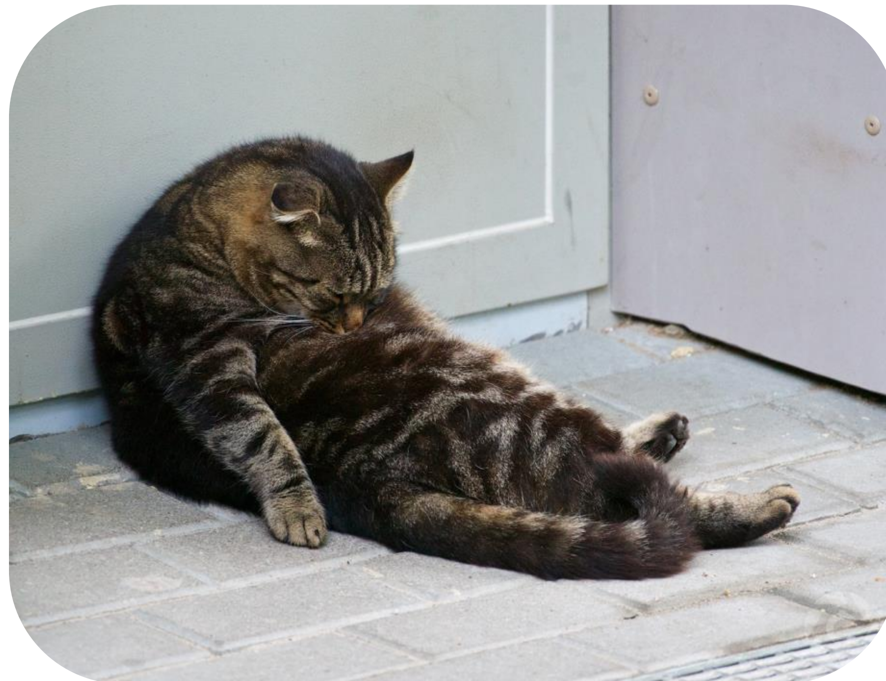
Lecture 13
Iterators & Generators



Announcements

Iterators

Definitions

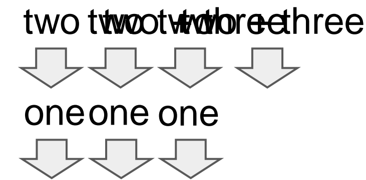
- Lazy evaluation - Delays evaluation of an expression until its value is needed

- Iterable - An object capable of returning its members one at a time. Examples include all sequences (lists, strings, tuples) and some non-sequence types (dictionaries).

- Iterator - An object that provides sequential access to values, one by one.
    - All iterators are iterables. Not all iterables are iterators.

- Metaphor: Iterables are books & Iterators are bookmarks

Iterators



How do we create iterators?

`iter(iterable)`: Return an iterator over the elements of an iterable value.

- This method creates a bookmark from a book starting at the front.

`next(iterator)`: Return the next element in an iterator.

- Returns the current page and moves the bookmark to the next page.
- The iterator remembers where you left off. If the current page is the end of the book, error.

```
>>> s = [1, 2, 3] # the book
>>> one, two = iter(s), iter(s)
>>> next(one) # move bookmark 1
1

>>> next(two) # move bookmark 2
1

>>> next(one) # move bookmark 1
2

>>> next(two) # move bookmark 2
2

>>> three = iter(two)

>>> next(three) # move bookmark 2 & 3
3

>>> next(two) # Ran out of pages
Stop Iteration
```

Check Your Understanding: Fibonacci

Define a function that returns an iterator that outputs up to the nth value in the Fibonacci sequence. You can assume n will always be 2 or greater

- Remember, iter(iterable) creates an iterator. Lists are iterables.

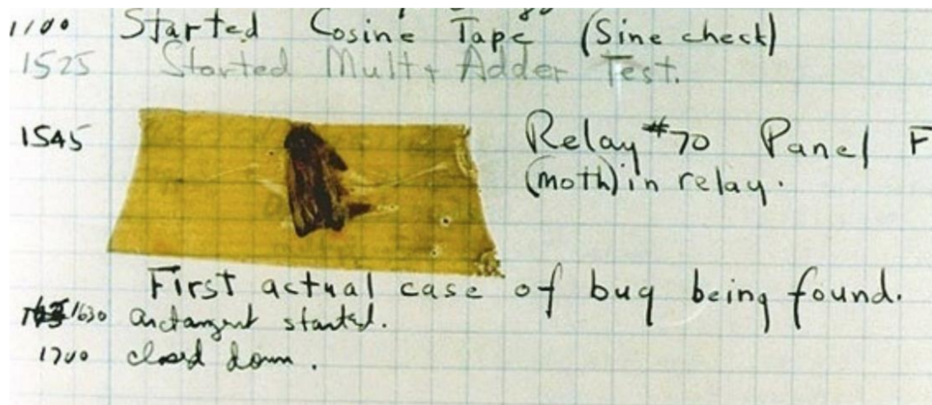
```
def fib_iter(n):
    """
    >>> x = fib_iter(4)
    >>> next(x)
    0
    >>> next(x)
    1
    >>> next(x)
    1
    >>> next(x)
    2
    """
```

