Lecture 10: Linked Lists

Brian Hou
July 6, 2016

Announcements

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Thank you to all the participants!

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Thank you to all the participants!

Full rankings: cs61a.org/proj/hog_contest

Roadmap

Introduction

Functions

Data

Mutability

Objects

Interpretation

Paradigms

Applications

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- This week (Data), the goals are:
  - To continue our journey through abstraction with *data abstraction*
  - To study useful data types we can construct with data abstraction

Data Abstraction

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  - How compound values are *used* (the unit)

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  - How compound values are *represented* (the parts)

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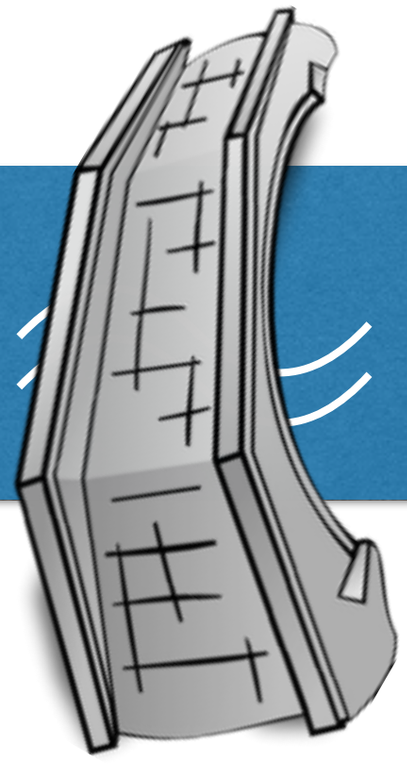

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Data Abstraction

- Great programmers use data abstraction to separate:
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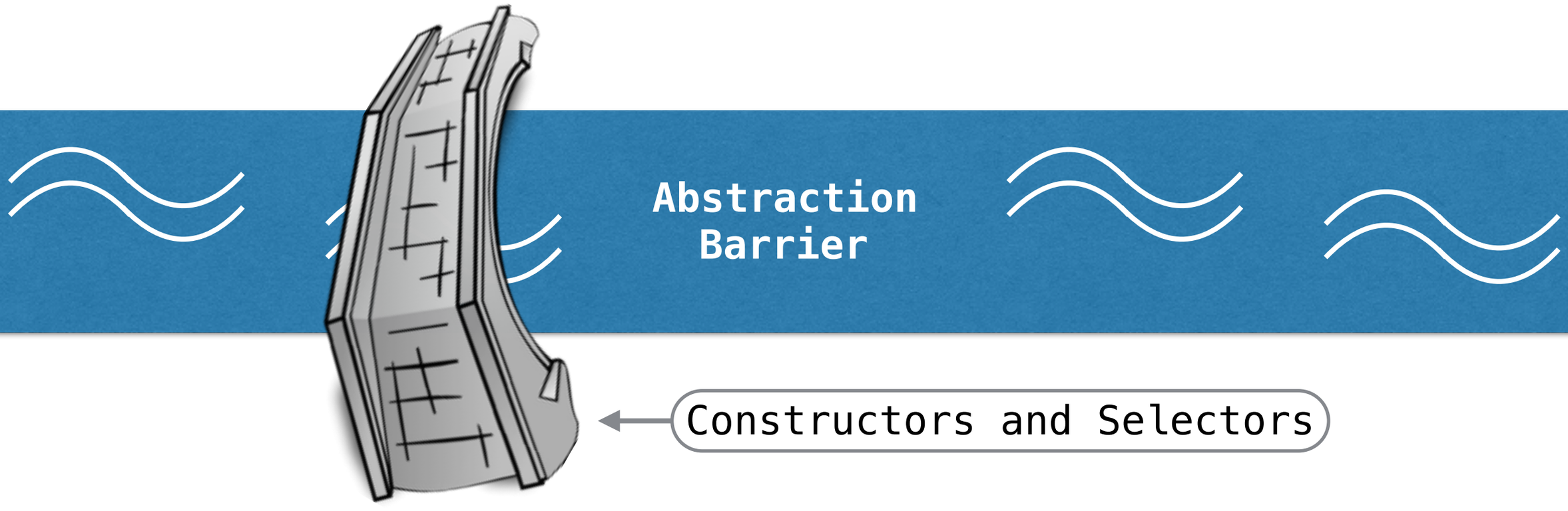

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Abstraction Barrier Violations

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- An abstraction barrier violation is when we assume knowledge about the data type implementation, rather than using constructors and selectors

Never violate the abstraction barrier!

