Iterators
Class outline:

• Iterators
• For loops with iterators
• Built-in functions for iterators
Reminder: Iterables

Lists, tuples, dictionaries, strings, and ranges are all iterable objects.

my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]

ranked_chocolates = ("Dark", "Milk", "White")

best_topping = "pineapple"

scores = range(1, 21)

prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
Iterators

An **iterator** is an object that provides sequential access to values, one by one.

```
iter(iterable) returns an iterator over the elements of an iterable.
next(iterator) returns the next element in an iterator.
```

toppings = ["pineapple", "pepper", "mushroom", "roasted red pepper"]
topperator = iter(toppings)
next(it)
next(it)
next(it)
next(it)
Iterators

An **iterator** is an object that provides sequential access to values, one by one.

**iter(iterable)** returns an iterator over the elements of an iterable.

**next(iterator)** returns the next element in an iterator.

toppings = ['pineapple', 'pepper', 'mushroom', 'roasted red pepper']

topperator = iter(toppings)
next(iter)  # 'pineapple'
next(iter)  # 'pepper'
next(iter)  # 'mushroom'
next(iter)  # 'roasted red pepper'
next(iter)
Iterators

An **iterator** is an object that provides sequential access to values, one by one.

- `iter(iterable)` returns an iterator over the elements of an iterable.
- `next(iterator)` returns the next element in an iterator.

```python
toppings = ['pineapple', 'pepper', 'mushroom', 'roasted red pepper']

topperator = iter(toppings)
next(iter)  # 'pineapple'
next(iter)  # 'pepper'
next(iter)  # 'mushroom'
next(iter)  # 'roasted red pepper'
next(iter)  # ❌ StopIteration exception
```
A useful detail

Calling `iter()` on an iterator just returns the iterator:

```python
callables = ["一つ", "二つ", "三つ"]
num_iter = iter(callables)
num_iter2 = iter(num_iter)

assert num_iter is num_iter2
```
Making iterators for iterables

iter() can return an iterator for any iterable object.

```python
my_order = ['Yuca Shepherds Pie', 'Pão de queijo', 'Guaraná']
order_iter = iter(my_order)
next(order_iter)

ranked_chocolates = ('Dark', 'Milk', 'White')
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)

best_topping = 'pineapple'
topping_iter = iter(best_topping)
next(topping_iter)

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```
iter() can return an iterator for any iterable object.

```python
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter)

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```
Making iterators for iterables

\texttt{iter()} can return an iterator for any iterable object.

```python
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)  # "Dark"

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter)

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```
iter() can return an iterator for any iterable object.

```python
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)  # "Dark"

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter)  # "p"

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```
Making iterators for iterables

*iter()* can return an iterator for any iterable object.

```python
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)  # "Dark"

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter)  # "p"

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)  # 1
```
Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:
```
price_iter = iter(prices.keys())
next(price_iter)
```

An iterator for the values:
```
price_iter = iter(prices.values())
next(price_iter)
```

An iterator for key/value tuples:
```
price_iter = iter(prices.items())
next(price_iter)
```
Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:

```
price_iter = iter(prices.keys())
next(price_iter)  # "pineapple"
```

An iterator for the values:

```
price_iter = iter(prices.values())
next(price_iter)
```

An iterator for key/value tuples:

```
price_iter = iter(prices.items())
next(price_iter)
```
Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```python
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:

```python
price_iter = iter(prices.keys())
next(price_iter)  # "pineapple"
```

An iterator for the values:

```python
price_iter = iter(prices.values())
next(price_iter)  # 9.99
```

An iterator for key/value tuples:

```python
price_iter = iter(prices.items())
next(price_iter)
```
Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:

```
price_iter = iter(prices.keys())
next(price_iter)  # "pineapple"
```

An iterator for the values:

```
price_iter = iter(prices.values())
next(price_iter)  # 9.99
```

