Data Examples
Class outline:

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

Is a linked list ordered from least to greatest?

def ordered(s):
    """Is Link s ordered?"
    
    print(ordered(Link(1, Link(3, Link(4)))))
    True
    print(ordered(Link(1, Link(4, Link(3)))))
    False
    print(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 \texttt{abs}?

\begin{verbatim}

```python
def ordered(s, key=lambda x: x):
    """Is Link \texttt{s} ordered?"
    >>> ordered(\texttt{Link(1, Link(3, Link(4)))})
    True
    >>> ordered(\texttt{Link(1, Link(4, Link(3)))})
    False
    >>> ordered(\texttt{Link(1, Link(-3, Link(4)))})
    False
    >>> ordered(\texttt{Link(1, Link(-3, Link(4))), key=abs})
    True
    >>> ordered(\texttt{Link(-4, Link(-1, Link(3)))})
    True
    >>> ordered(\texttt{Link(-4, Link(-1, Link(3))), key=abs})
    False
    """
```

\end{verbatim}

\end{document}
Exercise: Is it ordered? Part 2 (Solution)

Is it ordered when a key function is applied, like \texttt{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
    ""
    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)
```
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.

```
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))
    """
    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.

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

```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))))
    ""
    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?

```
[-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

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]
    """
```
Exercise: Find indices (Solution)

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

```
[-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
```

```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]
```
Exercise: Largest sum

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
    """
```
Exercise: Largest sum (Solution)

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

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)))
Exercise: Digits dictionary

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

```python
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]}
    """
```

[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.

\[5, 8, 13, 21, 34, 55, 89\] → \{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

```python
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

```python
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:

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

<table>
<thead>
<tr>
<th>Operation</th>
<th>Example</th>
<th>Result</th>
</tr>
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<tbody>
<tr>
<td>append</td>
<td>adds one element to a list</td>
<td><code>s.append(t)</code></td>
</tr>
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<td></td>
<td></td>
<td><code>t = 0</code></td>
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</tr>
<tr>
<td>extend</td>
<td>adds all elements in one list to another list</td>
<td><code>s.extend(t)</code></td>
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</tr>
<tr>
<td>addition &amp; slicing</td>
<td>create new lists containing existing elements</td>
<td><code>a = s + [t]</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>b = a[1:]</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>a[1] = 9</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>b[1][1] = 0</code></td>
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# List operations

Starting from:

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

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## List operations

### Starting from:

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

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

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

addition & slicing create new lists containing existing elements | \(a = s + [t]\)  
\(b = a[1:]\)  
\(a[1] = 9\)  
\(b[1][1] = 0\)
List operations

Starting from:

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

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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                         | \[ s[0:0] = t \]
\[ s[3:] = t \]
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List operations

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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
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)
Santa's helpers

class Elf:
    greeting = 'Boss'
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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