CS 134:
Iterators

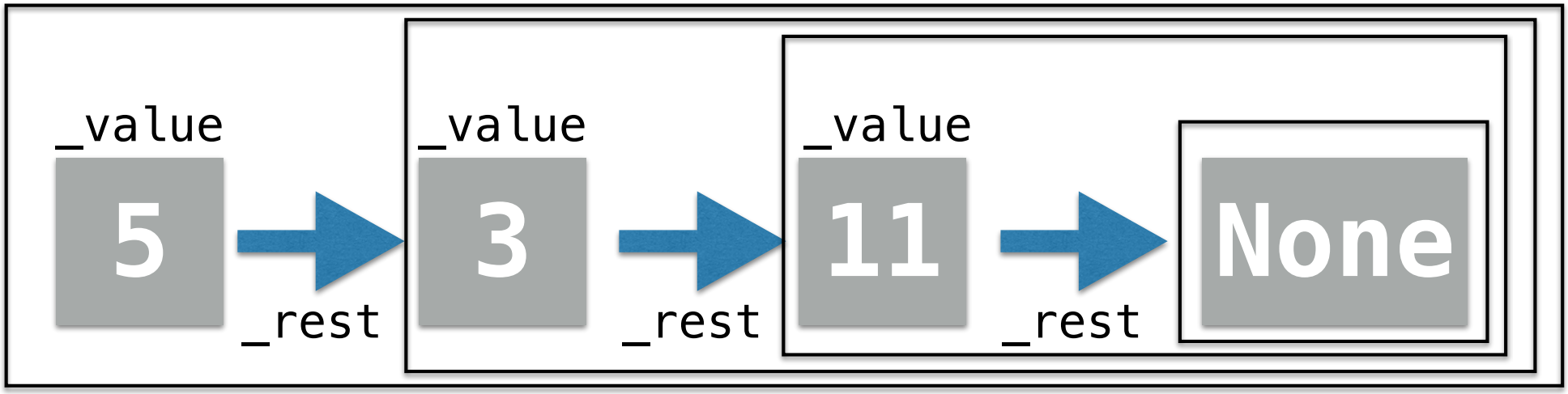
Announcements & Logistics

- **Lab 7 and 8** feedback coming soon!
- **No homework** this week
- **Lab 9 Boggle**
  - **Parts 1 & 2 (BoggleBoard and BoggleLetter)** due today/tomorrow
  - **Parts 3 (BoggleGame)** due next week
- **Lab next week:** More Boggle!

Do You Have Any Questions?