An iterator for key/value tuples:

```
price_iter = iter(prices.items())
next(price_iter)  # ("pineapple", 9.99)
```
For loops
For loop execution

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

1. Python evaluates `<expression>` to make sure it's iterable.
2. Python gets an iterator for the iterable.
3. Python gets the next value from the iterator and assigns to `<name>`.
4. Python executes `<suite>`.
5. Python repeats until it sees a StopIteration error.

```
iterator = iter(<expression>)
try:
    while True:
        <name> = next(iterator)
        <suite>
except StopIteration:
    pass
```
Iterating over iterables

A standard for-in loop on an iterable will iterate through all the items from start to finish.

```python
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
for item in my_order:
    print(item)
lowered = [item.lower() for item in my_order]

ranked_chocolates = ("Dark", "Milk", "White")
for chocolate in ranked_chocolates:
    print(chocolate)

prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
for product in prices:
    print(product, " costs ", prices[product])
discounted = {item: prices[item] * 0.75 for item in prices}

best_topping = "pineapple"
for letter in best_topping:
    print(letter)
```
For loop with iterator

When used in a for loop, Python will call `next()` on the iterator in each iteration:

```python
nums = range(1, 4)
num_iter = iter(nums)
for num in num_iter:
    print(num)
```
For loops with used-up iterators

```python
nums = range(1, 4)
num_iter = iter(nums)
first = next(num_iter)

for num in num_iter:
    print(num)
```
For loops with used-up iterators

```python
nums = range(1, 4)
num_iter = iter(nums)
first = next(num_iter)

for num in num_iter:
    print(num)
```

Iterators are mutable! Once the iterator moves forward, it won't return the values that came before.

```python
nums = range(1, 4)
sum = 0
num_iter = iter(nums)

for num in num_iter:
    print(num)

for num in num_iter:
    sum += num
```
Use cases for iterators
Reasons for using iterators

A code that processes an iterator using `iter()` or `next()` makes few assumptions about the data itself.

- Changing the data storage from a list to a tuple, map, or dict doesn't require rewriting code.
- Others are more likely to be able to use your code on their data.

An iterator **bundles together a sequence and a position** with the sequence in a single object.

- Passing that object to another function always retains its position.
- Ensures that each element of the sequence is only processed once.
- Limits the operations that can be performed to only calling `next()`.
Blackjack demo

Player

Dealer
Blackjack demo

Player

Dealer
Blackjack demo

Player

Dealer
Blackjack demo

Player

Dealer
Blackjack demo

Player

Dealer
Blackjack demo

Player

Dealer
Blackjack demo

Player

Dealer
Blackjack demo

Player

Dealer
Useful built-in functions
Functions that return iterables

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>list(iterable)</code></td>
<td>Returns a list containing all items in <code>iterable</code></td>
</tr>
<tr>
<td><code>tuple(iterable)</code></td>
<td>Returns a tuple containing all items in <code>iterable</code></td>
</tr>
<tr>
<td><code>sorted(iterable)</code></td>
<td>Returns a sorted list containing all items in <code>iterable</code></td>
</tr>
</tbody>
</table>
# Functions that return iterators

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>reversed(sequence)</td>
<td>Iterate over item in sequence in reverse order</td>
</tr>
<tr>
<td></td>
<td><em>(See example in PythonTutor)</em></td>
</tr>
<tr>
<td>zip(*iterables)</td>
<td>Iterate over co-indexed tuples with elements from each of the iterables</td>
</tr>
<tr>
<td></td>
<td><em>(See example in PythonTutor)</em></td>
</tr>
<tr>
<td>map(func, iterable, ...)</td>
<td>Iterate over func(x) for x in iterable</td>
</tr>
<tr>
<td></td>
<td>Same as [func(x) for x in iterable]</td>
</tr>
<tr>
<td></td>
<td><em>(See example in PythonTutor)</em></td>
</tr>
<tr>
<td>filter(func, iterable)</td>
<td>Iterate over x in iterable if func(x)</td>
</tr>
<tr>
<td></td>
<td>Same as [x for x in iterable if func(x)]</td>
</tr>
<tr>
<td></td>
<td><em>(See example in PythonTutor)</em></td>
</tr>
</tbody>
</table>
Built-in map function

