# Lecture 10: Linked Lists

Brian Hou
July 6, 2016

# Announcements

- Project 2 is due 7/12 (+1 EC point if submitted 7/12)
  - Run ok --submit to check against hidden tests
  - Check your submission at ok.cs61a.org
  - Invite your partner (watch this video)
- Homework 4 is due 7/7
- Quiz 3 is tomorrow at the beginning of lecture
  - If you have an alternate time or are not enrolled in the class, please arrive at 11:45 am
- Quiz 4 will be released 9 am on 7/11, due 10 am on 7/12
- **61A Potluck** on 7/8! 5 – 8 pm (or later) in Wozniak Lounge
  - Bring food and board games!

# Hog Contest

- 76 contestants
  - 20 new challengers on the last day
  - 11 new challengers in the last 6 hours
- The winner:
  1. Edgar Orendain
  1. Going Deep Blue
  1. The best team on the
     3rd floor of Davidson (U2)
  1. Going DeepMind

Thank you to all the participants!

Full rankings: cs61a.org/proj/hog_contest

# Roadmap

Introduction

Functions

Data

Mutability

Objects

Interpretation

Paradigms

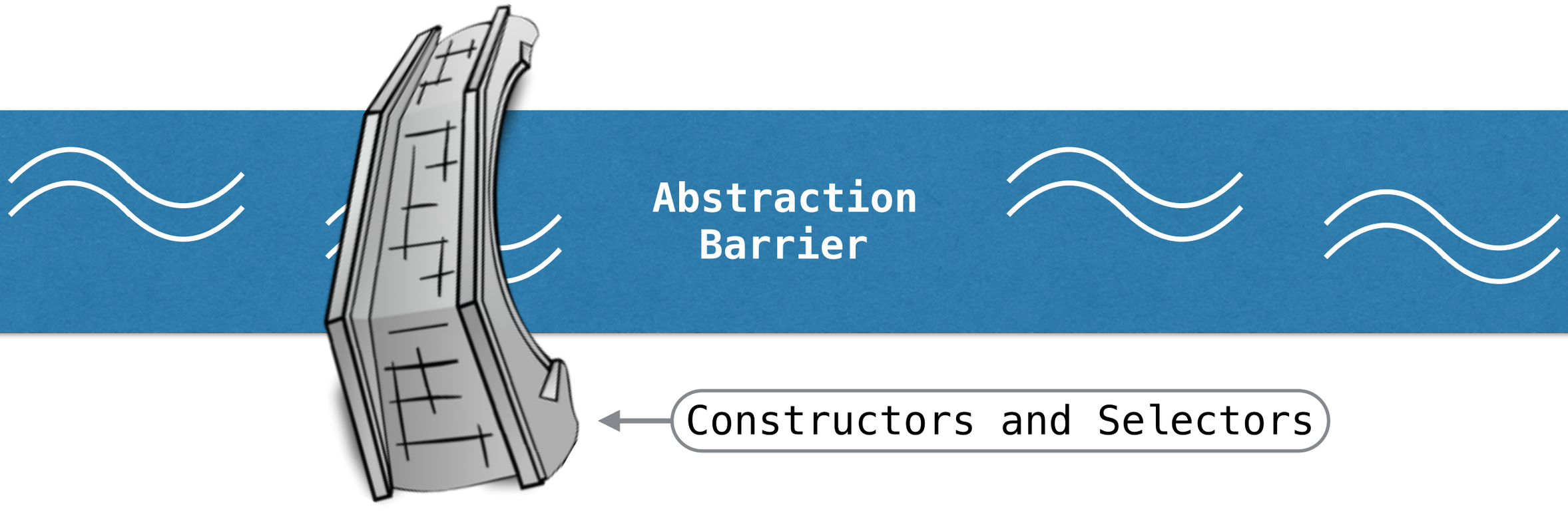
Applications

- 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

# Data Abstraction

- Great programmers use data abstraction to separate:
  - How compound values are *used* (the unit)




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

# Abstraction Barrier Violations

- Constructors and selectors provide us with abstraction, allowing us to use the data type without having to know its implementation
- 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 (demo)

The sequence abstraction is a collection of behaviors:

> **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.

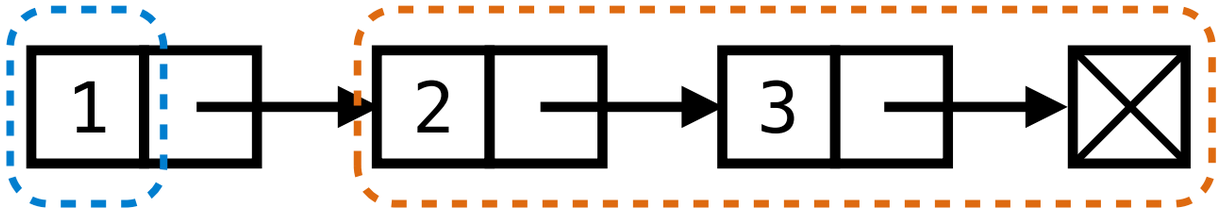
Lists and strings are both examples of sequences.

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

# Linked Lists

# Linked Lists

- Another way to implement the sequence abstraction
- Links have two parts
  - `first`: the element in the link
  - `rest`: the next link in the list
- This is a recursive definition: the rest of a linked list is another linked list




- This data structure has many names:
  - Linked list (C, Java)
  - List (Lisp)
  - Forward list (C++)
  - Linky Listys (TAs)

# Linked List Abstraction

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

```
def first(s):
    """Return the first element of a linked
    list S."""
def rest(s):
    """Return the rest of the elements of a
    linked list S."""
```

If a linked list `s` is constructed from a first element `h` and a linked list `t`, then

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

# Implementing Linked Lists (v1) (demo)

```
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]
```

# 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)
```

**Never violate the abstraction barrier!**

# Linked Lists are Recursive (demo)

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

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

**Never violate the abstraction barrier!**

# Break!

# Linked List Processing

# Sequences as Containers (demo)

```
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)

```
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 (demo)

```
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) (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