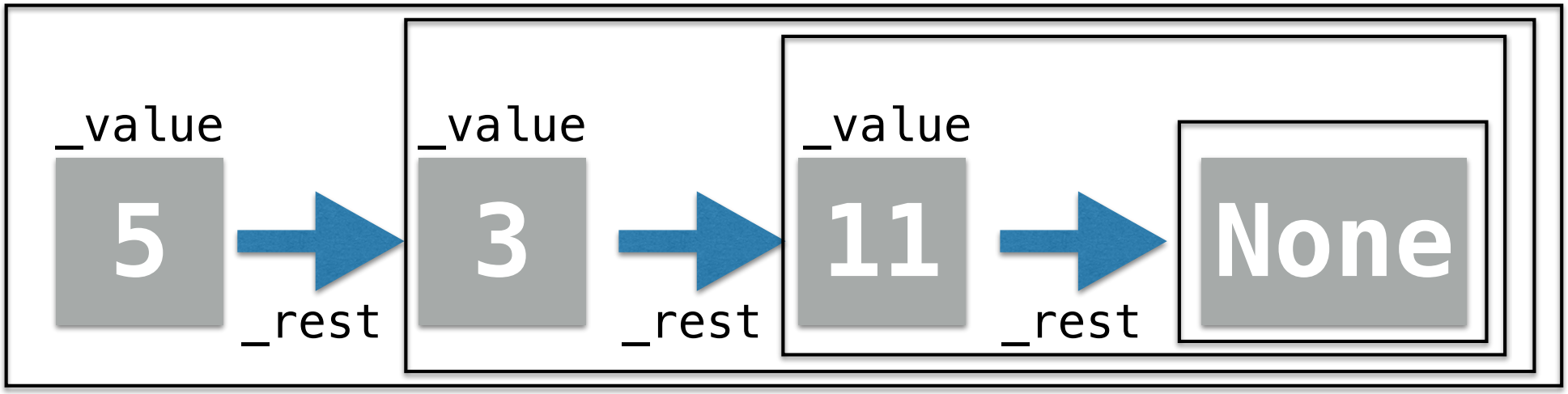
Last Time

- Started the implementation of our own linked list class
  - Why? Help us understand what's happening in Python's built-in classes
  - A glimpse of data structure design (precursor to CS136)
- Implemented several special methods:
  - `__init__`, `__str__`, `__len__`, `__contains__` (in), `__add__` (+)
  - `__getitem__`, `__setitem__` ([ ] brackets to get/set value at index)



Today

- Wrap up our linked list class:
  - Look at `__eq__, prepend, append, insert`
- Discuss how we can turn our LinkedList into an "**iterable**" object
  - This will allow us to iterate over our lists in a for loop
  - We'll also look behind the scenes at how for loops work in Python
  - Implement more special methods: `__iter__` and `__next__`



== Operator: __eq__

- **`__eq__(self, other)`**
  - When using lists, we can compare their values using the `==` operator
  - To support the `==` operator in our `LinkedList` class, we need to implement `__eq__`
  - We want to walk the lists and check the values
  - Make sure the sizes of lists match, too

== Operator: __eq__

- **__eq__(self, other)**
  - When using lists, we can compare their values using the == operator
  - To support the == operator in our LinkedList class, we need to implement __eq__

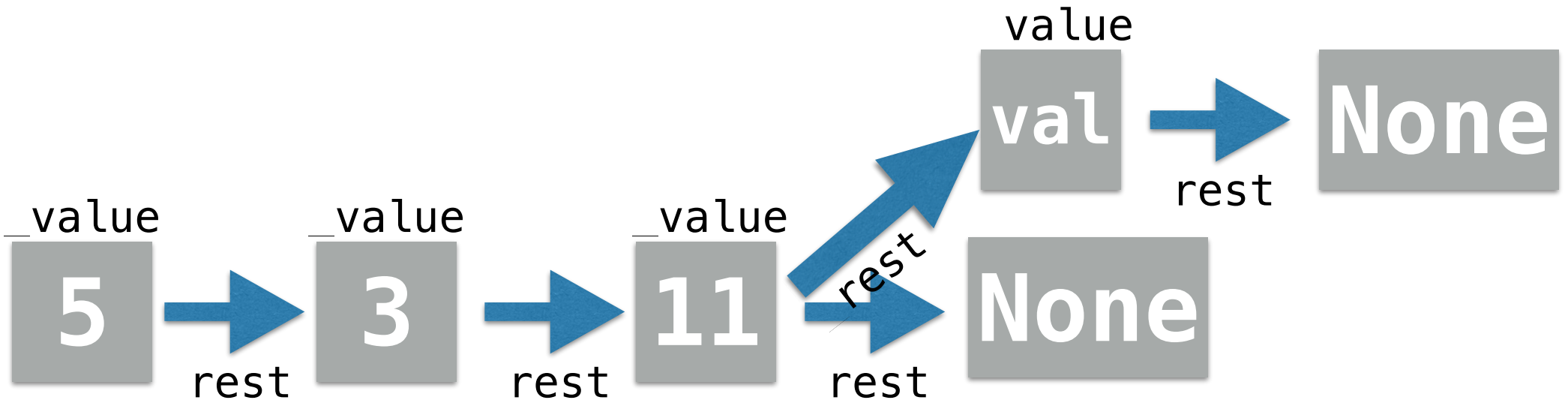
```
# == operator calls __eq__() method
# if we want to test two LinkedLists for equality, we test
# if all items are the same
# other is another LinkedList
def __eq__(self, other):
    # If both lists are empty
    if self._rest is None and other.getRest() is None:
        return True

    # If both lists are not empty, then value of current list elements
    # must match, and same should be recursively true for
    # rest of the list
    elif self._rest is not None and other.getRest() is not None :
        return self._value == other.getValue() and self._rest == other.getRest()

    # If we reach here, then one of the lists is empty and other is not
    return False
```

Many Other Special Methods!