Sequences

The Sequence Abstraction

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Length. A sequence has a finite length.

Element selection. A sequence has an element corresponding to any non-negative integer index less than its length, starting at 0.

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Lists and strings are both examples of sequences.

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We can use built-in syntax associated with this behavior.
We can also use functions.

The Sequence Abstraction (demo)

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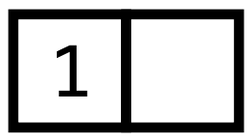

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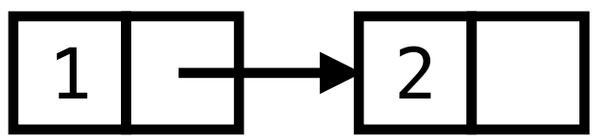

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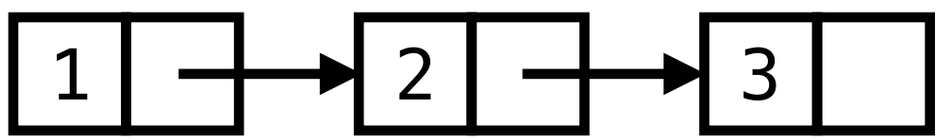

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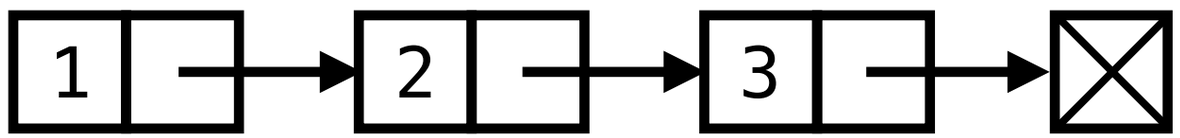

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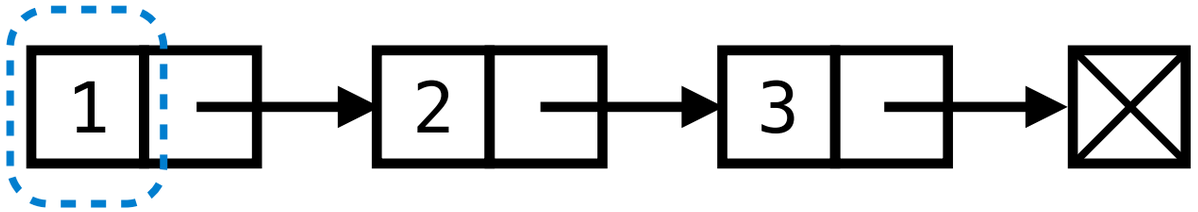

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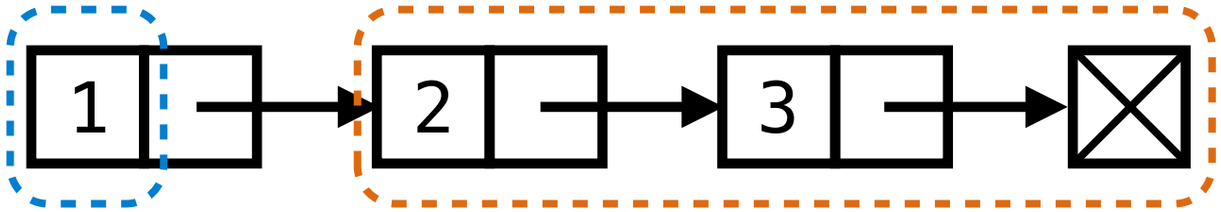