map(func, iterable): Applies \texttt{func(x)} for \texttt{x} in \texttt{iterable} and returns an \texttt{iterator}

```python
def double(num):
    return num * 2

for num in map(double, [1, 2, 3]):
    print(num)

for word in map(lambda text: text.lower(), ["SuP", "HELLO", "Hi"])�:
    print(word)
```
Built-in map function

map(func, iterable): Applies `func(x)` for `x` in `iterable` and returns an `iterator`

```python
def double(num):
    return num * 2

for num in map(double, [1, 2, 3]):
    print(num)
```

```python
for word in map(lambda text: text.lower(), ["SuP", "HELLO", "Hi"])�
    print(word)
```

Turn the iterator into a list using `list()`

```python
doubled = list(map(double, [1, 2, 3]))
lowered = list(map(lambda text: text.lower(), ["SuP", "HELLO", "Hi"]))
```
Exercise: Termified

Let's implement this without using a list comprehension.

def termified(n, term):
    """Returns every the result of calling TERM on each element in the range from 0 to N (inclusive).
    """
    >>> termified(5, lambda x: 2 ** x)
    [1, 2, 4, 8, 16, 32]
    """
Exercise: Termified (solution)

Using map:

```python
def termified(n, term):
    """Returns every the result of calling TERM on each element in the range from 0 to N (inclusive).
    """
    return list(map(term, range(n + 1)))

>>> termified(5, lambda x: 2 ** x)
[1, 2, 4, 8, 16, 32]
```

def termified(n, term):
    """Returns every the result of calling TERM on each element in the range from 0 to N (inclusive).
    """
    return list(map(term, range(n + 1)))

>>> termified(5, lambda x: 2 ** x)
[1, 2, 4, 8, 16, 32]

Compare to list comprehension version:

def termified(n, term):
    return [term(x) for x in range(n + 1)]
**Built-in filter function**

*filter(func, iterable)*: Returns an iterator from the items of *iterable* where *func(item)* is true.

```python
def is_fourletterword(text):
    return len(text) == 4

for word in filter(is_fourletterword, ['braid', 'bode', 'brand', 'band']):
    print(word)

for num in filter(lambda x: x % 2 == 0, [1, 2, 3, 4]):
    print(num)
```
Built-in filter function

`filter(func, iterable)`: Returns an iterator from the items of `iterable` where `func(item)` is true.

```python
def is_fourletterword(text):
    return len(text) == 4

for word in filter(is_fourletterword, ['braid', 'bode', 'brand', 'band']):
    print(word)
```

```python
for num in filter(lambda x: x % 2 == 0, [1, 2, 3, 4]):
    print(num)
```

Turn the iterator into a list using `list()`

```python
filtered = list(is_fourletterword, ['braid', 'bode', 'brand', 'band']))
evens = list(filter(lambda x: x % 2 == 0, [1, 2, 3, 4]))
```
def divisors(n):
    """Returns all the divisors of N."

    >>> divisors(12)
    [1, 2, 3, 4, 6]
    """
Exercise: Divisors (solution)

Using filter:

```python
def divisors(n):
    """Returns all the divisors of N."
    return list(filter(lambda x: n % x == 0, range(1, n)))
```

```bash
>>> divisors(12)
[1, 2, 3, 4, 6]
"""
```
Exercise: Divisors (solution)

Using filter:

```python
def divisors(n):
    """Returns all the divisors of N."
    
    >>> divisors(12)
    [1, 2, 3, 4, 6]
    """
    return list(filter(lambda x: n % x == 0, range(1, n)))
```

Compare to list comprehension version:

```python
def divisors(n):
    return [x for x in range(1, n) if n % x == 0]
```
Built-in zip function

