M2 ch14: Binary Search Trees, Queues and Stacks

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CMPT14x
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Binary search trees

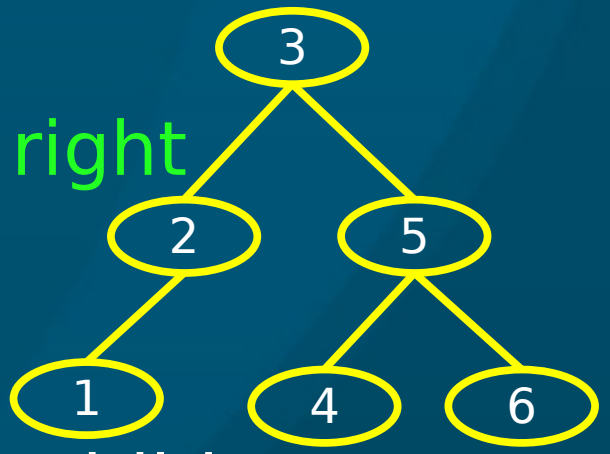
- Binary trees (degree=2) are handy for keeping things in sorted order:

```
class BST:
    def __init__(self, data=None):
        self.data = data
        self.left = None
        self.right = None
            (* could also have a parent ptr
               *)
root = BST( 'Braeburn' )
root.left = BST( 'Ambrosia' )
root.right = BST( 'Gala' )
root.right.left = BST( 'Fuji' )
```

- Everything in left subtree is smaller
- Everything in right subtree is bigger

Binary tree traversals

- Pre-order traversal of binary tree:
  - Do self first, then left child, then right
    - 3 – 2 – 1 – 5 – 4 - 6
- In-order traversal:
  - Do left child, then self, then right child
    - 1 – 2 – 3 – 4 – 5 – 6 (sorted order in BST)
    - e.g. expressions: “12 + (2 * 5)”
- Post-order traversal:
  - Do both children first before self
    - 1 – 2 – 4 – 6 – 5 - 3
    - e.g. Reverse Polish Notation: 12, 2, 5, *, +



