# CS 61A Lecture 13

Wednesday, October 1

## Announcements

- Homework 3 Due Wednesday 10/1 @ 11:59pm
- Optional Hog Contest Due Wednesday 10/1 @ 11:59pm
- Project 2 Due Thursday 10/9 @ 11:59pm
  - Project party Monday 10/6, 6pm-8pm in location TBD
- Special event on Tuesday 10/14 @ 7pm in Wheeler:
  Fireside chat with Founder & CEO of DropBox Drew Houston, hosted by John
- You can submit questions, and I'll ask them: http://goo.gl/HtkXFf

## Dictionaries

{'Dem': 0}

## Limitations on Dictionaries

Dictionaries are **unordered** collections of key-value pairs

Dictionary keys do have two restrictions:

- A key of a dictionary **cannot be** a list or a dictionary (or any *mutable type*)
- Two **keys cannot be equal**; There can be at most one value for a given key

This first restriction is tied to Python's underlying implementation of dictionaries

The second restriction is part of the dictionary abstraction

If you want to associate multiple values with a key, store them all in a sequence value

## Linked Lists

## Linked List Data Abstraction

Constructor:

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

Selectors:

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

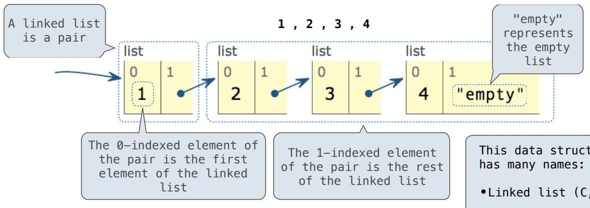
```
def rest(s):
    """Return the rest of the elements of a linked list s."""
```

Behavior condition(s):

> If a linked list s is constructed from a first element a and a linked list b, then
>
> - first(s) returns a, which is an element of the sequence
> - rest(s) returns b, which is a linked list

## Implementing Recursive Lists with Pairs

We can implement linked lists as pairs. We'll use two-element lists to represent pairs.



A linked list is a pair
1 , 2 , 3 , 4
list
0
1
1
list
0
1
2
list
0
1
3
list
0
1
4
"empty"
"empty" represents the empty list
The 0-indexed element of the pair is the first element of the linked list
The 1-indexed element of the pair is the rest of the linked list

This data structure has many names:

- Linked list (C, Java)
- List (Lisp)
- Forward list (C++)

(Demo)

## Sequence Abstraction Implementation

## Implementing the Sequence Abstraction

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

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

**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 for the first element.

(Demo)

Interactive Diagram

## Recursive implementations

(Demo)

## Linked List Processing

extend
reverse
apply_to_all_link
join_link
partitions
print_partitions

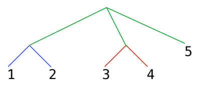
(Demo)

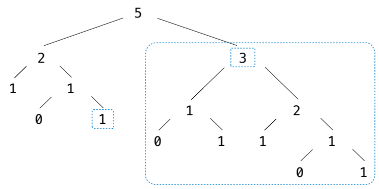
## Rooted Trees

## Rooted Trees Have a Value at the Root of Every Tree

Previously, trees ***either*** had branches ***or*** they were a leaf value; Rooted trees have **both**

**[[1, 2], [3, 4], 5]**





A rooted tree has a root value and a sequence of branches, which are rooted trees

A rooted tree with zero branches is called a leaf

The root values of sub-trees within a rooted tree are often called node values or nodes

## Implementing the Rooted Tree Abstraction

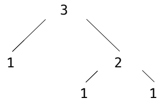
```
def rooted(value, branches):
    for branch in branches:
        assert is_rooted(branch)
    return [value] + list(branches)

def root(tree):
    return tree[0]

def branches(tree):
    return tree[1:]

def is_rooted(tree):
    if type(tree) != list or len(tree) < 1:
        return False
    for branch in branches(tree):
        if not is_rooted(branch):
            return False
    return True
```

A rooted tree has a root value and a sequence of branches, which are each rooted trees



```
>>> rooted(3, [rooted(1, []),
...            rooted(2, [rooted(1, []),
...                       rooted(1, [])])])
[3, [1], [2, [1], [1]]]
```

(Demo)

## Encoding Strings

(Bonus Material)

## Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

"Bell" (\a)

"Line feed" (\n)

**ASCII Code Chart**

8 rows: 3 bits

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | NUL | SOH | STX | ETX | EOT | ENQ | ACK | BEL | BS | HT | LF | VT | FF | CR | SO | SI |
| 1 | DLE | DC1 | DC2 | DC3 | DC4 | NAK | SYN | ETB | CAN | EM | SUB | ESC | FS | GS | RS | US |
| 2 | | ! | " | # | $ | % | & | ' | ( | ) | * | + | , | - | . | / |
| 3 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | : | ; | < | = | > | ? |
| 4 | @ | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
| 5 | P | Q | R | S | T | U | V | W | X | Y | Z | [ | \ | ] | ^ | _ |
| 6 | ` | a | b | c | d | e | f | g | h | i | j | k | l | m | n | o |
| 7 | p | q | r | s | t | u | v | w | x | y | z | { | \| | } | ~ | DEL |

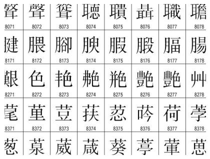
16 columns: 4 bits

- Layout was chosen to support sorting by character code
- Rows indexed 2–5 are a useful 6-bit (64 element) subset
- Control characters were designed for transmission

(Demo)

## Representing Strings: the Unicode Standard

- 109,000 characters
- 93 scripts (organized)
- Enumeration of character properties, such as case
- Supports bidirectional display order
- A canonical name for every character



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 聱 | 聲 | 聳 | 聴 | 聵 | 聶 | 職 | 聸 |
| 8071 | 8072 | 8073 | 8074 | 8075 | 8076 | 8077 | 8078 |
| 腱 | 腲 | 腳 | 腴 | 腵 | 腶 | 腷 | 腸 |
| 8171 | 8172 | 8173 | 8174 | 8175 | 8176 | 8177 | 8178 |
| 艱 | 色 | 艳 | 艴 | 艵 | 艶 | 艷 | 艸 |
| 8271 | 8272 | 8273 | 8274 | 8275 | 8276 | 8277 | 8278 |
| 荱 | 荲 | 荳 | 荴 | 荵 | 荶 | 荷 | 荸 |
| 8371 | 8372 | 8373 | 8374 | 8375 | 8376 | 8377 | 8378 |
| 葱 | 葲 | 葳 | 葴 | 葵 | 葶 | 葷 | 葸 |

http://ian-albert.com/unicode_chart/unichart-chinese.jpg

U+0058 LATIN CAPITAL LETTER X

U+263a WHITE SMILING FACE

U+2639 WHITE FROWNING FACE

'☺'     '☹'

(Demo)

## Representing Strings: UTF-8 Encoding

UTF (UCS (Universal Character Set) Transformation Format)

Unicode: Correspondence between characters and integers

UTF-8: Correspondence between those integers and bytes

A byte is 8 bits and can encode any integer 0-255.

| | | | |
|---|---|---|---|
| bytes | 00000000 | 0 | integers |
| | 00000001 | 1 | |
| | 00000010 | 2 | |
| | 00000011 | 3 | |

Variable-length encoding: integers vary in the number of bytes required to encode them.

In Python: string length is measured in characters, bytes length in bytes.

(Demo)