

Iterating and Comparing

Welcome back to CS 2100!

Prof. Rasika Bhalerao

Oh no...

We can iterate over collections and `str`s using `for` loops, but we can't iterate over `int`s:

```
for letter in 'hello':  
    print(letter)  
  
for digit in 12345: # TypeError: 'int' object is not iterable  
    print(digit)
```

What does `str` do that `int` doesn't? And how can we change that?

Where we're headed...

```
from collections.abc import Iterable, Iterator

class INTerable(Iterable[int]):
    def __init__(self, number: int) -> None:
        self.number = number

    def __iter__(self) -> Iterator[int]:
        return INTerator(self.number)

class INTerator(Iterator[int]):
    def __init__(self, number: int) -> None:
        self.current = number

    def __next__(self) -> int:
        if self.current > 0:
            value = self.current % 10
            self.current //= 10
            return value
        else:
            raise StopIteration()
```

```
if __name__ == "__main__":
    iterable = INTerable(12345)
    for digit in iterable:
        print(digit)
```

5
4
3
2
1

Recall:

Python's beautiful alternative to interfaces: Contracts

- **Interface** using `ABC` is an explicit contract: classes must follow the rules (enforced)
 - Early error detection, readability, easier to follow, requires other implementors to follow our rules, teaches fundamental concepts
- Python's built-in **contracts** are followed by convention but not enforced
 - Includes things that interfaces cannot include (like specifying *what the methods should do*, rather than simply listing the methods that need to be implemented)

Length / size protocol and `Sized` interface

Protocol:

- `def __len__(self) -> int` which returns a non-negative `int`
- this is what is returned by the `len()` function

ABC interface `Sized`:

- Enforces that we implement `__len__()`

```
from collections.abc import Sized

class Cat(Sized):
    def __len__(self) -> int:
        return 900

print(len(Cat())) # 900
```

Neglecting to implement `__len__()` (or having it return a negative number) will cause an error.

Membership test protocol and **Container** interface

"Membership test protocol" / "containment protocol":

- When you use `in`, Python calls `__contains__()`

ABC interface **Container**

```
from collections.abc import Container

class Document(Container[str]):
    def __init__(self, text: str):
        self.words = text.split()

    def __contains__(self, word: object) -> bool:
        if not isinstance(word, str):
            raise TypeError
        return word in self.words

print('hi' in Document('hi this is mini')) # True
print('cat' in Document('hi this is mini')) # False
```

New: Iterable protocol

We can iterate over collections and `str` s using `for` loops, but we can't iterate over `int` s:

```
for letter in 'hello':  
    print(letter)  
  
for digit in 12345: # TypeError: 'int' object is not iterable  
    print(digit)
```

That's because `str` and collections like `list` follow the Iterable protocol, and `int` s don't.

Iterable protocol (and ABC interface)

- Any object that follows the `Iterable` protocol can be iterated over.
- The `Iterable` protocol requires one method: `__iter__()`, which returns an object that follows the `Iterator` protocol.

```
from collections.abc import Iterable

class Calendar(Iterable[str]):
    def __init__(self, days: list[str]):
        self.days = days

    def __iter__(self) -> Iterator[str]:
        """Returns an iterator over the lecture days this week"""
        return iter(self.days)

for lecture in Calendar(['Monday', 'Wednesday', 'Thursday']):
    print(lecture)
```


Iterator protocol (and ABC interface)

```
from collections.abc import Iterable, Iterator

class Calendar(Iterable[str]):
    def __init__(self, days: list[str]):
        self.days = days

    def __iter__(self) -> Iterator[str]:
        """Returns an iterator that returns
        every other day this week"""
        return AlternatingDayIterator(
            self.days)

class AlternatingDayIterator(Iterator[str]):
    def __init__(self, days: list[str]):
        self.days = days
        self.index: int = 0

    def __next__(self) -> str:
        if self.index >= len(self.days):
            raise StopIteration

        value = self.days[self.index]
        self.index += 2
        return value
```

```
days = Calendar(
    ['Monday', 'Tuesday',
     'Wednesday', 'Thursday',
     'Friday'])

for alternating_day in days:
    print(alternating_day)
```