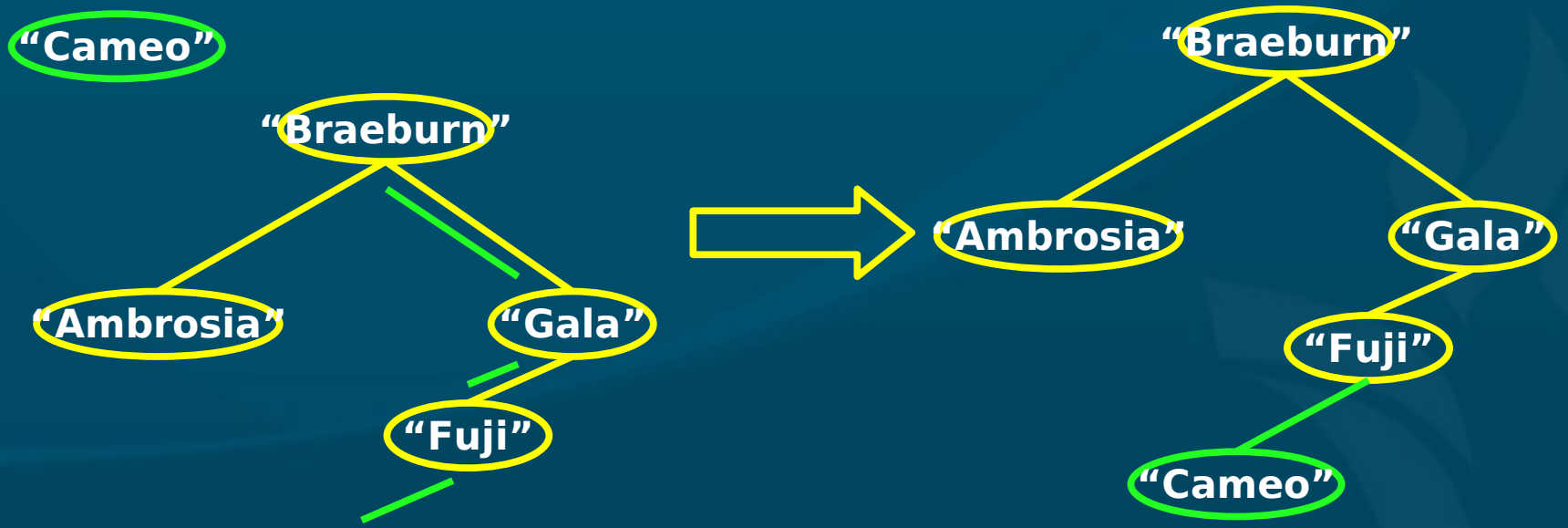
Searching a BST

- Recursive algorithm:

```
def search (self, key):
    if key == self.data:
        return self
    elif key < self.data and self.left !=
      None:
        return self.left.search(key)
    elif key > self.data and self.right !=
      None:
        return self.right.search(key)
    else:
        return None
```

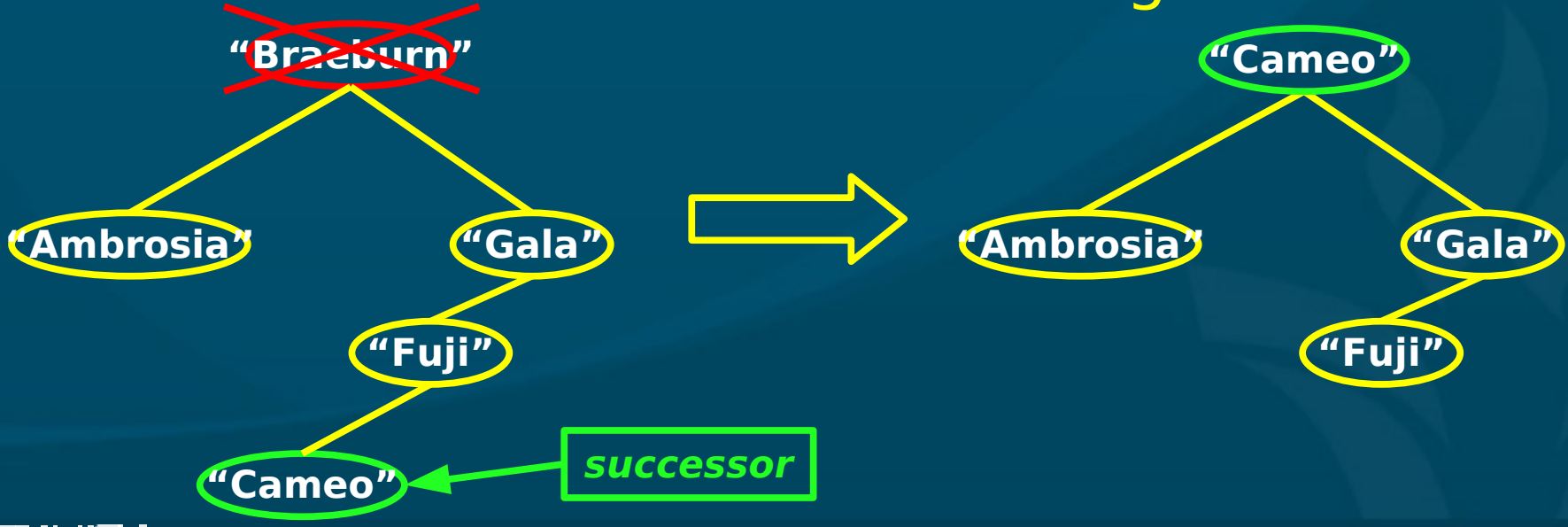
Inserting into a BST

- Keep it sorted: insert in a proper place
- One choice: always insert as a leaf
  - Use search() algorithm to hunt for where the node ought to be if it were already in the tree



Deleting from a BST

- Need to maintain sorted structure of BST
- Replace node with predecessor or successor leaf
  - Predecessor: largest node in left subtree
  - Successor: smallest node in right subtree



