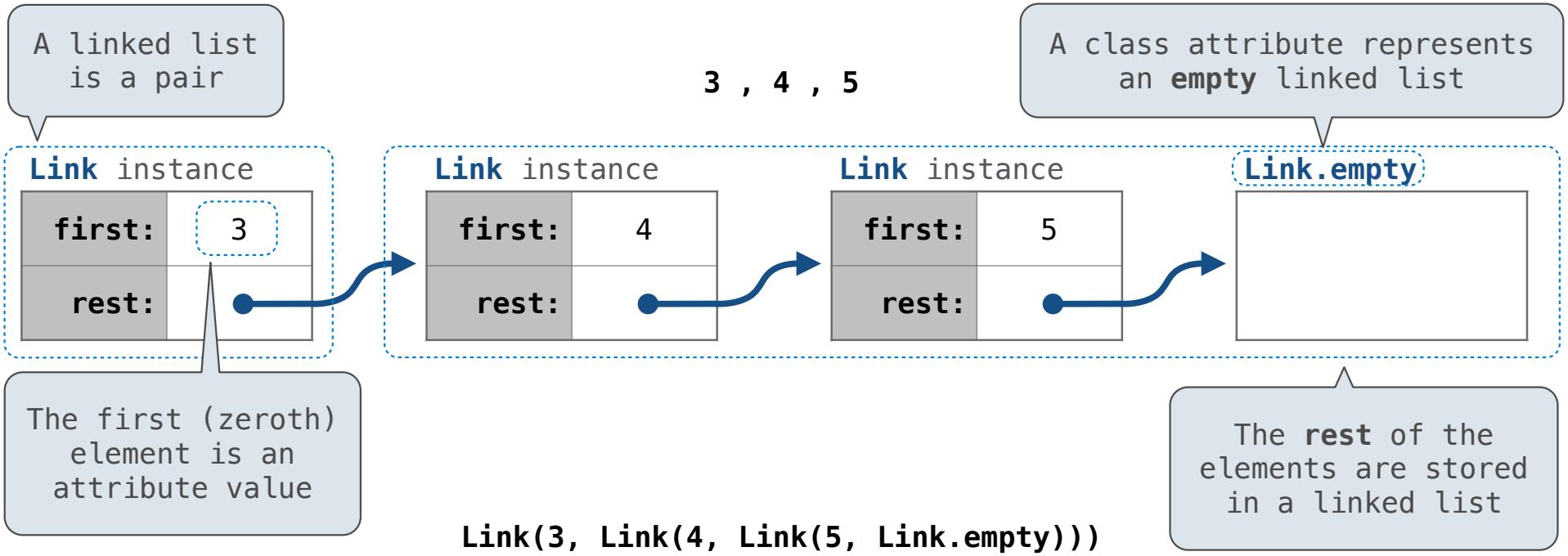
```
def using_insert(n):
    s = []
    for k in range(n):
        s.insert(0, k * k)
    return s

def using_add(n):
    s = []
    for k in range(n):
        s = s + [k*k]
    return s
```

```
When n = 100,000
using_list_comprehension:  1.58 ms
using_append:              1.76 ms
using_assign:              2.58 ms
using_insert:          1,470    ms
using_add:             9,210    ms
```

Linked Lists

Linked List Structure

A linked list is either empty **or** a first value and the rest of the linked list