- Examples:
  - `__eq__ (self, other): x == y`
  - `__ne__ (self, other): x != y`
  - `__lt__ (self, other): x < y`
  - `__gt__ (self, other): x > y`
  - `__add__(self, other) : x + y`
  - `__sub__(self, other): x - y`
  - `__mul__(self, other): x * y`
  - `__truediv__(self, other): x / y`
  - `__pow__(self, other): x ** y`
  - …

Useful List Method: `append`

- **`append(self, val)`**
  - When using lists, we can add an element to the end of an existing list by calling append (note that append mutates our list)
  - Basic idea:
    - Walk to end of list
    - Create a new `LinkedList(val)` and add it to the end



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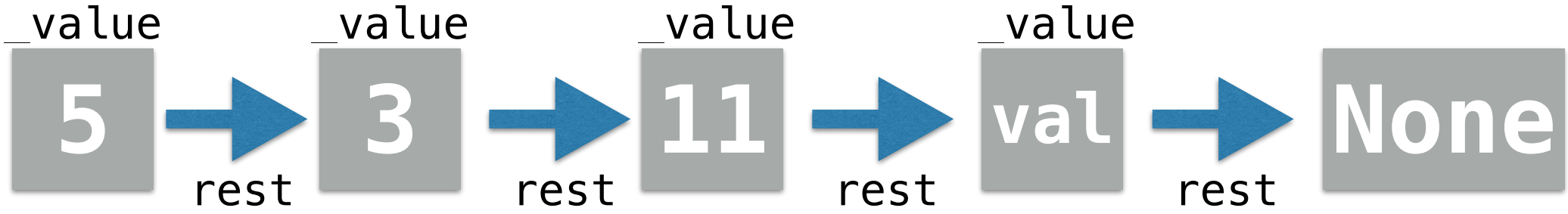


Useful List Method: `append`

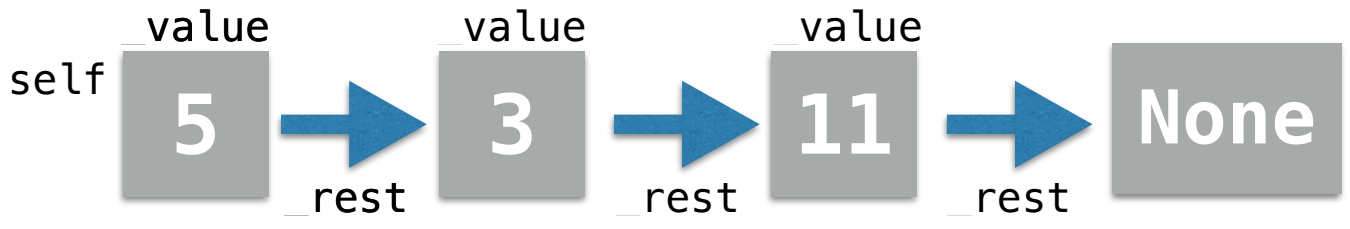
- **`append(self, val)`**
  - When using lists, we can add an element to the end of an existing list by calling append (mutates our list)
  - Adding it to the end just entails setting the _rest attribute of the last element to be a new LinkedList with the given value. The following implementation is recursive.

```
# append is not a special method, but it is a method
# that we know and love from the Python list class.
# unlike __add__, we do not return a new LinkedList instance
def append(self, val):
    # if am at the list item
    if self._rest is None:
        # add a new LinkedList to the end
        self._rest = LinkedList(val)
    else:
        # else recurse until we find the end
        self._rest.append(val)
```

Useful List Method: `prepend`

- **`prepend(self, val)`**
  - We may also want to add elements to the beginning of our list (this will also mutate our list, similar to `append`)
  - The prepend operation is really efficient, we don't need to walk through the list at all — just do some variable reassignments.

```
# prepend allows us to add an element to the beginning of our list.
# like append, it will mutate the LinkedList instance it is called on
# LinkedLists are really fast at doing prepend operations -- you can
# see that there's no for loop required, just a few variable re-assignments!
def prepend(self, val):
    oldVal = self._value
    oldRest = self._rest
    self._value = val
    self._rest = LinkedList(oldVal, oldRest)
```



