61A Lecture 20

Announcements

Sets

Sets

One more built-in Python container type

- Set literals are enclosed in braces
- Duplicate elements are removed on construction
- Sets have arbitrary order, just like dictionary entries

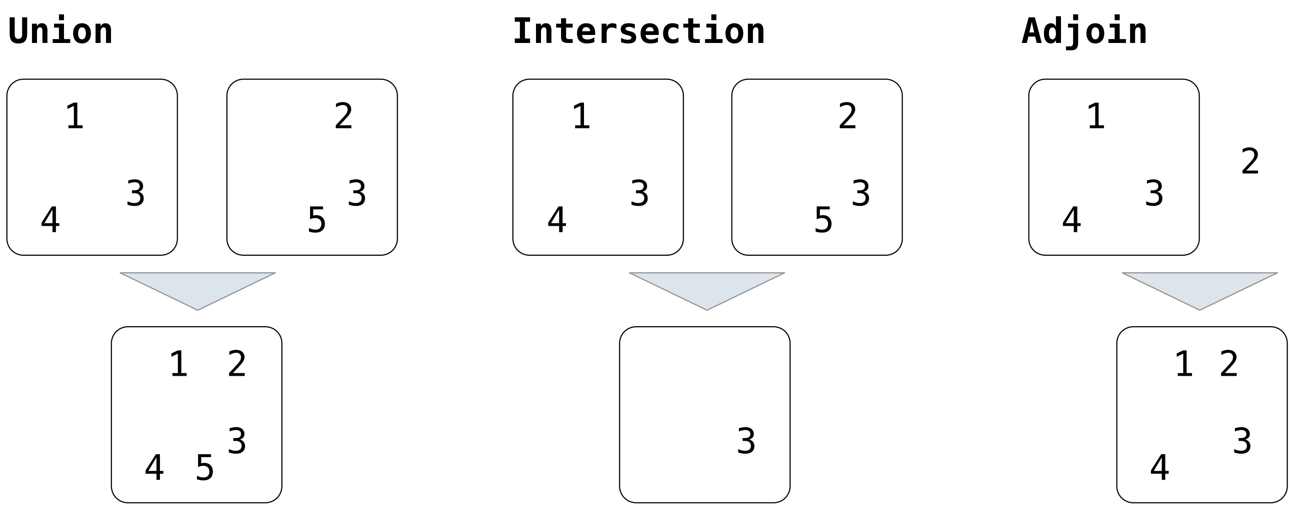
```
>>> s = {3, 2, 1, 4, 4}
>>> s
{1, 2, 3, 4}
>>> 3 in s
True
>>> len(s)
4
>>> s.union({1, 5})
{1, 2, 3, 4, 5}
>>> s.intersection({6, 5, 4, 3})
{3, 4}
>>> s
{1, 2, 3, 4}
```

(Demo)

Implementing Sets

What we should be able to do with a set:

- **Membership testing:** Is a value an element of a set?
- **Union:** Return a set with all elements in set1 or set2
- **Intersection:** Return a set with any elements in set1 and set2
- **Adjoin:** Return a set with all elements in s and a value v



Sets as Linked Lists

Sets as Unordered Sequences

Proposal 1: A set is represented by a linked list that contains no duplicate items.

Time order of growth

```
def empty(s):
    return s is Link.empty
```

$\Theta(1)$

```
def contains(s, v):
    """Return whether set s contains value v.

    >>> s = Link(1, Link(3, Link(2)))
    >>> contains(s, 2)
    True
    """
```

Time depends on whether & where v appears in s

$\Theta(n)$

Assuming v either does not appear in s ***or*** *appears in a uniformly distributed random location*

(Demo)

Sets as Unordered Sequences

Time order of growth

```
def adjoin(s, v):
    if contains(s, v):
        return s
    else:
        return Link(v, s)
```

$\Theta(n)$

The size of the set

```
def intersect(set1, set2):
    in_set2 = lambda v: contains(set2, v)
    return filter_link(in_set2, set1)
```

Return elements x for which in_set2(x) returns a true value

$\Theta(n^2)$

If sets are the same size

```
def union(set1, set2):
    not_in_set2 = lambda v: not contains(set2, v)
    set1_not_set2 = filter_link(not_in_set2, set1)
    return extend_link(set1_not_set2, set2)
```