Linked List Structure

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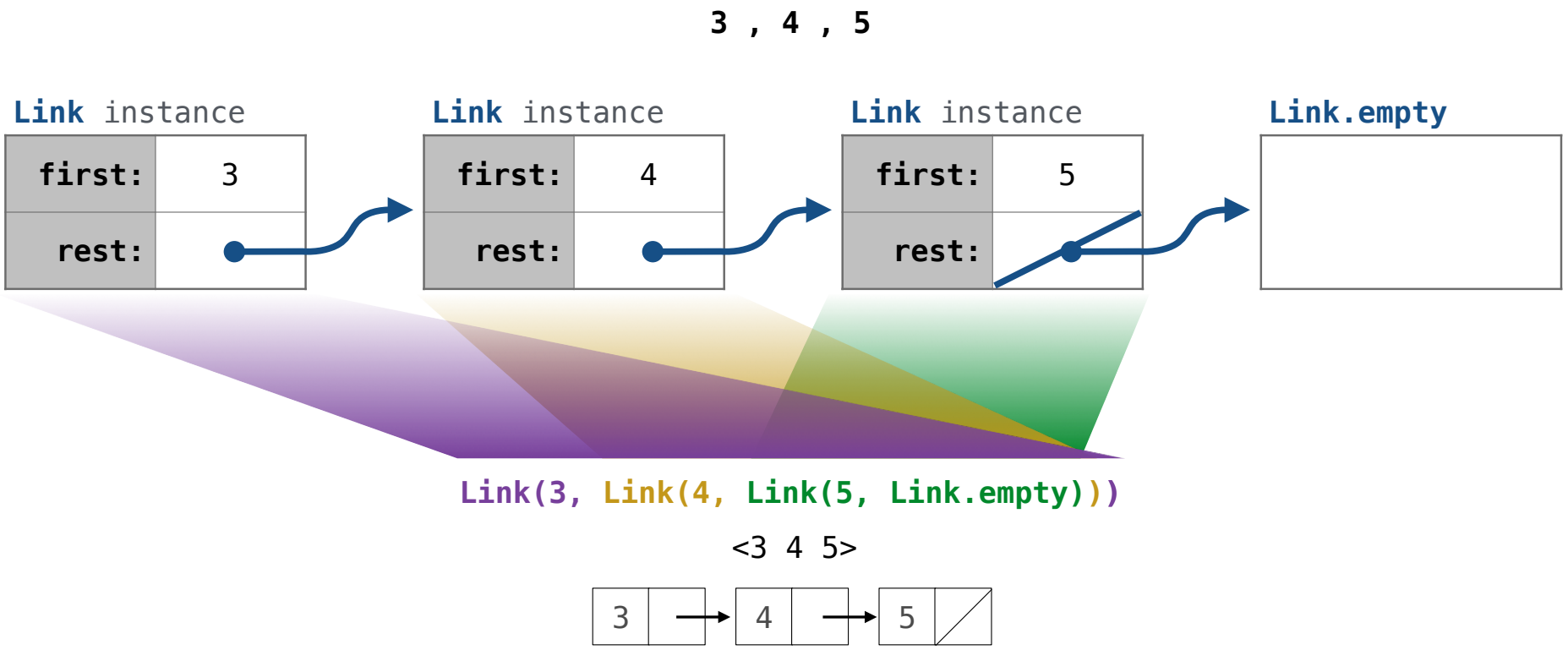


Linked List Class

Linked list class: attributes are passed to `__init__`

```
class Link:
    empty = ()

    def __init__(self, first, rest=empty):
        assert rest is Link.empty or isinstance(rest, Link)
        self.first = first
        self.rest = rest
```

Some zero-length sequence

Returns whether rest is a Link

`help(isinstance)`: Return whether an object is an instance of a class or of a subclass thereof.

```
Link(3, Link(4, Link(5            )))
```

(Demo)

Repeated Inserts

Double a List

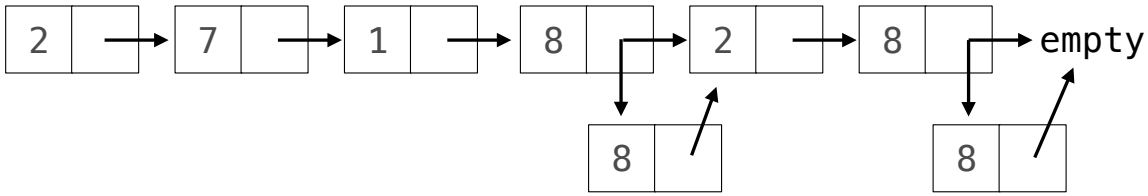
```
def double(s, v):
    """Insert another v after each v in list s.

    >>> s = [2, 7, 1, 8, 2, 8]
    >>> double(s, 8)
    >>> s
    [2, 7, 1, 8, 8, 2, 8, 8]
    """
    i = 0
    while i < len(s):
        if s[i] == v:
            s.insert(i+1, v)
            i += 2
        else:
            i += 1
```

Double a Linked List

```
def double_link(s, v):
    """Insert another v after each v in linked list s.

    >>> s = Link(2, Link(7, Link(1, Link(8, Link(2, Link(8))))))
    >>> double_link(s, 8)
    >>> print(s)
    <2 7 1 8 8 2 8 8>
    """
    while s is not Link.empty:
        if s.first == v:
            s.rest = Link(v, s.rest)
            s = s.rest.rest
        else:
            s = s.rest
```



Speed Comparison: Double a Cycle

```
def cycle(k, n):
    """Build an n-element list that cycles among range(k).

    >>> cycle(3, 10)
    [0, 1, 2, 0, 1, 2, 0, 1, 2, 0]
    """
    s = []
    for i in range(n):
        s.append(i % k)
    return s

def cycle_link(k, n):
    """Build an n-element linked list that cycles among range(k).

    >>> print(cycle_link(3, 10))
    <0 1 2 0 1 2 0 1 2 0>
    """
    first = Link.empty
    for i in range(n):
        new_link = Link(i % k)
        if first is Link.empty:
            first, last = new_link, new_link
        else:
            last.rest, last = new_link, new_link
    return first
```

```
double(     cycle(     5, 100000), 3): 299ms
double_link(cycle_link(5, 100000), 3):  14ms
```

