Decomposition (Linked List Practice)
Announcements
Linear-Time Intersection of Sorted Linked Lists

Given two sorted **linked lists** with no repeats, return the number of elements that appear in both.

```
def fast_overlap(s, t):
    k = 0
    while s and t:
        if s.first == t.first:
            k, s, t, = k + 1, s.rest, t.rest
        elif s.first < t.first:
            return 1 + fast_overlap(s.rest, t.rest)
        elif s.first > t.first:
            return fast_overlap(s, t.rest)
    return k
```
Slow Overlap

def count_if(f, s):
    if s is Link.empty:
        return 0
    else:
        if f(s.first):
            return 1 + count_if(f, s.rest)
        else:
            return count_if(f, s.rest)

def contained_in(s):
    def f(s, x):
        if s is Link.empty:
            return False
        else:
            return s.first == x or f(s.rest, x)
    return lambda x: f(s, x)

def overlap(s, t):
    "For s and t with no repeats, count the numbers that appear in both."
    return count_if(contained_in(t), s)

Exponential growth. E.g., recursive fib
Incrementing $n$ multiplies time by a constant

Quadratic growth.
Incrementing $n$ increases time by $n$ times a constant

Linear growth.
Incrementing $n$ increases time by a constant
Linked Lists Mutation
Linked List Notation

\[ s = \text{Link}(3, \text{Link}(4, \text{Link}(5))) \]
Nested Linked Lists

```python
>>> s = Link(Link(8), Link(Link(4, Link(6, Link(Link(7)))), Link(5)))
>>> print(s)
<<8> <4 6 <7>> 5>
>>> s.first.first
8
>>> s.rest.first.rest.first.first
Link(7)
>>> s.rest.first.rest.first.first.first
7
```
Recursion and Iteration

Many linked list processing functions can be written both iteratively and recursively.

Recursive approach:
- What recursive call do you make?
- What does this recursive call do/return?
- How is this result useful in solving the problem?

```python
def length(s):
    """The number of elements in s."
    if s is Link.empty:
        return 0
    else:
        return 1 + length(s.rest)

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

Iterative approach:
- Describe a process that solves the problem.
- Figure out what additional names you need to carry out this process.
- Implement the process using those names.

```python
def length(s):
    """The number of elements in s."
    k = 0
    while s is not Link.empty:
        s, k = s.rest, k + 1
    return k

>>> length(Link(3, Link(4, Link(5))))
3
```
**Linked List Mutation**

To change the contents of a linked list, assign to first and rest attributes

Example: Append x to the end of non-empty s

```python
>>> t = Link(3, Link(4, Link(5)))
>>> append(t, 6)
>>> t
Link(3, Link(4, Link(5, Link(6))))
```

Global Frame

```
Global Frame
  t

f1: append  p=G
  s
    x 6
```

```
s = s.rest
s.rest = Link(x)
```
Recursion and Iteration

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Recursive approach:
- What recursive call do you make?
- What does this recursive call do/return?
- How is this result useful in solving the problem?

```python
def append(s, x):
    """Append x to the end of non-empty s.
    >>> append(s, 6)  # returns None!
    >>> print(s)
    <3 4 5 6>
    """
    if s.rest is not Link.empty:
        append(s.rest, x)
    else:
        s.rest = Link(x)
```

Iterative approach:
- Describe a process that solves the problem.
- Figure out what additional names you need to carry out this process.
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```python
def append(s, x):
    """Append x to the end of non-empty s.
    >>> append(s, 6)  # returns None!
    >>> print(s)
    <3 4 5 6>
    """
    while s.rest is not Link.empty:
        s = s.rest
        s.rest = Link(x)
```
**Example: Pop**

Implement pop, which takes a linked list \( s \) and positive integer \( i \). It removes and returns the element at index \( i \) of \( s \) (assuming \( s.first \) has index 0).

```python
def pop(s, i):
    """Remove and return element \( i \) from linked list \( s \) for positive \( i \).
    >>> t = Link(3, Link(4, Link(5, Link(6))))
    >>> pop(t, 2)
    5
    >>> pop(t, 2)
    6
    >>> pop(t, 1)
    4
    >>> t
    Link(3)
    """
    assert i > 0 and i < length(s)
    for x in range(i - 1):
        s = s.rest
    result = s.rest.first
    s.rest = s.rest.rest
    return result
```

```
Example: Pop

Implement pop, which takes a linked list s and positive integer i. It removes and returns the element at index i of s (assuming s.first has index 0).

def pop(s, i):
    """Remove and return element i from linked list s for positive i.
    >>> t = Link(3, Link(4, Link(5, Link(6))))
    >>> pop(t, 2)
    5
    >>> pop(t, 2)
    6
    >>> pop(t, 1)
    4
    >>> t
    Link(3)
    """
    assert i > 0 and i < length(s)
    for x in range(i - 1):
        s = s.rest
    result = s.rest.first
    s.rest = s.rest.rest
    return result
```
Linked List Construction
Constructing a Linked List

Build the rest of the linked list, then combine it with the first element.

```
>>> range_link(3, 6)
Link(3, Link(4, Link(5)))
```

```
def range_link(start, end):
    """Return a Link containing consecutive integers from start up to end."

    >>> range_link(3, 6)
    Link(3, Link(4, Link(5)))
    """

    if start >= end:
        return Link.empty
    else:
        return Link(start, range_link(start + 1, end))
```