Return a linked list containing all elements in set1_not_set2 followed by all elements in set2

$\Theta(n^2)$

Sets as Ordered Linked Lists

Sets as Ordered Sequences

Proposal 2: A set is represented by a linked list with unique elements that is ***ordered from least to greatest***

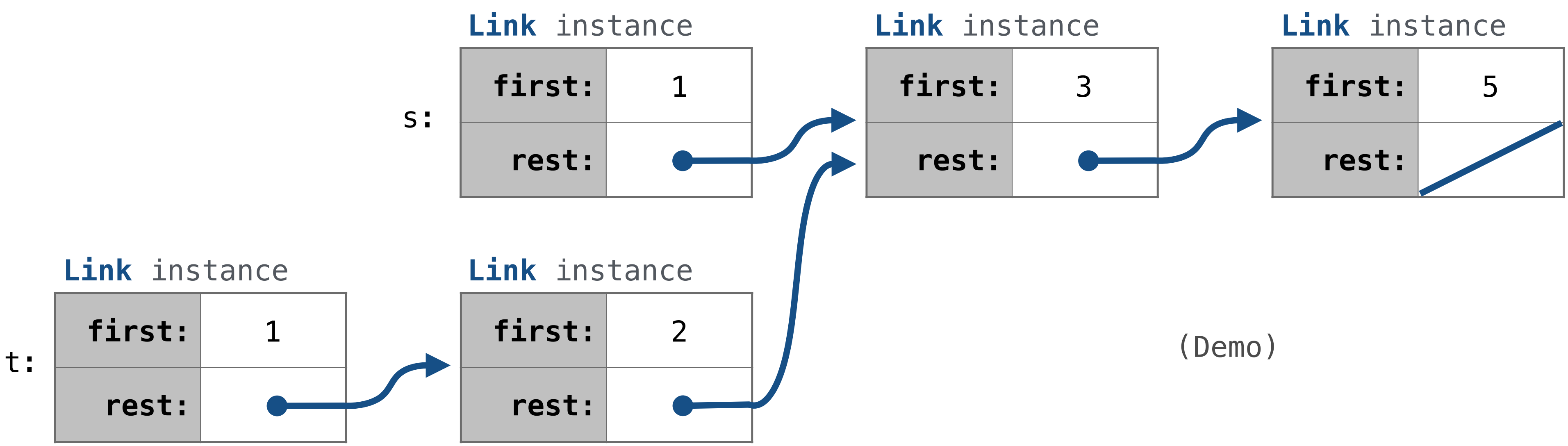
Parts of the program that...	Assume that sets are...	Using...
Use sets to contain values	Unordered collections	empty, contains, adjoin, intersect, union
Implement set operations	Ordered linked lists	first, rest, <, >, ==

Different parts of a program may make different assumptions about data

Searching an Ordered List

```
>>> s = Link(1, Link(3, Link(5)))
>>> contains(s, 1)
True
>>> contains(s, 2)
False
>>> t = adjoin(s, 2)
```

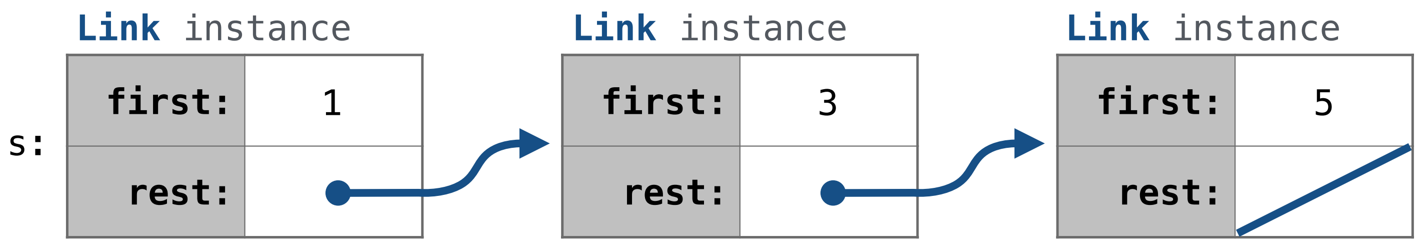
Operation	Time order of growth
contains	$\Theta(n)$
adjoin	$\Theta(n)$