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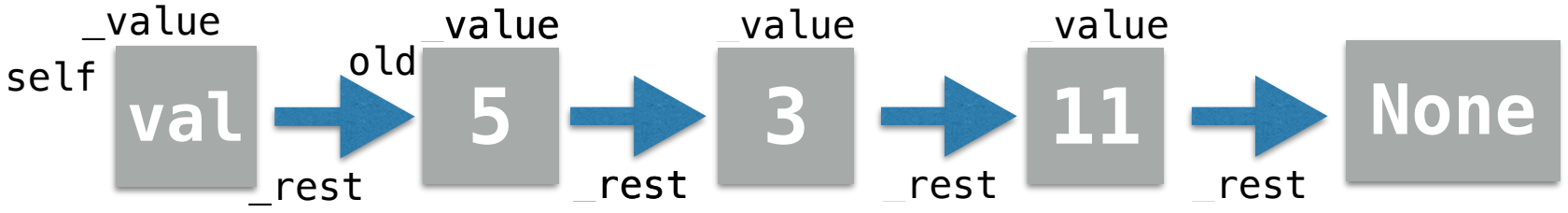
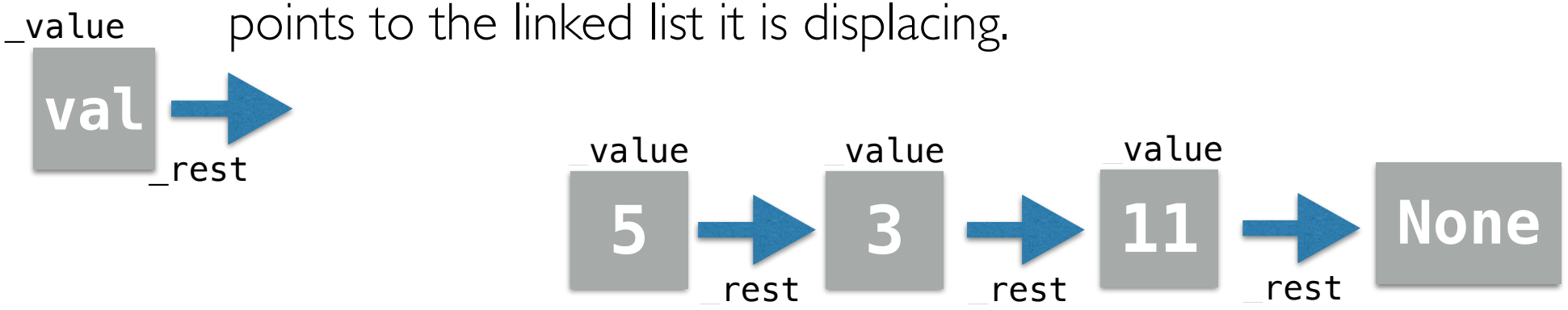


Useful List Method: `insert`

- **`insert(self, val, index)`**
  - Finally, we may want to allow for list insertions at any point specified by some valid index.
  - Basic idea:
    - If the specified index is 0, we can just use the prepend method.
    - Otherwise, we walk to the appropriate index in the list, and reassign the `_rest` attribute at that location to point to a new LinkedList with the given value, and whose `_rest` attribute points to the linked list it is displacing.



Useful List Method: `insert`

- **`insert(self, val, index)`**
  - If the specified index is 0, we can just use the prepend method.
  - Otherwise, we walk to the appropriate index in the list, and perform the insertion

```
# inserts need a bit of iteration, but only until the index where
# we'd like to insert the new element. once we reach that spot -- the
# insertion operation itself is easy
def insert(self, val, index):

    if index == 0:
        self.prepend(val)
    else:
        currList = self
        while index > 1:
            index -= 1
            currList = currList._rest
        currList._rest = LinkedList(val, currList._rest)
```

