Data Examples
Class outline:

- Linked lists
- Lists
- Objects
Linked lists
Exercise: Is it ordered?

Is a linked list ordered from least to greatest?

```python
def ordered(s):
    """Is Link s ordered?""

    >>> ordered(Link(1, Link(3, Link(4))))
    True
    >>> ordered(Link(1, Link(4, Link(3))))
    False
    >>> ordered(Link(1, Link(-3, Link(4))))
    False
    """
```
Exercise: Is it ordered? (Solution)

Is a linked list ordered from least to greatest?

def ordered(s, key=lambda x: x):
    """Is Link s ordered?"

    >>> ordered(Link(1, Link(3, Link(4))))
    True
    >>> ordered(Link(1, Link(4, Link(3))))
    False
    >>> ordered(Link(1, Link(-3, Link(4))))
    False
    """
    if s is Link.empty or s.rest is Link.empty:
        return True
    elif s.first > s.rest.first:
        return False
    else:
        return ordered(s.rest)
Exercise: Is it ordered? Part 2

Is it ordered when a key function is applied, like `abs`?

```
def ordered(s, key=lambda x: x):
    """Is Link s ordered?"
    >>> ordered(Link(1, Link(3, Link(4))))
    True
    >>> ordered(Link(1, Link(4, Link(3))))
    False
    >>> ordered(Link(1, Link(-3, Link(4))))
    False
    >>> ordered(Link(1, Link(-3, Link(4))), key=abs)
    True
    >>> ordered(Link(-4, Link(-1, Link(3))))
    True
    >>> ordered(Link(-4, Link(-1, Link(3))), key=abs)
    False
    """
```
Exercise: Is it ordered? Part 2 (Solution)

Is it ordered when a key function is applied, like \texttt{abs}?

```python
def ordered(s, key=lambda x: x):
    """Is Link s ordered?"
    >>> ordered(Link(1, Link(3, Link(4))))
    True
    >>> ordered(Link(1, Link(4, Link(3))))
    False
    >>> ordered(Link(1, Link(-3, Link(4))))
    False
    >>> ordered(Link(1, Link(-3, Link(4))), key=abs)
    True
    >>> ordered(Link(-4, Link(-1, Link(3))))
    True
    >>> ordered(Link(-4, Link(-1, Link(3))), key=abs)
    False
    """
    if s is Link.empty or s.rest is Link.empty:
        return True
    elif key(s.first) > key(s.rest.first):
        return False
    else:
        return ordered(s.rest)
```

```python
1 4 -3
1 -3 4
```
Exercise: Sorted merged list

Create a sorted Link containing all the elements of two sorted Links.

```
def merge(s, t):
    """Return a sorted Link containing the elements of sorted s & t."

    >>> a = Link(1, Link(5))
    >>> b = Link(1, Link(4))
    >>> merge(a, b)
    Link(1, Link(1, Link(4, Link(5)))))
    >>> a
    Link(1, Link(5))
    >>> b
    Link(1, Link(4))
    """
```
Exercise: Sorted merged list (Solution)

Create a sorted Link containing all the elements of two sorted Links.

\[
\begin{array}{c}
1 & 5 \\
\end{array}
+ \begin{array}{c}
1 & 4 \\
\end{array} =
\begin{array}{c}
1 & 1 & 4 & 5 \\
\end{array}
\]

```python
def merge(s, t):
    """Return a sorted Link containing the elements of sorted s & t."

    if s is Link.empty:
        return t
    elif t is Link.empty:
        return s
    elif s.first <= t.first:
        return Link(s.first, merge(s.rest, t))
    else:
        return Link(t.first, merge(s, t.rest))
```
Exercise: Sorted merged list II

This time, do it without creating any new Link objects.

```python
def merge_in_place(s, t):
    """Return a sorted Link containing the elements of sorted s & t."

    >>> a = Link(1, Link(5))
    >>> b = Link(1, Link(4))
    >>> merge_in_place(a, b)
    Link(1, Link(1, Link(4, Link(5)))))
    >>> a
    Link(1, Link(1, Link(4, Link(5)))))
    >>> b
    Link(1, Link(4, Link(5)))))
    """
```
Exercise: Sorted merged list II (Solution)

This time, do it without creating any new Link objects.

```
def merge_in_place(s, t):
    """Return a sorted Link containing the elements of sorted s & t.
    """
    if s is Link.empty:
        return t
    elif t is Link.empty:
        return s
    elif s.first <= t.first:
        s.rest = merge_in_place(s.rest, t)
        return s
    else:
        t.rest = merge_in_place(s, t.rest)
        return t
```
Iterables & Iterators
Exercise: Find indices

What are the indices of all elements in a list that have the smallest absolute value?

```python
def min_abs_indices(s):
    """Indices of all elements in list s that have the smallest absolute value."

    >>> min_abs_indices([-4, -3, -2, 3, 2, 4])
    [2, 4]
    >>> min_abs_indices([1, 2, 3, 4, 5])
    [0]
    """
```

[-4, -3, -2, 3, 2, 4] → [2, 4]

0 1 2 3 4 5

[ 1, 2, 3, 4, 5, 6] → [0]