But, please use an existing Iterator when possible (like `list`'s, `set`'s, etc.)

```
from collections.abc import Iterable, Iterator

class INTerable(Iterable[int]):
    def __init__(self, number: int) -> None:
        self.number = number

    def __iter__(self) -> Iterator[int]:
        return INTerator(self.number)

class INTerator(Iterator[int]):
    def __init__(self, number: int) -> None:
        self.current = number

    def __next__(self) -> int:
        if self.current > 0:
            value = self.current % 10
            self.current //= 10
            return value
        else:
            raise StopIteration()
```

```
if __name__ == "__main__":
    iterable = INTerable(12345)
    for digit in iterable:
        print(digit)
```

5
4
3
2
1

Iterator protocol (and ABC interface)

The Iterator protocol and interface require two methods:

- `__next__(self) -> T` : returns the next value in the sequence, or raises `StopIteration` if there are no more values left to iterate through
- `__iter__(self) -> Iterator[T]` : returns the iterator object itself
 - Inherited version usually works, no need to rewrite

Exercise:

If we pass a `min` which is bigger than a `max`, there is no output:

```
for i in range(5, 2):  
    print(i)
```

Let's write our own version called `Range` (with a capital R) that works forwards or backwards. Our version will require a `start` and a `stop`, with an optional `step`.

```
class Range(Iterable[int]):
    def __init__(self, start: int, stop: int, step: int = 1):
        self.start = start
        self.stop = stop
        self.step = step

    def __iter__(self) -> Iterator[int]:
        if self.start < self.stop:
            return iter(range(self.start, self.stop, self.step))
        else:
            return BackwardsIter(self.start, self.stop, self.step)

class BackwardsIter(Iterator[int]):
    def __init__(self, start: int, stop: int, step: int = 1):
        self.start = start
        self.stop = stop
        self.step = step
        self.current = start

    def __next__(self) -> int:
        if self.current <= self.stop:
            raise StopIteration
        value = self.current
        self.current -= self.step
        return value
```

Poll: In a `for` loop using the built-in `range()`, what happens if a client passes in a `min` which is bigger than the `max`?

1. Python doesn't allow it because it will iterate forever
2. Python doesn't allow it because it would raise a `StopIteration` before iterating even once
3. There is no output because it raises a `StopIteration`, which is caught by the `for` loop's internal workings
4. It will work as expected, and the loop will count down from the `min` to the `max`

	Iterable	Iterator
Protocol's required methods	<code>__iter__(self) -></code> <code>Iterator[T]</code> : returns an iterator	<code>__next__(self) -> T</code> : returns the next element or raises <code>StopIteration</code> <code>__iter__(self) -></code> <code>Iterator[T]</code> : returns itself
<code>abc</code> interface's required methods	<code>__iter__(self) -></code> <code>Iterator[T]</code> (same as protocol)	<code>__next__(self) -> T</code> (same as protocol) not <code>__iter__(self) -></code> <code>Iterator[T]</code> because it's already there

Modifying things while iterating over them

Lists

It is possible, though confusing / discouraged, to modify a list while iterating over it:

```
nums: list[int] = [1, 2, 3]
for i in nums:
    print(f'Element: {i}')
    print(f'Removing {nums.pop(0)}')
    print(f'List: {nums}\n')
```

```
Element: 1
Removing 1
List: [2, 3]
```

```
Element: 3
Removing 2
List: [3]
```


Instead, iterate over a copy of the list or use list comprehension:

```
nums: list[int] = [1, 2, 3]
for i in nums.copy(): # iterating over a copy
    print(f'Element: {i}')
    print(f'Removing {nums.pop(0)}')
    print(f'List: {nums}\n')

more_nums: list[int] = [1, 2, 3, 4, 5, 6]
even = [i for i in more_nums if i % 2 == 0] # list comprehension
print(even)
```

Modifying things while iterating over them

Sets and dictionaries

Modifying a set or a dictionary while iterating over it will result in a `RuntimeError`.

```
nums = {1, 2, 3, 4, 5}
for item in nums:
    nums.add(600) # RuntimeError
```

```
my_dict = {'a': 1, 'b': 2, 'c': 3}
for key in my_dict:
    my_dict['d'] = 4 # RuntimeError
```

Though it's discouraged, and the linter complains about it, we can directly call `__iter__()` in any iterable object, and `__next__()` in any iterator object.