`zip(*iterables)`: Returns an iterator that aggregates elements from each of the iterables into co-indexed pairs

```python
# From:
["one", "two", "three"]
["uno", "dos", "tres"]
```
Built-in zip function

`zip(*iterables)`: Returns an `iterator` that aggregates elements from each of the `iterables` into co-indexed pairs

```
# From:           # To:
["one", "two", "three"]  -->  ("one", "uno")  ("two", "dos")  ("three", "tres")
["uno", "dos", "tres"]
```
**Built-in zip function**

`zip(*iterables)`: Returns an **iterator** that aggregates elements from each of the **iterables** into co-indexed pairs

```python
# From:
['one', 'two', 'three']
['uno', 'dos', 'tres']

# To:
('one', 'uno') ('two', 'dos') ('three', 'tres')
```

```python
inglish_nums = ['one', 'two', 'three']
spanish_nums = ['uno', 'dos', 'tres']

zip_iter = zip(english_nums, spanish_nums)
english, spanish = next(zip_iter)
print(english, spanish)

for english, spanish in zip(english_nums, spanish_nums):
    print(english, spanish)
```

Turn the iterator into a list using **list()**

```python
zipped = list(zip(english_nums, spanish_nums))
```
def matches(a, b):
    """Return the number of values k such that A[k] == B[k]."
    
    >>> matches([1, 2, 3, 4, 5], [3, 2, 3, 0, 5])
    3
    >>> matches("abdomens", "indolence")
    4
    >>> matches("abcd", "dcba")
    0
    >>> matches("abcde", "edcba")
    1
    >>> matches("abcdefg", "edcba")
    1
    """
Exercise: matches (solution)

```python
def matches(a, b):
    """Return the number of values k such that A[k] == B[k]."
    >>> matches([1, 2, 3, 4, 5], [3, 2, 3, 0, 5])
    3
    >>> matches("abdomens", "indolence")
    4
    >>> matches("abcd", "dcba")
    0
    >>> matches("abcde", "edcba")
    1
    >>> matches("abcdefg", "edcba")
    1
    """
```

def list_o_lists(n):
    """Assuming \( N \geq 0 \), return the list consisting of \( N \) lists:
    \([1]\), \([1, 2]\), \([1, 2, 3]\), \ldots \([1, 2, \ldots, N]\).
    >>> list_o_lists(0)
    []
    >>> list_o_lists(1)
    [[1]]
    >>> list_o_lists(5)
    [[1], [1, 2], [1, 2, 3], [1, 2, 3, 4], [1, 2, 3, 4, 5]]
    """
def list_o_lists(n):
    """Assuming N >= 0, return the list consisting of N lists:
    [1], [1, 2], [1, 2, 3], ... [1, 2, ... N].
    >>> list_o_lists(0)
    []
    >>> list_o_lists(1)
    [[1]]
    >>> list_o_lists(5)
    [[1], [1, 2], [1, 2, 3], [1, 2, 3, 4], [1, 2, 3, 4, 5]]
    """
    return [list(range(1, i + 1)) for i in range(1, n+1)]
def palindrome(s):
    """Return whether s is the same sequence backward and forward."

    >>> palindrome([3, 1, 4, 1, 5])
    False
    >>> palindrome([3, 1, 4, 1, 3])
    True
    >>> palindrome('seveneves')
    True
    >>> palindrome('seven eves')
    False
    """
def palindrome(s):
    """Return whether s is the same sequence backward and forward."
    return all([a == b for a, b in zip(s, reversed(s))])
    # OR
    return list(s) == list(reversed(s))
Icon project
Icon design

main.py
- Creates an Icon and displays in DisplayFrame.

icon.py
- Icon
- Pixel
- Color
- Defines classes for icon + parts.

display_frame.py
- DisplayFrame
- Defines class for displaying icon on canvas.
An OOP Icon

Goal: Use OOP to represent an Icon with pixels at a particular location with a particular color.