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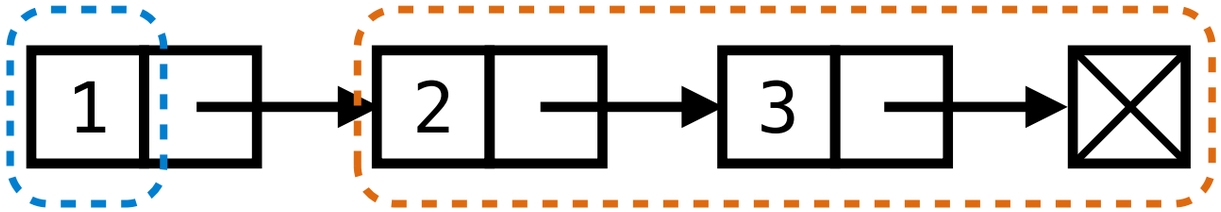

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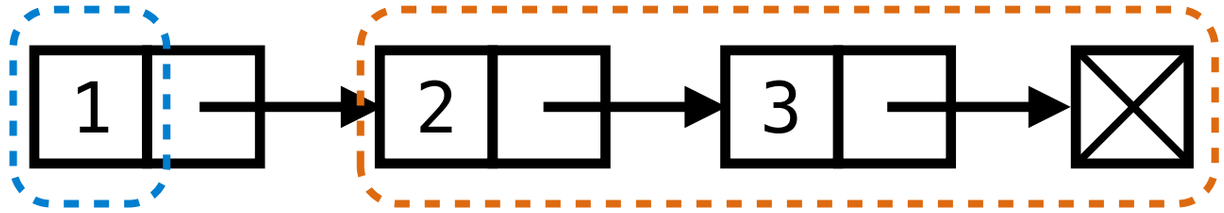

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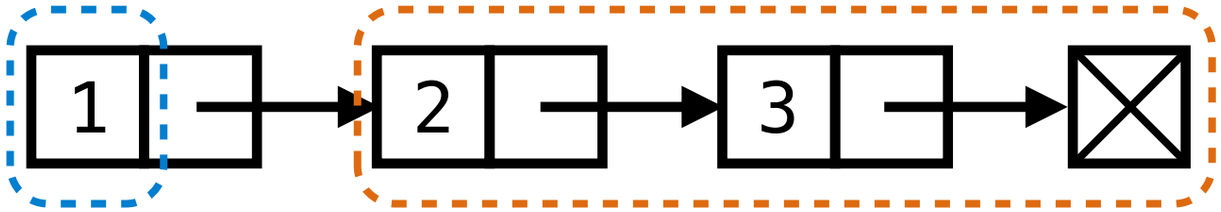

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- `first(s)` returns `h`, which is an element of the sequence
- `rest(s)` returns `t`, which is a linked list

Implementing Linked Lists (v1)

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Implementing Linked Lists (v1)

```
def link(first, rest):
    """Construct a linked list from its first
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    return [first, rest]
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```
def first(s):
    """Return the first element of a linked
    list S."""
    return s[0]

def rest(s):
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Linked Lists are Sequences

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```
def len_link(s):
    """Return the length of the linked list."""
    length = 0
    while s != empty:
        s, length = rest(s), length + 1
    return length
```

Linked Lists are Sequences (demo)

```
def len_link(s):
    """Return the length of the linked list."""
    length = 0
    while s != empty:
        s, length = rest(s), length + 1
    return length

def getitem_link(s, i):
    """Return the element at index i."""
    while i > 0:
        s, i = rest(s), i - 1
    return first(s)
```

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```

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Linked Lists are Recursive

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```
def len_link(s):
    """Return the length of the linked list."""
    if s == empty:
        return 0
    else:
        return 1 + len_link(rest(s))
```

Linked Lists are Recursive (demo)

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Break!

Linked List Processing

Sequences as Containers

Sequences as Containers (demo)

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```
def contains(s, elem):
    """Return whether ELEM is in the sequence S.
    >>> contains([1, 2, 3], 1)
    True
    >>> contains([1, 2, 3], 4)
    False
    """
    for x in s:
        if x == elem:
            return True
    return False
```

Linked Lists as Containers (demo)

Linked Lists as Containers (demo)

```
def contains_link(s, elem):
    """Return whether ELEM is in the sequence S.
    >>> contains_link(link(1, link(2, link(3, empty))), 1)
    True
    >>> contains_link(link(1, link(2, link(3, empty))), 4)
    False
    """
    if s == empty:
        return False
    if first(s) == elem:
        return True
    else:
        return contains(rest(s), elem)
```