Exceptions / Errors

Exceptions / Errors

Sometimes, computer programs behave in non-standard ways

- A function receives a argument value of an improper type
- Some resources (such as a file) is not available
- A network connection is lost in the middle of data transmission



Grace Hopper's Notebook, 1947, Moth found in a Mark II Computer

Raise Exceptions

Exceptions are raised with a raise statement

```
raise <expression>
```

<expression> must be an Exception, which is created like so:

E.g., `TypeError('Error message')`

`TypeError` -- A function was passed the wrong number/type of argument
`NameError` -- A name wasn't found
`KeyError` -- A key wasn't found in a dictionary
`RuntimeError` -- Catch-all for troubles during interpretation

Try Statements

Try statements handle exceptions

```
try:
    <try suite>
except <exception class> as <name>:
        <except suite>
```

Execution rule:

1. The <try suite> is executed first
2. If, during the course of executing the <try suite>, an exception is raised that is not handled otherwise then the <except suite> is executed with <name> bound to the exception

```
>>>try
... x = 1/0
... except ZeroDivisionError as e:
...     print('Except a', type(e))
...     x = 0
Except a <class ‘ZeroDivisionError’>
>>> x
0
```

Back to Iterators - The For Statement

```
for <name> in <expression>:
        <suite>
```

1. Evaluate the header <expression>, which must evaluate to an iterable object.
2. For each element in that sequence, in order:
   a. Bind <name> to that element in the first frame of the current environment
   b. Execute the <suite>

When executing a for statement, `iter` returns an iterator and `next` provides each item:

```
>>> counts = [1, 2, 3]
>>> for item in counts:
...     print(item)
1
2
3
```

These are equivalent!

```
>>> counts = [1, 2, 3]
>>> items = iter(counts)
>>> try:
...   while True:
...     item = next(items)
...     print(item)
... except StopIteration:
...               pass
1
2
3
```

StopIteration is raised whenever next is called on an empty iterator

Generators

Definitions and Rules

Some definitions:

- Generator: An iterator created automatically by calling a generator function.
- Generator function: A function that contains the keyword `yield` anywhere in the body

When a generator function is called, it returns a generator **instead of** going into the body of the function. The only way to go into the body of a generator function is by calling `next` on the returned generator.

Yielding values are the same as returning values except `yield` remembers where it left off.

Generators and Generator Functions

```
>>> def plus_minus(x):
...             yield x
...             yield -x

>>> t = plus_minus(3)
>>> next(t)
3
>>> next(t)
-3
>>> t
<generator object>
>>> next(t)
StopIteration
```

We are allowed to call `next` on generators because generators are a type of iterator.

Calling `next` on a generator goes into the function and evaluates to the first `yield` statement. The next time we call `next` on that generator, it resumes where it left off (just like calling `next` on any iterator!)

Once the generator hits a return statement, it raises a `StopIteration`

Generators to Represent Infinite Sequences

Iterators are used to represent infinite sequences. In this course, when we ask you to write an iterator, we want you to write a generator.

```
>>> def naturals():
...             x = 0
...             while True:
...                     yield x
...                     x += 1

>>> nats = naturals()
>>> next(nats)
0
>>> next(nats)
1
>>> nats1, nats2 = naturals(), naturals()
>>> [next(nats1) * next(nats2) for _ in range(5)]
[0, 1, 4, 9, 16] # Squares the first 5 natural numbers
```

Check Your Understanding: Generators

Given the following generator function, what will the call to gen() return?

```
>>> def gen():
...             start = 0
...             while start != 10:
...                     yield start
...                     start += 1

>>> gen()
```

Check Your Understanding: Generators

```
def map_gen(fn, iter1):
    """
    >>> i = iter([1, 2, 3, 4])
    >>> fn = lambda x: x**2
    >>> m = map_gen(fn, i)
    >>> next(m)
    1
    >>> next(m)
    4
    >>> next(m)
    9
    >>> next(m)
    16
    >>> next(m)
    Traceback (most recent call last):
      ...
    StopIteration
    """
    "*** YOUR CODE HERE ***"
```

Generators can Yield From Iterators

A `yield from` statement yields all values from an iterable.

```
def a_then_b(a, b):
    for x in a:
        yield x
    for x in b:
        yield x
```

```
def a_then_b(a, b):
    yield from a
    yield from b
```

```
def countdown(k):
    if k == 0:
        yield 'Blast off'
    else:
        yield k
        yield from countdown(k-1)
```

Summary

- We finally made it! What did we even talk about…
- Iterators (bookmarks) are used to iterate over iterables (books).
  - We use the iter method to turn iterables into iterators and we use the next method to get the next element.
- Exceptions can be raised and handled.
- Generators are how we implement iterators in this course and use yield statements.
  - We can use yield from to yield multiple values from an iterable.