![Icon and Pixel Diagram]

- x = 7
- y = 0
- r = 255
- g = 0
- b = 0
The Color class

class Color:
    
def __init__(self, r, g, b):
        self.r = r
        self.g = g
        self.b = b
    
def __repr__(self):
        return f"Color({self.r},{self.g},{self.b})"
    
def to_hex(self):
        return f"#{self.r:02x}{self.g:02x}{self.b:02x}"

red = Color(255, 0, 0)
print(red.to_hex())
class Pixel:
    def __init__(self, x, y, r, g, b):
        self.x = x
        self.y = y
        self.color = Color(r, g, b)

    def __repr__(self):
        return f'Pixel({self.x},{self.y},{self.color})'

pixel = Pixel(0, 7, 255, 0, 0)
print(pixel.color.to_hex())
class Icon:
    
def __init__(self, width, height, pixels=None):
        self.width = width
        self.height = height
        self.pixels = pixels
        if not self.pixels:
            self.pixels = [Pixel(x, y, 0, 0, 0) for x in range(width) for y in range(height)]

    def __repr__(self):
        pixels = "".join([repr(pixel) for pixel in self.pixels])
        return f"Icon({self.width}, {self.height}, {self.pixels})"

icon = Icon(2, 2, [Pixel(0, 0, 255, 0, 0),
                   Pixel(0, 1, 255, 50, 0),
                   Pixel(1, 0, 255, 100, 0),
                   Pixel(1, 1, 255, 150, 0)])

for pixel in icon.pixels:
    pixel.color.g += 50
from tkinter import Canvas, Frame, BOTH, font

class DisplayFrame(Frame):
    def __init__(self):
        super().__init__()
        self.pack(fill=BOTH, expand=1)
        self.canvas = Canvas(self)
        self.canvas.pack(fill=BOTH, expand=1)

    def draw_icon(self, icon):
        x_offset = 50
        y_offset = 50
        pixel_size = 20

        for pixel in icon.pixels:
            top_left_x = x_offset + pixel.x * pixel_size
            top_left_y = y_offset + pixel.y * pixel_size
            self.canvas.create_rectangle(top_left_x,
                                          top_left_y,
                                          top_left_x + pixel_size,
                                          top_left_y + pixel_size,
                                          outline="",
                                          fill=pixel.color.to_hex())
All together

```python
from tkinter import Tk
from icon import Icon, Pixel, Color
from display_frame import DisplayFrame

# Initialize the Tkinter frame and canvas
root = Tk()
display = DisplayFrame()
display.draw_icon(icon)

# Run Tkinter loop
root.mainloop()
```

Visit the Repl.it demo to see all the classes used with the Python tkinter package for graphics rendering.
Iterator-producing functions

What happens if we...

map the pixels?

```python
changer = lambda p: Pixel(p.x, p.y,
    p.x * 30,
    p.color.g + 30,
    p.y * 30)
icon.pixels = list(map(changer, icon.pixels))
```

filter the pixels?

```python
is_odd = lambda p: p.x % 2 == 0
icon.pixels = list(filter(is_odd, icon.pixels))
```
Iterable-processing functions

What happens if we ask for the min and max of the pixels?

\[
\text{max}\_\text{pix} = \max(\text{icon.pixels}) \\
\text{min}\_\text{pix} = \min(\text{icon.pixels})
\]
Iterable-processing functions

What happens if we ask for the min and max of the pixels?

```python
max_pix = max(icon.pixels)
min_pix = min(icon.pixels)
```

Python doesn't know how to compare `Pixel` instances!

Two options:

- Implement dunder methods (\_eq\_, \_lt\_, etc)
- Pass in a key function that returns a numerical value:

```python
rgb_adder = lambda p: p.color.r + p.color.g + p.color.b
max_pix = max(icon.pixels, key=rgb_adder)
min_pix = min(icon.pixels, key=rgb_adder)
```