Announcements
Data Processing
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Many data sets can be processed sequentially:
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• The set of all Twitter posts
Data Processing

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• The set of all Twitter posts
• Votes cast in an election
Data Processing

Many data sets can be processed sequentially:

- The set of all Twitter posts
- Votes cast in an election
- Sensor readings of an airplane
Data Processing

Many data sets can be processed sequentially:
- The set of all Twitter posts
- Votes cast in an election
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- The positive integers: 1, 2, 3, ...
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• The set of all Twitter posts
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However, the sequence interface we used before does not always apply
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• A sequence has a finite, known length
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- A sequence has a finite, known length
- A sequence allows element selection for any element
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Some important ideas in big data processing:
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Some important ideas in **big data processing**:  
• Implicit representations of streams of sequential data
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- Declarative programming languages to manipulate and transform data
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Some important ideas in big data processing:
• Implicit representations of streams of sequential data
• Declarative programming languages to manipulate and transform data
• Distributed computing
Iterators
Iterators
Iterators

A container can provide an iterator that provides access to its elements in some order.
Iterators

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- `iter(iterable)`: Return an iterator over the elements of an iterable value.
- `next(iterator)`: Return the next element in an iterator.
Iterators

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

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```

```python
>>> s = [3, 4, 5]
```
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A container can provide an iterator that provides access to its elements in some order:

- **`iter(iterable)`**: Return an iterator over the elements of an iterable value
  ```python
  >>> s = [3, 4, 5]
  >>> t = iter(s)
  ```

- **`next(iterator)`**: Return the next element in an iterator
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iter(iterable): Return an iterator over the elements of an iterable value

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```

```python
>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
```
Iterators

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```python
>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
4
```
Iterators

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- `iter(iterable)`: Return an iterator over the elements of an iterable value
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```python
>>> s = [3, 4, 5]
>>> u = iter(s)
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
4
```
Iterators

A container can provide an iterator that provides access to its elements in some order

\texttt{iter(iterable)}: Return an iterator over the elements of an iterable value

\texttt{next(iterator)}: Return the next element in an iterator

```python
>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
4
```
Iterators

A container can provide an iterator that provides access to its elements in some order

\[ \text{iter(iterable): Return an iterator over the elements of an iterable value} \]

\[ \text{next(iterator): Return the next element in an iterator} \]

```python
>>> s = [3, 4, 5]  
>>> t = iter(s)  
>>> next(t)  
3
>>> next(t)  
4
>>> u = iter(s)  
>>> next(u)  
3
>>> next(t)  
5
```
Iterators

A container can provide an iterator that provides access to its elements in some order.

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

*`next(iterator)`: Return the next element in an iterator*
Iterators

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```
iter(iterable): Return an iterator over the elements of an iterable value
next(iterator): Return the next element in an iterator
```

Iterators are always ordered, even if the container that produced them is not

```python
>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
5
>>> next(t)
4
>>> u = iter(s)
>>> next(u)
3
>>> next(u)
4
```
Iterators

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```
iter(iterable): Return an iterator over the elements of an iterable value
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```
>>> s = [3, 4, 5]  # >>> u = iter(s)
>>> t = iter(s)    # >>> next(u)
>>> next(t)        #   3
3
>>> next(t)        # >>> next(t)
5
4
>>> next(t)        #   4
4
```
Iterators

A container can provide an iterator that provides access to its elements in some order

\[\text{iter(iterable)}: \text{Return an iterator over the elements of an iterable value}\]

\[\text{next(iterator)}: \text{Return the next element in an iterator}\]

Iterators are always ordered, even if the container that produced them is not

>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
4
>>> next(t)
5
>>> u = iter(s)
>>> next(u)
3
>>> next(u)
4

>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)
Iterators

A container can provide an iterator that provides access to its elements in some order

\begin{align*}
\text{iter}(\text{iterable}): & \text{ Return an iterator over the elements of an iterable value} \\
\text{next}(\text{iterator}): & \text{ Return the next element in an iterator}
\end{align*}