Linked List Examples

Counting Partitions

```
def count_partitions(n, m):
    if n == 0:
        return 1
    elif n < 0:
        return 0
    elif m == 0:
        return 0
    else:
        with_m = count_partitions(n-m, m)
        without_m = count_partitions(n, m-1)
        return with_m + without_m
```

Enumerating Partitions

Enumerating Partitions (demo)

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```
def partitions(n, m):
```

Enumerating Partitions (demo)

```
def partitions(n, m):
    if n == 0:
```

Enumerating Partitions (demo)

```
def partitions(n, m):
    if n == 0:
        return link(empty, empty)
```

Enumerating Partitions (demo)

```
def partitions(n, m):
    if n == 0:
        return link(empty, empty)
    elif n < 0 or m == 0:
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Enumerating Partitions (demo)

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def partitions(n, m):
    if n == 0:
        return link(empty, empty)
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    else:
        with_m = partitions(n-m, m)
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Enumerating Partitions (demo)

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def partitions(n, m):
    if n == 0:
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Enumerating Partitions (demo)

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def partitions(n, m):
    if n == 0:
        return link(empty, empty)
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    else:
        with_m = partitions(n-m, m)
        without_m = partitions(n, m-1)
        add_m = lambda s: link(m, s)
```

Enumerating Partitions (demo)

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def partitions(n, m):
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    else:
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        without_m = partitions(n, m-1)
        add_m = lambda s: link(m, s)
        with_m = map_link(add_m, with_m)
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Enumerating Partitions (demo)

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def partitions(n, m):
    if n == 0:
        return link(empty, empty)
    elif n < 0 or m == 0:
        return empty
    else:
        with_m = partitions(n-m, m)
        without_m = partitions(n, m-1)
        add_m = lambda s: link(m, s)
        with_m = map_link(add_m, with_m)
        return extend(with_m, without_m)
```

Other Linked List Implementations

Implementing Linked Lists (v1)

```
def link(first, rest):
    """Construct a linked list from its first
    element and the rest of the linked list."""
    return [first, rest]
```

```
def first(s):
    """Return the first element of a linked
    list S."""
    return s[0]

def rest(s):
    """Return the rest of the elements of a
    linked list S."""
    return s[1]
```

Implementing Linked Lists (v2)

Implementing Linked Lists (v2)

```
def link(first, rest):
```

Implementing Linked Lists (v2)

```
def link(first, rest):


```

```
def first(s):


def rest(s):
```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
```

```
def first(s):

def rest(s):
```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
```

```
def first(s):

def rest(s):
```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
```

```
def first(s):

def rest(s):
```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
        elif msg == 'rest':
```

```
def first(s):


def rest(s):
```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
        elif msg == 'rest':
            return rest
```

```
def first(s):


def rest(s):
```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
        elif msg == 'rest':
            return rest
    return dispatch
```

```
def first(s):


def rest(s):

```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
        elif msg == 'rest':
            return rest
    return dispatch
```

```
def first(s):
    return s('first')

def rest(s):

```

Implementing Linked Lists (v2)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
        elif msg == 'rest':
            return rest
    return dispatch
```

```
def first(s):
    return s('first')

def rest(s):
    return s('rest')
```

Implementing Linked Lists (v2) (demo)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
        elif msg == 'rest':
            return rest
    return dispatch
```

```
def first(s):
    return s('first')

def rest(s):
    return s('rest')
```

Implementing Linked Lists (v2) (demo)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'first':
            return first
        elif msg == 'rest':
            return rest
    return dispatch
```

```
def first(s):
    return s('first')

def rest(s):
    return s('rest')
```

Implementing Linked Lists (v3)

```
def link(first, rest):
    def dispatch(msg):
        if msg == 'brian':
            return first
        elif msg == 'marvin':
            return rest
    return dispatch
```

```
def first(s):
    return s('brian')

def rest(s):
    return s('marvin')
```

Summary

- Linked lists are one implementation of the sequence abstraction
- Linked lists are composed of two parts:
  - first: the element in the link
  - rest: the next link in the list (may be empty)
- Data abstraction means that the implementation details of the first and rest selectors are unnecessary
- We can use functions to implement linked lists
  - We can use lists to implement dictionaries
  - Therefore, we can use functions to implement dictionaries