Useful List Method: `insert`

- **`insertRec(self, val, index)`**
  - If the specified index is 0, we can just use the prepend method.
  - Otherwise, we walk to the appropriate index in the list, and perform the insertion
  - Here is the recursive version

```
# here is a recursive version of insert
def insertRec(self, val, index):
   # if index is 0, we found the item we need to return
    if index == 0:
        self.prepend(val)
    # elif we have reached the end of the list, so just append to the end
    elif self._rest is None:
        self._rest = LinkedList(val)
    # else we recurse until index reaches 0
    else:
        self._rest.insertRec(val, index - 1)
```

Iterating Over Our List

- We can iterate over a Python list in a `for loop`
- It would be nice if we could iterate over our LinkedList in a for loop
- This won't quite work right now

```
In [108]: for item in myList:
              print(item)

5
3
11

---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-108-4bf86db75685> in <module>
----> 1 for item in myList:
      2     print(item)

<ipython-input-104-8a5ab5d1919c> in __getitem__(self, index)
     68             # else we recurse until index reaches 0
     69             # remember that this implicitly calls __getitem__
---> 70             return self._rest[index - 1]
     71
     72     # [] list index notation also calls __setitem__() method

TypeError: 'NoneType' object is not subscriptable
```

Iterating Over Our List

- Currently, we can only indirectly iterate over the list using a loop over a `range` object.
- We'd really like to iterate directly over the elements of the list (without using a range)
- Side note: given our LinkedList implementation, this loop is also inefficient! A call to `len()` iterates over the entire list. Each indexing call `newList[i]` also iterates over the list up to index `i` each time.

```
newList = LinkedList(5)
newList.append(10)
newList.append(42)

for i in range(len(newList)):
    print(newList[i])
```

```
5
10
42
```

Making our List Iterable

- What do we need to directly iterate over our list?
  - We need to make our class **iterable**
  - We need to implement the special methods `__iter__` and `__next__`

Making our List Iterable

- A Python object is considered **iterable** if it supports the `iter()` function: that is, the special method `__iter__` is defined
  - All ***sequences*** in Python are **iterable,** e.g., strings, lists, ranges, tuples, even files
  - We can iterate over an **iterable** directly in a for loop
  - When an **iterable** is passed to the `iter()` function, it creates an **iterator**
- An **iterator** object can generate values from the sequence **on demand**
  - This is accomplished using the `next()` function (and `__next__` method) which simply provides the "next" value in the sequence
  - We have already seen a few iterators that used `next()`: file objects, CSV reader objects, etc

For loop: Behind the Scenes

- A for loop in Python iterates directly over **iterable** objects. For example:

```
# a simple for loop to iterate over a list
for item in numList:
        print(item)
```

- Behind the scenes, the for loop is simply a while loop in disguise, driving iteration within a ***try-except*** statement. The above loop is really:

```
try:
    it = iter(numList)
    while True:
        item = next(it)
        print(item)
 except StopIteration:
     pass
```

Call the `iter` method on object to get an iterator

Access the `next` item if it exists, then print it

This is a way to "hide" the error

As Aside: `try-except` blocks

- The try/except block has the following form:

```
try:
 <possibly faulty suite>
except <error>:
    <cleanup suite>
```

- The `<possibly faulty suite>` is a collection of statements that has the potential to fail and generate an error.
  - If the failure occurs, rather than causing the program to crash, the statements inside the `except` branch are run
- You can even have more than one `except`, to handle different types of errors
- Fortunately, Python handles this automatically for us in for loops!

Python's Built-in Iterables

- We can create **iterators** for lists/strings/tuples by passing them to `iter()`
  - Benefit? We can generate values from the sequence on demand (one at a time)
  - An **iterator** maintains state between calls to `next()`
  - Once all values in the sequence have been iterated over, the **iterator** "runs dry" (and becomes empty)
  - We can only iterate over values once (unless we create another iterator)

```
In [3]: charIterator = iter(charList)

In [4]: type(charIterator)
Out[4]: list_iterator

In [5]: next(charIterator)
Out[5]: 'r'

In [6]: next(charIterator)
Out[6]: 'a'

In [7]: next(charIterator)
Out[7]: 'i'

In [8]: next(charIterator)
Out[8]: 'n'

In [9]: next(charIterator)
---------------------------
StopIteration
/var/folders/h8/n5myy3jd1d7cfv4
----> 1 next(charIterator)

StopIteration:
```