0 1 2 3 4 5
Exercise: Find indices (Solution)

What are the indices of all elements in a list that have the smallest absolute value?

```python
def min_abs_indices(s):
    """Indices of all elements in list s that have the smallest absolute value.
    >>> min_abs_indices([-4, -3, -2, 3, 2, 4])
    [2, 4]
    >>> min_abs_indices([1, 2, 3, 4, 5])
    [0]
    """
    min_abs = min(map(abs, s))
    return list(filter(lambda i: abs(s[i]) == min_abs, range(len(s))))
    # OR
    return [i for i in range(len(s)) if abs(s[i]) == min_abs]
```

[-4, -3, -2, 3, 2, 4] → [2, 4] 

[1, 2, 3, 4, 5, 6] → [0]
Exercise: Largest sum

What's the largest sum of two adjacent elements in a list? (Assume length > 1)

def largest_adj_sum(s):
    """Largest sum of two adjacent elements in a list s.

    >>> largest_adj_sum([-4, -3, -2, 3, 2, 4])
    6
    >>> largest_adj_sum([-4, 3, -2, -3, 2, -4])
    1
    """
Exercise: Largest sum (Solution)

What's the largest sum of two adjacent elements in a list? (Assume length > 1)

```python
def largest_adj_sum(s):
    '''Largest sum of two adjacent elements in a list s.

    >>> largest_adj_sum([-4, -3, -2, 3, 2, 4])
    6
    >>> largest_adj_sum([-4, 3, -2, -3, 2, -4])
    1
    '''
    return max([x + y for x, y in zip(s[:-1], s[1:])])
    # OR
    return max([s[i] + s[i + 1] for i in range(len(s) - 1)])
    # OR
    return max(map(lambda i: s[i] + s[i + 1], range(len(s) - 1)))
```

[-4, -3, -2, 3, 2, 4] → 6
-7 -5 1 5 6

[-4, 3, -2, -3, 2, -4] → 1
-1 1 -5 -1 -2
Exercise: Digits dictionary

Create a dictionary mapping each digit d to the lists of elements in s that end with d.

```
[5, 8, 13, 21, 34, 55, 89] → {1: [21], 3: [13], 4: [34], 5: [5, 55], 8: [8], 9: [89]}
```

def digit_dict(s):
    """Map each digit d to the lists of elements in s that end with d.
    
    >>> digit_dict([5, 8, 13, 21, 34, 55, 89])
    {1: [21], 3: [13], 4: [34], 5: [5, 55], 8: [8], 9: [89]}
    """
Exercise: Digits dictionary (Solution)

Create a dictionary mapping each digit d to the lists of elements in s that end with d.

\[
[5, 8, 13, 21, 34, 55, 89] \rightarrow \{1: [21], 3: [13], 4: [34], 5: [5, 55], 8: [8], 9: [89]\}
\]

def digit_dict(s):
    
    # Map each digit d to the lists of elements in s that end with d.
    
    >>> digit_dict([5, 8, 13, 21, 34, 55, 89])
    {1: [21], 3: [13], 4: [34], 5: [5, 55], 8: [8], 9: [89]}
    
    return {i: [x for x in s if x % 10 == i]
            for i in range(10) if any([x % 10 == i for x in s])}

    # OR
    last_digits = list(map(lambda x: x % 10, s))
    return {i: [x for x in s if x % 10 == i]
            for i in range(10) if i in last_digits}
Exercise: Element comparer

Does every element equal some other element in s?

```
[-4, -3, -2, 3, 2, 4] → False
[4, 3, 2, 3, 2, 4] → True
```

def all_have_an_equal(s):
    """Does every element equal some other element in s?"

    >>> all_have_an_equal([-4, -3, -2, 3, 2, 4])
    False
    >>> all_have_an_equal([4, 3, 2, 3, 2, 4])
    True
    """
Exercise: Element comparer (Solution)

Does every element equal some other element in s?

[-4, -3, -2, 3, 2, 4] → False
[4, 3, 2, 3, 2, 4] → True

def all_have_an_equal(s):
    """Does every element equal some other element in s?"
    
    >>> all_have_an_equal([-4, -3, -2, 3, 2, 4])
    False
    >>> all_have_an_equal([4, 3, 2, 3, 2, 4])
    True
    """
    return min([sum([1 for y in s if x == y]) for x in s]) > 1
    # OR
    return all([s[i] in s[:i] + s[i+1:] for i in range(len(s))])
    # OR
    return all(map(lambda x: s.count(x) > 1, s))
Lists in environment diagrams
# List operations

Starting from:

\[
\begin{align*}
  s &= [2, 3] \\
  t &= [5, 6]
\end{align*}
\]

<table>
<thead>
<tr>
<th>Operation</th>
<th>Example</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>append</strong></td>
<td><code>s.append(t)</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>t = 0</code></td>
<td></td>
</tr>
<tr>
<td><strong>extend</strong></td>
<td><code>s.extend(t)</code></td>
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<tr>
<td></td>
<td><code>t[1] = 0</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Addition &amp; Slicing create new lists containing existing elements</td>
<td><code>a = s + [t]</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>b = a[1:]</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>a[1] = 9</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>b[1][1] = 0</code></td>
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# List operations