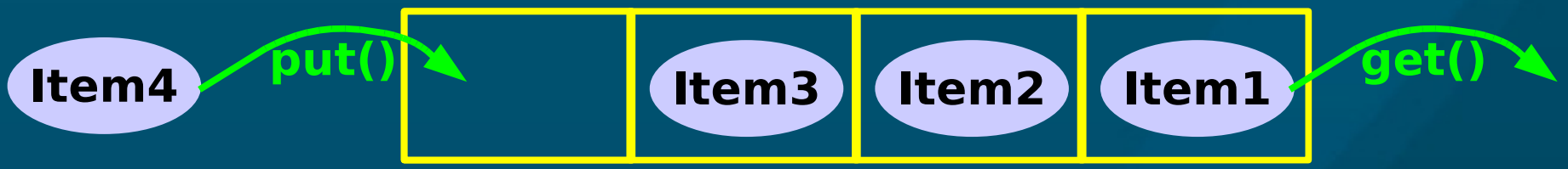
BSTs and algorithmic efficiency

- Searching in a balanced binary search tree takes worst-case O(log n) running time:
  - Depth of balanced tree is $\log_2 n$
  - Compare with arrays/linked lists: O(n)
- But depending on order of inserts, tree may be unbalanced:
  - Insert in order: Ambrosia, Braeburn, Fuji, Gala:
  - Tree degenerates to linked-list
  - Searching becomes O(n)

- Keeping a BST balanced is a larger topic
  - e.g., Splay-trees

Queues

- A queue is a list-like data structure where items added first to the queue are withdrawn first



- First-in / first-out: FIFO
- e.g., waiting in line for a bank teller
- Operations:
  - put(): add an item to the end of the queue
  - get(): withdraw item at the head of the queue
  - empty(), full(), size(): check number of items

Implementing queues

- Use a subclass of linked-lists (inheritance)

```
class Queue(LinkedList):
```

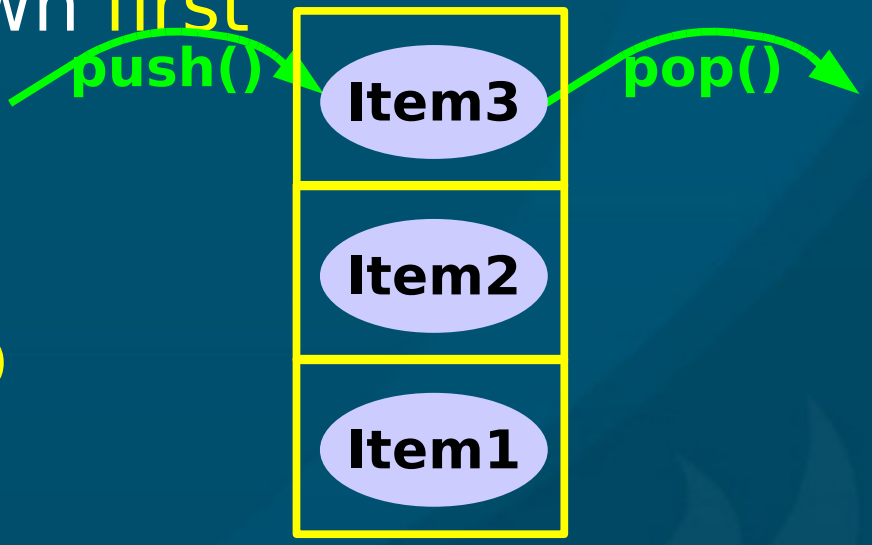
- Implement put()/get() using linked-list operations:

```
def put(self, data):
    self.insert(self.size, data)          # insert at tail
def get(self):
    data = self.head.data                 # save the
      payload
    self.delete(0)                        # delete first
      node
    return data
```

- M2 book gives a different implementation using dynamic arrays

Stacks

- A stack is like a queue, but items added last to the stack are withdrawn first



- Last-in / first-out: LIFO
- e.g., RPN calculator
- Operations:
  - push(): add an item to the top of the stack
  - pop(): withdraw item from the top of the stack
  - empty(), full(), size(): check number of items

Implementing stacks

- Could use either linked-lists or arrays

```
class Stack:
    def __init__( self, maxsize=1 ):
        self.stack = range( maxsize )      # allocate
          new array
        self.top = -1                      # index of top of
          stack
```

- push()/pop() from the array:

```
    def push( self, data ):                # what if
      array is full?
        self.top += 1
        self.stack[ self.top ] = data      # push onto top
    def pop( self ):
        self.top -= 1
        return self.stack[ top+1 ]
```

Python lists as queues/stacks

- Most languages only have arrays and pointers
  - Use pointers to build a linked-list ADT
  - Use either arrays or linked-lists to make queue or stack ADT
- Python lists are special
  - Many of the advantages of linked-lists
  - Can use Python lists naturally as queues/stacks
  - Stack: .append(), .pop() (pops from tail)
  - Queue: .append(), .pop(0) (pops from head)
  - See Py tut 5.1