Creating an Iterator

- To create an iterator for a class we need to implement two methods:
  - `__iter__()` which is called to creates the iterator
  - `__next__()` which is called to advance to the next value
- The key aspect of creating iterators: maintaining state to keep track of ***where you are currently in the sequence*** (and what is the **next** value that should be returned)
- Thus, `__iter__()` should always "reset" the current state to the beginning, and `__next__()` should update this state each time its called

Creating an Iterator for LinkedList

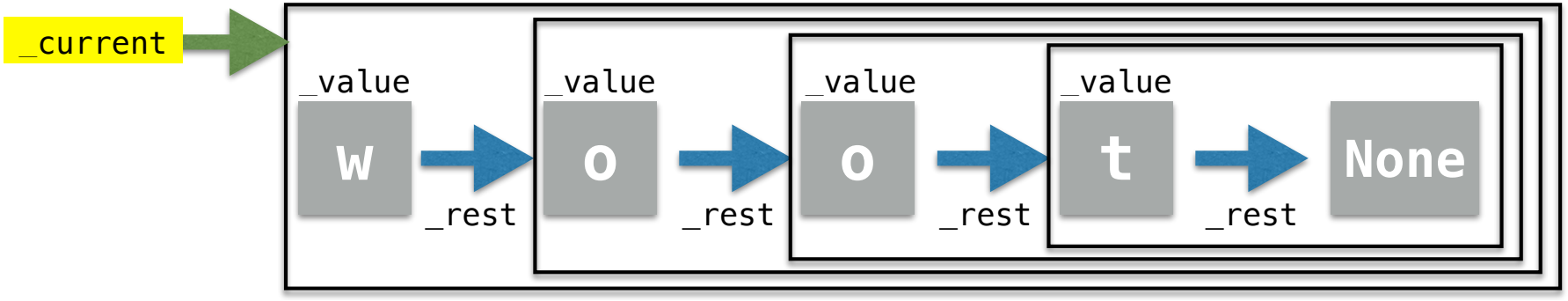
- Note: We added a new attribute '`_current`' to `__slots__`
  - `_current` keeps track of where we are in the iterator

```
def __iter__(self):
    # set current to head
    self._current = self
    return self

def __next__(self):
    if self._current is None:
        raise StopIteration
    else:
        val = self._current.value
        self._current = self._current.rest
        return val
```

```
In [2]: testList = LinkedList()
        testList.append("w")
        testList.append("o")
        testList.append("o")
        testList.append("t")
        for char in testList:
            print(char)
```

```
w
o
o
t
```



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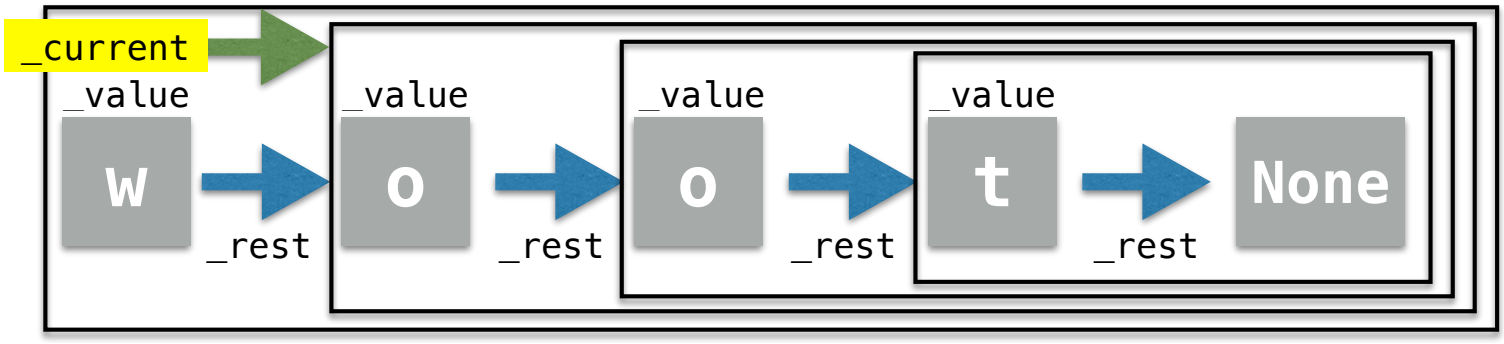