Iterators are always ordered, even if the container that produced them is not

\begin{verbatim}
>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
>>> u = iter(s)
>>> next(u)
3
>>> next(t)
5
>>> next(u)
4
>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)
>>> next(k)
'one'
\end{verbatim}
Iterators

A container can provide an iterator that provides access to its elements in some order

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\text{iter}(\text{iterable}): \text{Return an iterator over the elements of an iterable value}
\]

\[
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Iterators are always ordered, even if the container that produced them is not

```python
>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
5
>>> next(t)
4
```

```python
>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)
>>> next(k)
'one'
>>> next(k)
'three'
```
Iterators

A container can provide an iterator that provides access to its elements in some order

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

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

Iterators are always ordered, even if the container that produced them is not

```python
>>> s = [3, 4, 5]
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
5
>>> next(t)
4

>>> u = iter(s)
>>> next(u)
3
>>> next(u)
4

>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)
>>> next(k)
'one'
>>> next(k)
'three'
>>> next(k)
'two'
```
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```
>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)
>>> next(k)
'one'
>>> next(k)
'three'
>>> next(k)
'two'
```

Keys and values are iterated over in an arbitrary order which is non-random, varies across Python implementations, and depends on the dictionary’s history of insertions and deletions. If keys, values and items views are iterated over with no intervening modifications to the dictionary, the order of items will directly correspond.

[https://docs.python.org/3/library/stdtypes.html#dictionary-view-objects](https://docs.python.org/3/library/stdtypes.html#dictionary-view-objects)
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```python
iter(iterable): Return an iterator over the elements of an iterable value
```

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

Iterators are always ordered, even if the container that produced them is not

```python
>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)  >>> v = iter(d.values())
>>> next(k)
'one'
>>> next(k)
'three'
>>> next(k)
'two'
```

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```python
>>> s = [3, 4, 5]  >>> u = iter(s)
>>> t = iter(s)  >>> next(u)
>>> next(t) 3
>>> next(t) 5
>>> next(u) 4
```

```python
>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)  >>> v = iter(d.values())
>>> next(k)  >>> next(v)
'one'
1
>>> next(k)
'three'
>>> next(k)
'two'
```

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```python
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```

Iterators are always ordered, even if the container that produced them is not

```python
>>> s = [3, 4, 5]   >>> u = iter(s)
>>> t = iter(s)    >>> next(u)
>>> next(t)        3
3
>>> next(t)        5
4
>>> next(u)        4
```

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

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```python
>>> s = [3, 4, 5]
>>> u = iter(s)
>>> next(u)
3
>>> next(u)
5
>>> next(u)
4
>>> t = iter(s)
>>> next(t)
3
>>> next(t)
5
>>> next(t)
4
>>> d = {'one': 1, 'two': 2, 'three': 3}
>>> k = iter(d)
>>> v = iter(d.values())
>>> next(k)
'one'
>>> next(v)
1
>>> next(k)
'three'
>>> next(v)
3
>>> next(k)
'two'
>>> next(v)
2
```

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(Demo)

https://docs.python.org/3/library/stdtypes.html#dictionary-view-objects
For Statements
The For Statement
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for <name> in <expression>:
    <suite>
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    <suite>

1. Evaluate the header <expression>, which must evaluate to an iterable object
The For Statement

for <name> in <expression>:
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1. Evaluate the header <expression>, which must evaluate to an iterable object
2. For each element in that sequence, in order:
The For Statement

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

```python
>>> counts = [1, 2, 3]
>>> for item in counts:
    print(item)
1
2
3
```
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:
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```python
counts = [1, 2, 3]
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2
3
```
Processing Iterators
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A `StopIteration` exception is raised whenever `next` is called on an empty iterator.
Processing Iterators

A `StopIteration` exception is raised whenever `next` is called on an empty iterator