Starting from:

```python
s = [2, 3]
t = [5, 6]
```

## Operation

<table>
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<tbody>
<tr>
<td><code>append</code></td>
<td>adds one element to a list</td>
<td><code>s.append(t)</code></td>
</tr>
<tr>
<td></td>
<td><code>t = 0</code></td>
<td><code>s = [2, 3, [5, 6]]</code></td>
</tr>
<tr>
<td><code>extend</code></td>
<td>adds all elements in one list to another list</td>
<td><code>s.extend(t)</code></td>
</tr>
<tr>
<td></td>
<td><code>t[1] = 0</code></td>
<td><code>t = 0</code></td>
</tr>
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</table>

**addition & slicing** create new lists containing existing elements

```python
a = s + [t]
b = a[1:]
a[1] = 9
b[1][1] = 0
```
# List operations

Starting from:

\[
\begin{align*}
  s &= [2, 3] \\
  t &= [5, 6]
\end{align*}
\]

### Operation | Example | Result
--- | --- | ---
**append** | add one element to a list | 
| `s.append(t)` | `s → [2, 3, [5, 6]]` | 
| `t = 0` | `t → 0` | 

**extend** | adds all elements in one list to another list | 
| `s.extend(t)` | `s → [2, 3, 5, 6]` | 
| `t[1] = 0` | `t → [5, 0]` | 

addition & slicing create new lists containing existing elements

\[
\begin{align*}
  a &= s + [t] \\
  b &= a[1:] \\
  a[1] &= 9 \\
  b[1][1] &= 0
\end{align*}
\]
# List operations

Starting from:

\[
\begin{align*}
    s &= [2, 3] \\
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<td>(s = s + [t]) (\rightarrow [2, 3, [5, 6]])</td>
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**addition & slicing** create new lists containing existing elements

\[
\begin{align*}
    a &= s + [t] \\
    b &= a[1:] \\
    a[1] &= 9 \\
    b[1][1] &= 0
\end{align*}
\]

\[
\begin{align*}
    s &\rightarrow [2, 3] \\
    t &\rightarrow [5, 0] \\
    a &\rightarrow [2, 9, [5, 0]] \\
    b &\rightarrow [3, [5, 0]]
\end{align*}
\]
## List operations

Starting from:

\[
\begin{align*}
    s &= [2, 3] \\
    t &= [5, 6]
\end{align*}
\]

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| The `list` constructor also creates a new list containing existing elements | \[
    t = \text{list}(s) \\
    s[1] = 0
\] | |
| slice assignment replaces a slice with new values | \[
    s[0:0] = t \\
    s[3:] = t \\
    t[1] = 0
\] | |
## List operations

Starting from:

\[ s = [2, 3] \]
\[ t = [5, 6] \]

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## List operations

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| slice assignment replaces a slice with new values | \[ s[0:0] = t \]
\[ s[3:] = t \]
\[ t[1] = 0 \] | \[ s \rightarrow [5, 6, 2, 5, 6] \]
\[ t \rightarrow [5, 0] \] |
Lists in lists

```python
t = [1, 2, 3]
t[1:3] = [t]
t.extend(t)
```

View in PythonTutor

```python
t = [[1, 2], [3, 4]]
t[0].append(t[1:2])
```

View in PythonTutor
Objects
Santa's helpers

class Elf:
    greeting = 'Boss'
    def __init__(self):
        self.shelf = Elf
    def work(self):
        return self.greeting + ', I toil all day'
    def __repr__(self):
        return Santa.greeting

class Santa(Elf):
    greeting = 'Elfie'
    def work(self):
        print(Elf.work(self))
        return 'My job is to break into kid\'s homes!'

jack = Elf()
klaus = Santa()
jack.greeting = 'Your Jollyness'

>>> Elf().work()

>>> jack
>>> jack.work()

>>> klaus.work()

>>> klaus.shelf.work(klaus)
class Elf:
    greeting = 'Boss'
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        self.shelf = Elf
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Santa's helpers

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'Boss, I toil all day'
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>>> jack.work()
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        return Santa.greeting

class Santa(Elf):
    greeting = 'Elfie'
    def work(self):
        print(Elf.work(self))
        return 'My job is to break into kid\'s homes!'

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>>> Elf().work()
'Boss, I toil all day'
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Elfie
>>> jack.work()
'Your Jollyness, I toil all day'

>>> klaus.work()
Elfie, I toil all day

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    greeting = 'Boss'
    def __init__(self):
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    def __repr__(self):
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Santa's helpers

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'Boss, I toil all day'
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Elfie
```
>>> jack.work()
'Your Jollyness, I toil all day'
>>> klaus.work()
Elfie, I toil all day
"My job is to break into kid's homes!"
>>> klaus.shelf.work(klaus)
'Elfie, I toil all day'
Python Project of The Day!
Outreachy

Outreachy: An organization that provides internships in open source to people subject to systemic bias and impacted by underrepresentation in the technical industry where they are living.

Website written in Django, a popular Python web framework.

Github repository