(Demo)

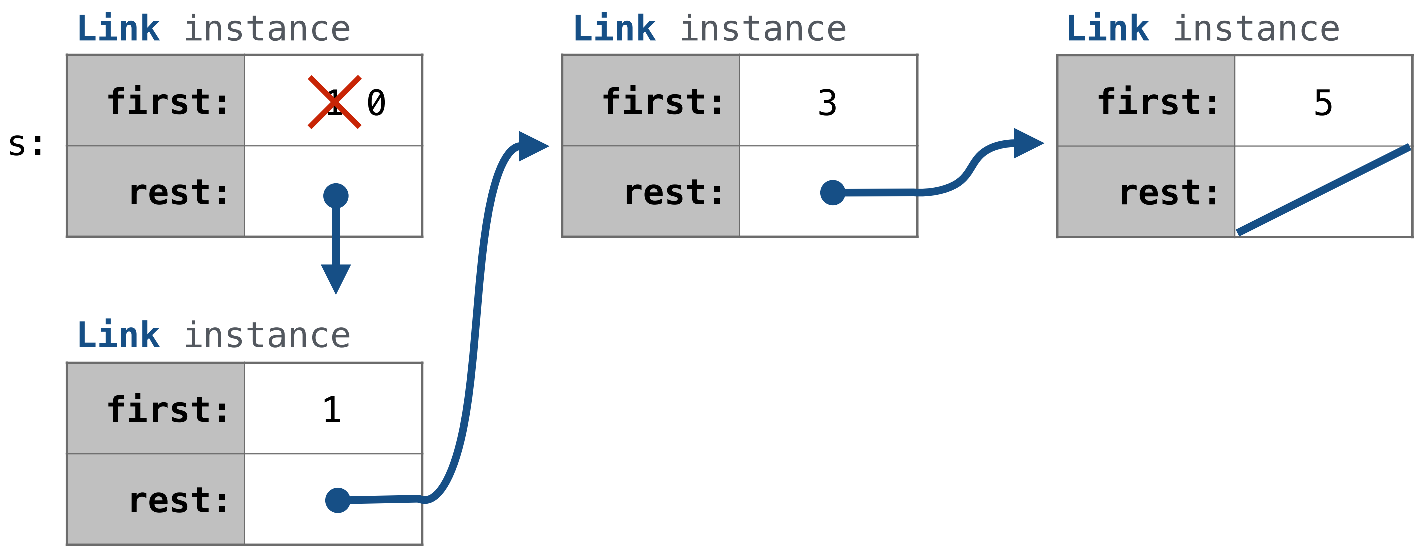
Set Mutation

Adding to an Ordered List



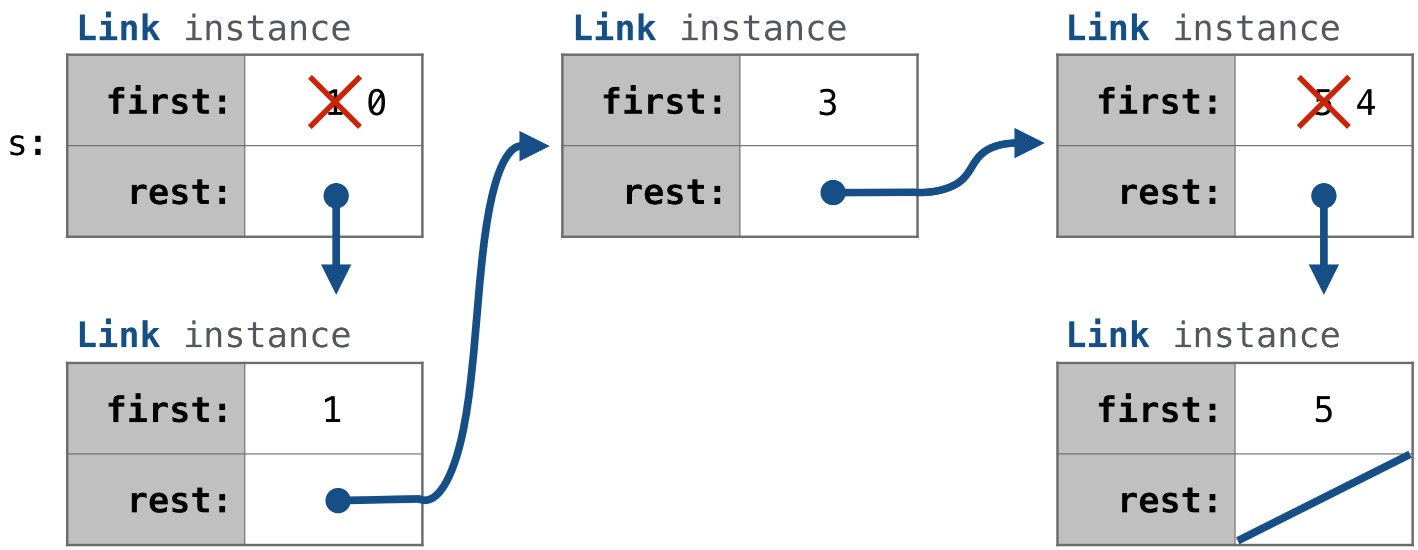

```
add(s, 0)
```

Adding to an Ordered List



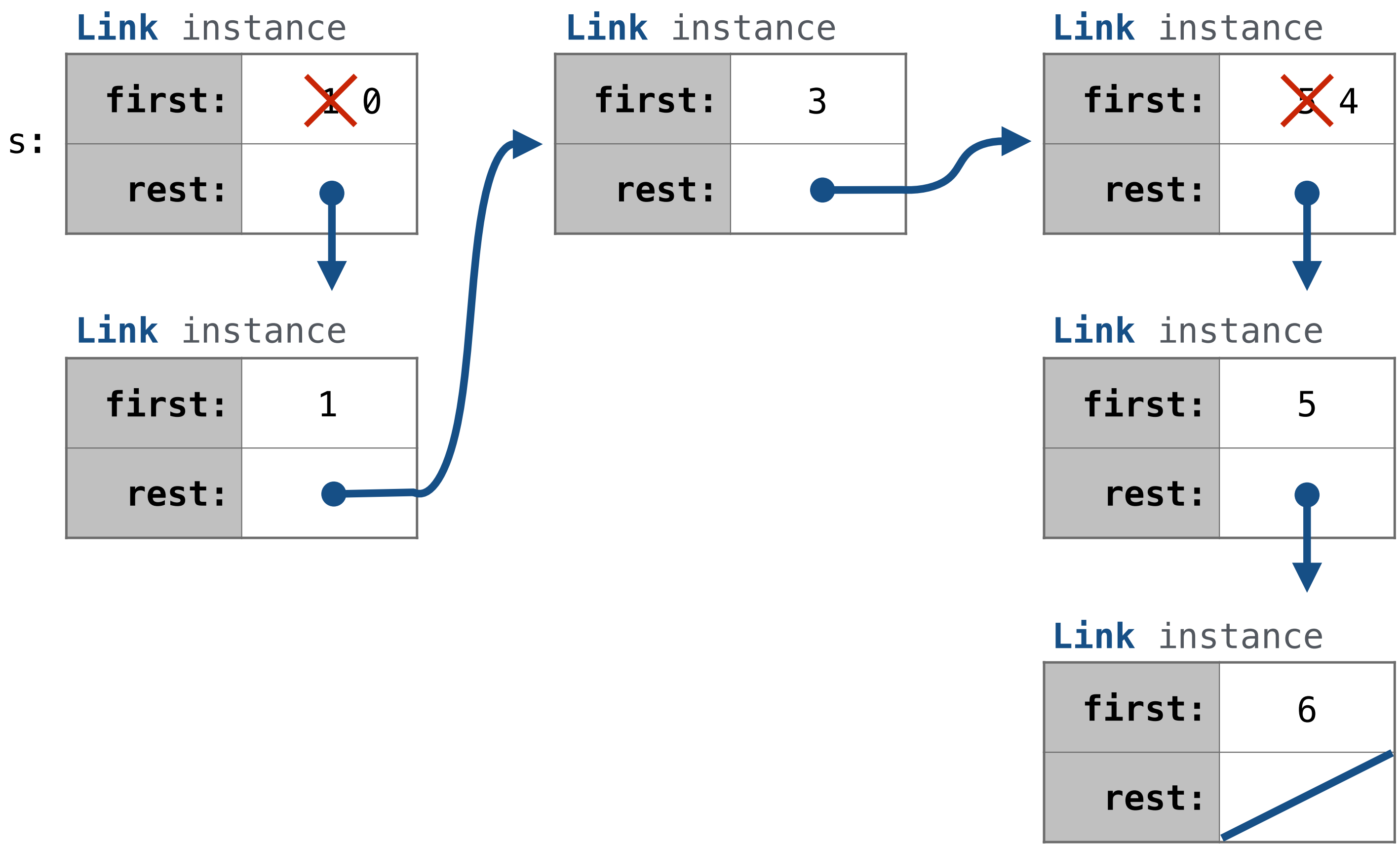

```
add(s, 3)

add(s, 4)
```

Adding to an Ordered List



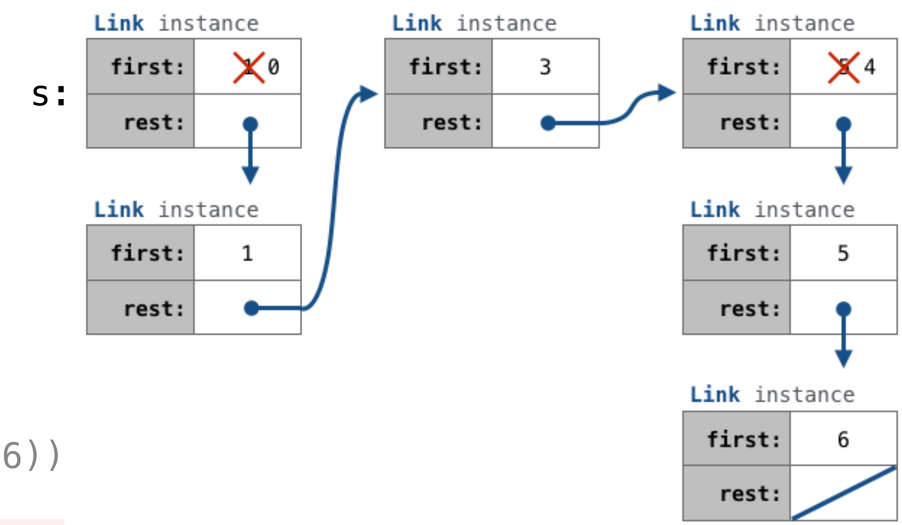
add(s, 6)

Adding to an Ordered List



Adding to an Ordered List

```
def add(s, v):
    """Add v to a set s and return s.

    >>> s = Link(1, Link(3, Link(5)))
    >>> add(s, 0)
    Link(0, Link(1, Link(3, Link(5))))
    >>> add(s, 3)
    Link(0, Link(1, Link(3, Link(5))))
    >>> add(s, 4)
    Link(0, Link(1, Link(3, Link(4, Link(5)))))
    >>> add(s, 6)
    Link(0, Link(1, Link(3, Link(4, Link(5, Link(6))
    """
    assert not empty(s), "Cannot add to an empty set."
    if s.first > v:
        s.first, s.rest = v, Link(s.first, s.rest)
    elif s.first < v and empty(s.rest):
        s.rest = Link(v, s.rest)
    elif s.first < v:
        add(s.rest, v)
    return s
```



Set Operations

Intersecting Ordered Linked Lists

Proposal 2: A set is represented by a linked list with unique elements that is ***ordered from least to greatest***

```
def intersect(set1, set2):
    if empty(set1) or empty(set2):
        return Link.empty
    else:
        e1, e2 = set1.first, set2.first
        if e1 == e2:
            return Link(e1, intersect(set1.rest, set2.rest))
        elif e1 < e2:
            return intersect(set1.rest, set2)
        elif e2 < e1:
            return intersect(set1, set2.rest)
```

Order of growth? $\Theta(n)$ (Demo)