Poll: What happens if we iterate through all items in the collection, and then call `__next__()` after that?

```
iterator: Iterator[int] = range(4).__iter__()  
print(iterator.__next__())  
print(iterator.__next__())  
print(iterator.__next__())  
print(iterator.__next__())  
print(iterator.__next__())
```

1. `__next__()` returns `None`
2. It goes back to the beginning and iterates through the collection again
3. It raises a `RuntimeError`
4. It raises a `StopIteration`

Another thing we can't do by default...

```
numbers = [20, 10, 30]
print(sorted(numbers))
```

```
numbers = [INTERable(20), INTERable(10), INTERable(30)]
print(sorted(numbers))
```

```
[10, 20, 30]
Traceback (most recent call last):
File "/Users/rasikabhalerao/2025Fall/2100/Lectures/l25/l25.py", line 34, in <module>
    print(sorted(numbers))
          ^^^^^^^^^^^^^^^
TypeError: '<' not supported between instances of 'INTERable' and 'INTERable'
```

Where we're headed...

```
class INTERable(Iterable[int]):
    def __init__(self, number: int) -> None:
        self.number = number

    def __iter__(self) -> Iterator[int]:
        return INTERator(self.number)

    def __repr__(self) -> str:
        return f"{self.number}"

    def __lt__(self, other: "INTERable") -> bool:
        return self.number < other.number

    def __eq__(self, other: object) -> bool:
        if not isinstance(other, INTERable):
            return NotImplemented
        return self.number == other.number
```

```
numbers = [
    INTERable(20),
    INTERable(10),
    INTERable(30)
]
print(sorted(numbers))
```

```
[10, 20, 30]
```

Comparable protocol (and no interface)

- `__eq__(self, other: object) -> bool`: equals `==`
- `__ne__(self, other: object) -> bool`: not equals `!=`
- `__lt__(self, other: object) -> bool`: less than `<`
- `__le__(self, other: object) -> bool`: less than or equal to `<=`
- `__gt__(self, other: object) -> bool`: greater than `>`
- `__ge__(self, other: object) -> bool`: greater than or equal to `>=`

Don't need all six

Common: Implement `__eq__()` and one ordering method like `__lt__()`

Exercise: Let's write a class for a Plant. Plant are bigger if they get more sunlight.

```
class Plant:
    def __init__(self) -> None:
        self.sunlight_hours = 0

    def get_sunlight(self) -> None:
        self.sunlight_hours += 1

    def __eq__(self, other: object) -> bool:
        if not isinstance(other, Plant):
            raise NotImplementedError
        return self.sunlight_hours == other.sunlight_hours

    def __lt__(self, other: object) -> bool:
        if not isinstance(other, Plant):
            raise NotImplementedError
        return self.sunlight_hours < other.sunlight_hours

plant1 = Plant()
plant2 = Plant()

plant1.get_sunlight()
```

Poll: What goes in the ??? ?

```
class Bouquet:
    """Bouquets are compared by the number of flowers in them"""
    def __init__(self, flowers: list[Flower]):
        self.flowers = flowers

    def __eq__(self, other: object) -> bool:
        if not isinstance(other, Bouquet):
            raise NotImplementedError
        return ???

    def __gt__(self, other: object) -> bool:
        if not isinstance(other, Bouquet):
            raise NotImplementedError
        return ???
```

1. `len(self.flowers) == len(other.flowers)` and `len(self.flowers) < len(other.flowers)`
2. `len(self.flowers) == len(other.flowers)` and `len(self.flowers) > len(other.flowers)`
3. `len(self.flowers) != len(other.flowers)` and `len(self.flowers) < len(other.flowers)`
4. `len(self.flowers) != len(other.flowers)` and `len(self.flowers) > len(other.flowers)`

Poll:

- 1. What is your main takeaway from today?**
- 2. What would you like to revisit next time?**