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o
o
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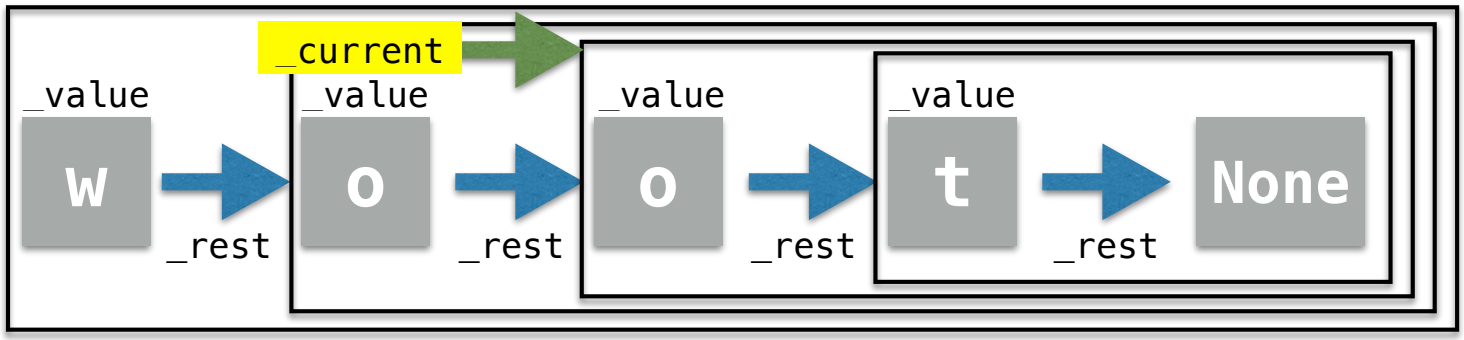

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o
o
t
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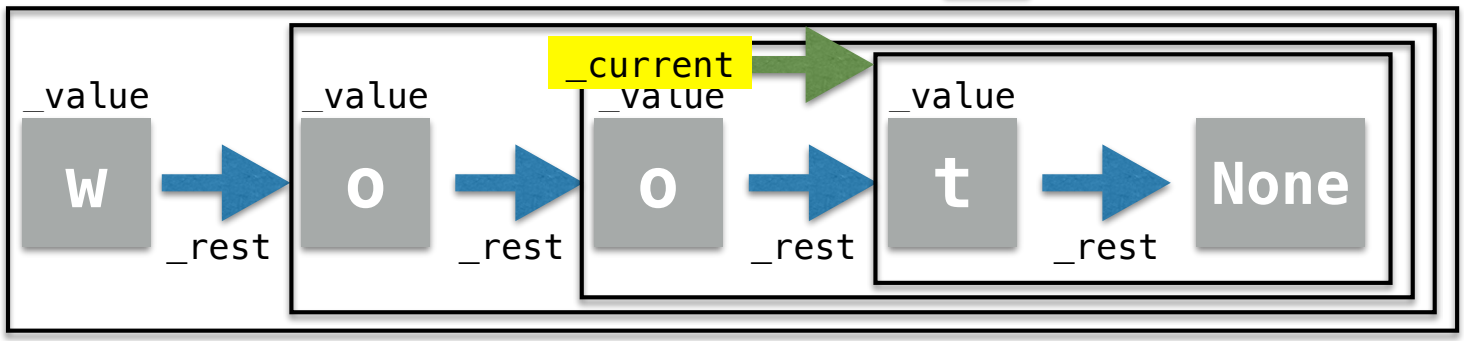

Using our New Iterable LinkedList

In [38]:
```
testList = LinkedList("w")
testList.append("o")
testList.append("o")
testList.append("t")
print("testList: ",testList)

# for loops automatically use iterators
for char in testList:
    print(char)
```

```
testList:  [w, o, o, t]
w
o
o
t
```

In [39]:
```
listIterator = iter(testList)
```

In [40]:
```
print(next(listIterator))
print(next(listIterator))
print(next(listIterator))
print(next(listIterator))
```

```
w
o
o
t
```