```python
>>> contains('strength', 'stent')
True
```
Processing Iterators

A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
```
Processing Iterators

A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```
A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
def contains(a, b):
    pass

>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```
Processing Iterators

A `StopIteration` exception is raised whenever `next` is called on an empty iterator

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```

def contains(a, b):
    ai = iter(a)
Processing Iterators

A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```
Processing Iterators

A *StopIteration* exception is raised whenever *next* is called on an empty iterator

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
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True
```
A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
def contains(a, b):
    ai = iter(a)
    for x in b:
        pass
```

```bash
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```
Processing Iterators

A StopIteration exception is raised whenever `next` is called on an empty iterator.

```python
def contains(a, b):
    ai = iter(a)
    for x in b:
        while next(ai) != x:
            pass  # do nothing

>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```
Processing Iterators

A **StopIteration** exception is raised whenever `next` is called on an empty iterator.

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```

def contains(a, b):
    ai = iter(a)
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>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```
A **StopIteration** exception is raised whenever `next` is called on an empty iterator.

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```

```python
def contains(a, b):
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>>> contains('strength', 'stent')
True
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False
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True
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>>> contains('strength', 'stent')
True
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False
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True
```
Processing Iterators

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```

```python
>>> contains('strength', 'stent')
True
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False
>>> contains('strength', 'tenth')
True
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A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
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True
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A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
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```

```python
def contains(a, b):
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    for x in b:
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A **StopIteration** exception is raised whenever `next` is called on an empty iterator

```python
>>> contains('strength', 'stent')
True
>>> contains('strength', 'rest')
False
>>> contains('strength', 'tenth')
True
```

```python
def contains(a, b):
    ai = iter(a)
    for x in b:
        while next(ai) != x:
            pass  # do nothing

    return True
```
**Processing Iterators**

A `StopIteration` exception is raised whenever `next` is called on an empty iterator.

```python
def contains(a, b):
    ai = iter(a)
    for x in b:
        try:
            while next(ai) != x:
                pass  # do nothing
        except StopIteration:
            return False
    return True
```

```python
contains('strength', 'stent')
# True
contains('strength', 'rest')  # False
contains('strength', 'tenth')
# True
```
Built-In Iterator Functions
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily.
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily

\[
\text{map(func, iterable): } \text{Iterate over func(x) for x in iterable}
\]
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily

- `map(func, iterable)`: Iterate over `func(x)` for `x` in `iterable`
- `filter(func, iterable)`: Iterate over `x` in `iterable` if `func(x)`
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily

- `map(func, iterable)`: Iterate over `func(x)` for `x` in `iterable`
- `filter(func, iterable)`: Iterate over `x` in `iterable` if `func(x)`
- `zip(first_iter, second_iter)`: Iterate over co-indexed `(x, y)` pairs
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily

- `map(func, iterable)`: Iterate over `func(x)` for `x` in `iterable`
- `filter(func, iterable)`: Iterate over `x` in `iterable` if `func(x)`
- `zip(first_iter, second_iter)`: Iterate over co-indexed `(x, y)` pairs
- `reversed(sequence)`: Iterate over `x` in a sequence in reverse order
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily:

- `map(func, iterable)`: Iterate over `func(x)` for `x` in `iterable`
- `filter(func, iterable)`: Iterate over `x` in `iterable` if `func(x)`
- `zip(first_iter, second_iter)`: Iterate over co-indexed `(x, y)` pairs
- `reversed(sequence)`: Iterate over `x` in a sequence in reverse order

To view the contents of an iterator, place the resulting elements into a container.
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily.

- `map(func, iterable)`: Iterate over `func(x)` for `x` in `iterable`
- `filter(func, iterable)`: Iterate over `x` in `iterable` if `func(x)`
- `zip(first_iter, second_iter)`: Iterate over co-indexed `(x, y)` pairs
- `reversed(sequence)`: Iterate over `x` in a sequence in reverse order

To view the contents of an iterator, place the resulting elements into a container.