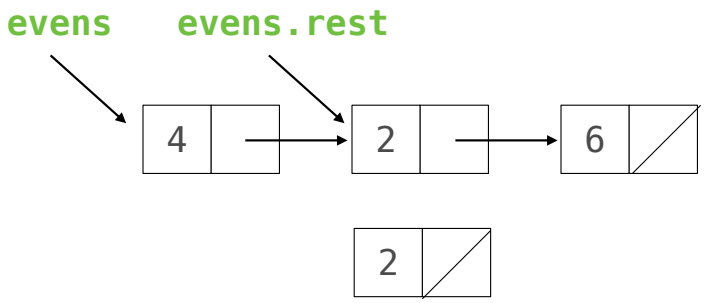
Linked List Practice

Slicing a Linked List

Normal slice notation (such as s[1:3]) doesn't work if s is a linked list.

```
def slice_link(s, i, j):
    """Return a linked list containing elements from i:j.

    >>> evens = Link(4, Link(2, Link(6)))
    >>> slice_link(evens, 1, 100)
    Link(2, Link(6))
    >>> slice_link(evens, 1, 2)
    Link(2)
    >>> slice_link(evens, 0, 2)
    Link(4, Link(2))
    >>> slice_link(evens, 1, 1) is Link.empty
    True
    """
    assert i >= 0 and j >= 0
    if ____j == 0____ or s is Link.empty:
        return Link.empty
    elif ____i == 0____:
        return Link(s.first, ____slice_link(s.rest, i, j-1)____)
    else:
        return slice_link(s.rest, ___i-1___ , ___j-1___ )
```



slice_link(evens, 1, 2) returns

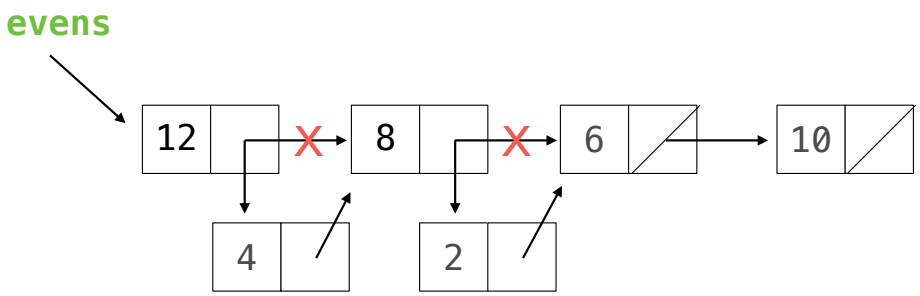
slice_link(evens.rest, 0, 1) links 2 to

slice_link(evens.rest.rest, 0, 0) returns Link.empty

Inserting into a Linked List

```
def insert_link(s, x, i):
    """Insert x into linked list s at index i.

    >>> evens = Link(4, Link(2, Link(6)))
    >>> insert_link(evens, 8, 1)
    >>> insert_link(evens, 10, 4)
    >>> insert_link(evens, 12, 0)
    >>> insert_link(evens, 14, 10)
    Index out of range
    >>> print(evens)
    <12 4 8 2 6 10>
    """
    if s is Link.empty:
        print('Index out of range')
    elif i == 0:
        second = Link(s.first, s.rest)
        s.first = x
        s.rest = second
    elif i == 1 and s.rest is Link.empty:
        s.rest = Link(x)
    else:
        insert_link(s.rest, x, i-1)
```



Spring 2023 Midterm 2 Question 3(b)

Definition. A *prefix sum* of a sequence of numbers is the sum of the first n elements for some positive length n.

Implement tens, which takes a non-empty linked list of numbers s represented as a Link instance. It prints all of the prefix sums of s that are multiples of 10 in increasing order of the length of the prefix.

```
def tens(s):
    """Print all prefix sums of Link s that are multiples of ten.
    >>> tens(Link(3, Link(9, Link(8, Link(10, Link(0, Link(14, Link(6)))))))
    20
    30
    30
    50
    """
    def f(suffix, total):
        if total % 10 == 0:
            print(total)

        if ____suffix is not Link.empty____:
            ____f(suffix.rest, total + suffix.first)____

    ____f(s.rest, s.first)____
```