- `list(iterable)`: Create a list containing all `x` in `iterable`
Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily:

- `map(func, iterable)`
  - Iterate over `func(x)` for `x` in `iterable`

- `filter(func, iterable)`
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- `zip(first_iter, second_iter)`
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  - Iterate over `x` in a sequence in reverse order

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- `list(iterable)`
  - Create a list containing all `x` in `iterable`

- `tuple(iterable)`
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Built-in Functions for Iteration

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Built-in Functions for Iteration

Many built-in Python sequence operations return iterators that compute results lazily

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(Demo)
Generators
Generators and Generator Functions
Generators and Generator Functions

```python
>>> def plus_minus(x):
...    yield x
...    yield -x
```
Generators and Generator Functions

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

>>> t = plus_minus(3)
```
Generators and Generator Functions

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

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

A generator function is a function that yields values instead of returning them.
Generators and Generator Functions

A **generator function** is a function that **yields** values instead of **returning** them. A normal function **returns** once; a **generator function** can **yield** multiple times.

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<generator object plus_minus ...>
```
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A normal function returns once; a generator function can yield multiple times.
A generator is an iterator created automatically by calling a generator function.
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When a generator function is called, it returns a generator that iterates over its yields.
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(Demo)
Iterable User-Defined Classes
Iterable User-Defined Classes

The special method \_\texttt{iter}\_\texttt{\_} is called by the built-in \texttt{iter()} & should return an iterator
Iterable User-Defined Classes

The special method `__iter__` is called by the built-in `iter()` & should return an iterator

```python
>>> list(Countdown(5))
[5, 4, 3, 2, 1]
```
Iterables User-Defined Classes

The special method \_\_iter\_\_ is called by the built-in \texttt{iter()} \& should return an iterator

\begin{verbatim}
>>> list(Countdown(5))
[5, 4, 3, 2, 1]
>>> for x in Countdown(3):
...     print(x)
3
2
1
\end{verbatim}
Iterable User-Defined Classes

The special method `__iter__` is called by the built-in `iter()` & should return an iterator.

```python
class Countdown:
    def __init__(self, start):
        self.start = start

>>> list(Countdown(5))
[5, 4, 3, 2, 1]

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```
Iterable User-Defined Classes

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>>> list(Countdown(5))
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>>> for x in Countdown(3):
    ...    print(x)
    ...    print(x)
3
2
1
class Countdown:
    def __init__(self, start):
        self.start = start
    def __iter__(self):
        ...
Iterable User-Defined Classes

The special method \texttt{\_\_iter\_\_} is called by the built-in \texttt{iter()} & should return an iterator

```python
class Countdown:
    def \_\_init\_\_(self, start):
        self.start = start
    def \_\_iter\_\_(self):
        v = self.start
        while v > 0:
            yield v
            v -= 1
```

```python
>>> list(Countdown(5))
[5, 4, 3, 2, 1]
>>> for x in Countdown(3):
    ...    print(x)
3
2
1
```
Generators & Iterators
Generators can Yield from Iterators
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A `yield from` statement yields all values from an iterator or iterable (Python 3.3)
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```python
>>> list(a_then_b([3, 4], [5, 6]))
[3, 4, 5, 6]
```
Generators can Yield from Iterators

A `yield from` statement yields all values from an iterator or iterable (Python 3.3)

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

>>> list(a_then_b([3, 4], [5, 6]))
[3, 4, 5, 6]
```
Generators can Yield from Iterators

A `yield from` statement yields all values from an iterator or iterable (Python 3.3)

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

>>> list(a_then_b([3, 4], [5, 6]))
[3, 4, 5, 6]
```

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

def countdown(k):
    if k > 0:
        yield k
    yield from countdown(k - 1)

>>> list(countdown(5))
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```
Generators can Yield from Iterators

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```

(Demo)