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(iter)
next(iter)
next(iter)
next(iter)
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.

```
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.

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

assert num_iter is num_iter2
```

Making iterators for iterables

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

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

Making iterators for iterables

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

```
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

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

```
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)
```

Making iterators for iterables

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

```
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.

```
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.

```
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)
```

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.

```
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:

```
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.

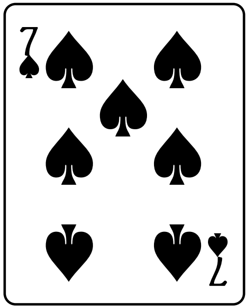
- Passing that object to another function always retains its position.
- Ensures that each element of the sequence is only processed once.
- Limits the operations that can be performed to only calling `next()`.

Blackjack demo

Player

Dealer

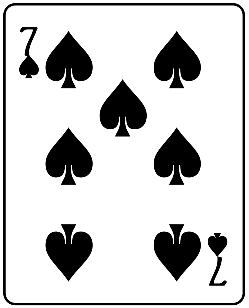
Blackjack demo



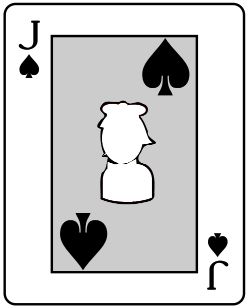
Player

Dealer

Blackjack demo

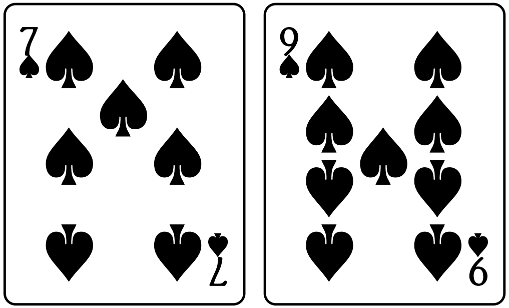


Player

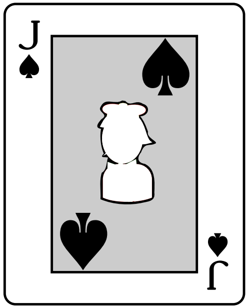


Dealer

Blackjack demo

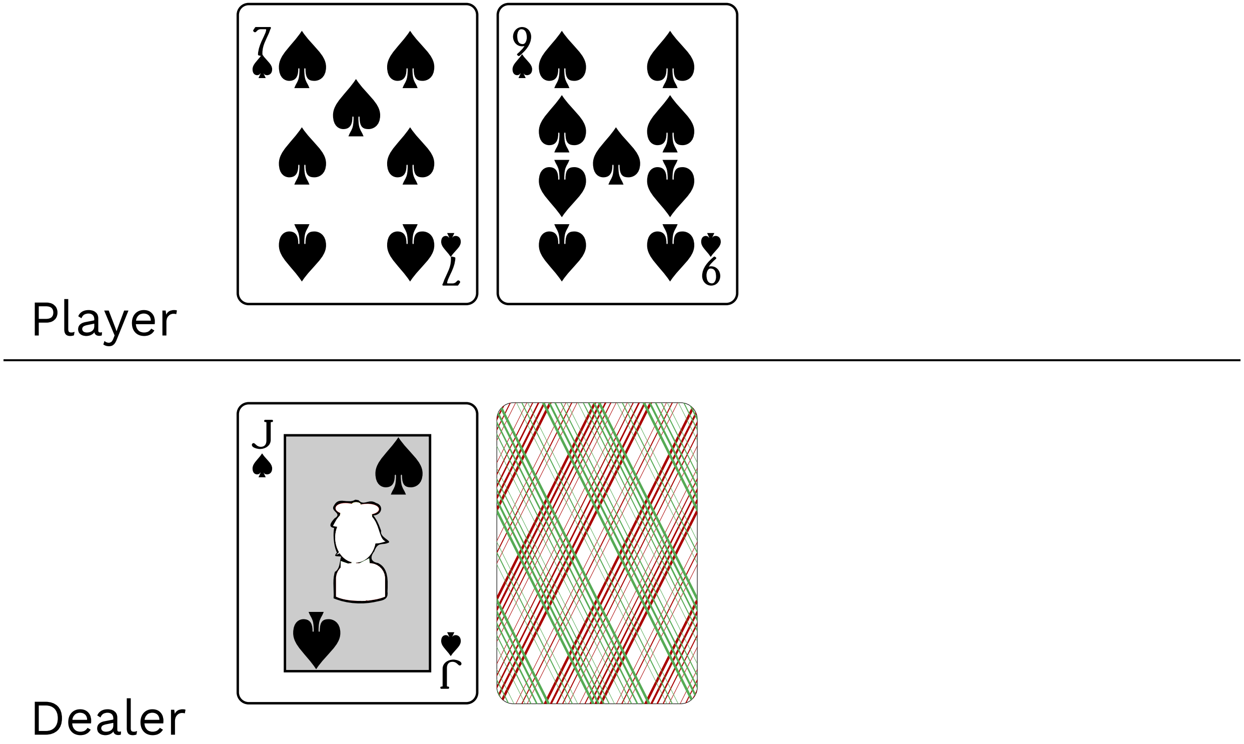


Player

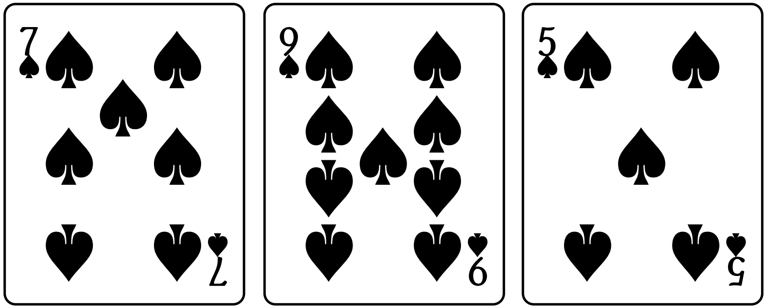


Dealer

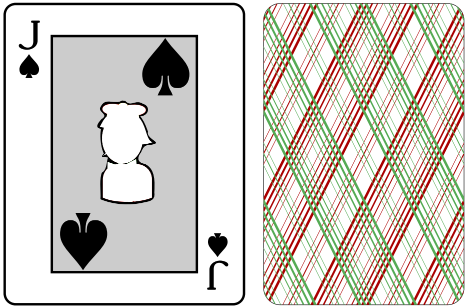
Blackjack demo



Blackjack demo

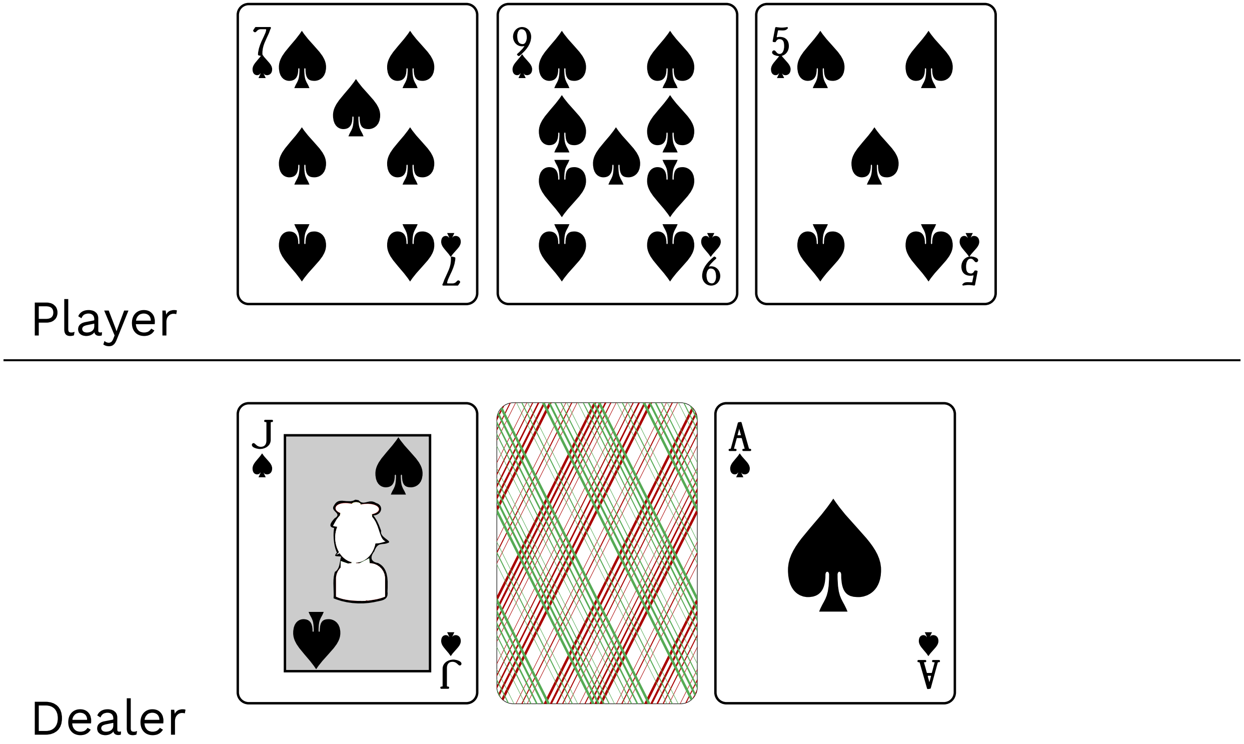


Player



Dealer

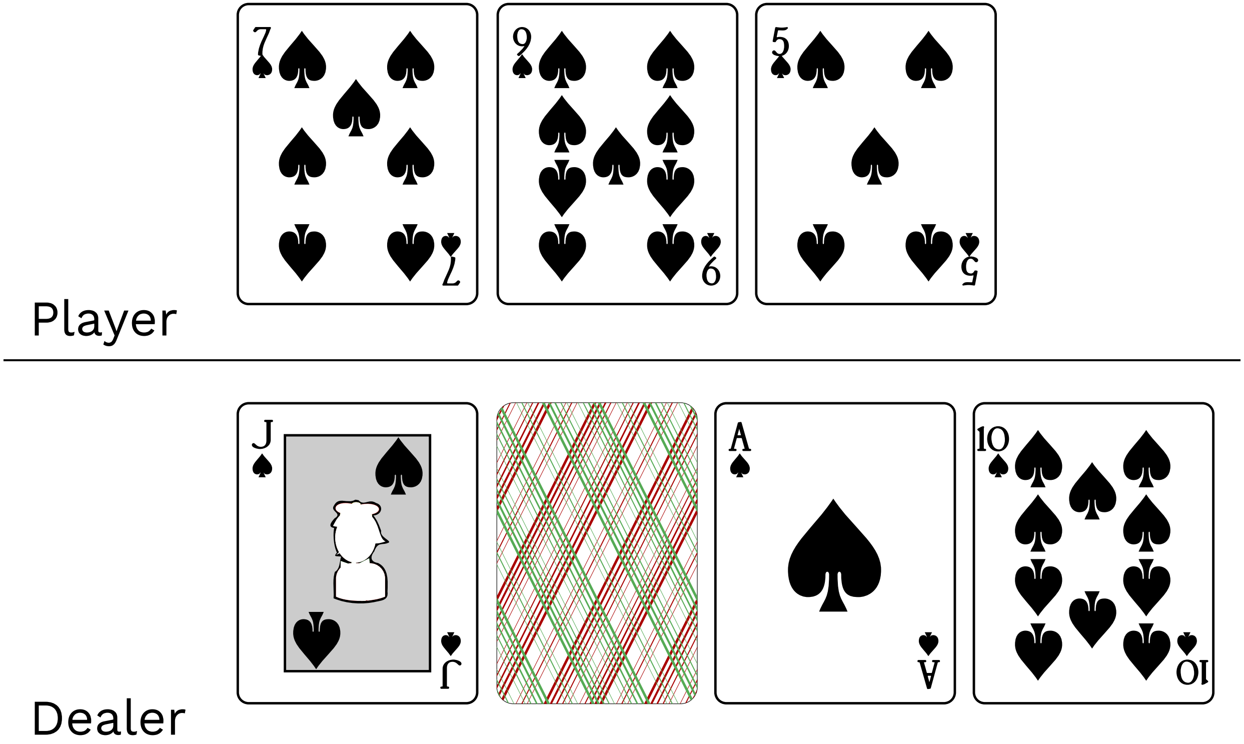
Blackjack demo



Player

Dealer

Blackjack demo



Player

Dealer

Useful built-in functions

Functions that return iterables

Function	Description
`list(iterable)`	Returns a list containing all items in `iterable`
`tuple(iterable)`	Returns a tuple containing all items in `iterable`
`sorted(iterable)`	Returns a sorted list containing all items in `iterable`

Functions that return iterators

Function	Description
`reversed(sequence)`	Iterate over item in `sequence` in reverse order (See example in PythonTutor)
`zip(*iterables)`	Iterate over co-indexed tuples with elements from each of the `iterables` (See example in PythonTutor)
`map(func, iterable, ...)`	Iterate over `func(x)` for `x` in `iterable` Same as `[func(x) for x in iterable]` (See example in PythonTutor)
`filter(func, iterable)`	Iterate over `x` in `iterable` if `func(x)` Same as `[x for x in iterable if func(x)]` (See example in PythonTutor)

Built-in map function

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

```
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`

```
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)
```

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

```
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.

```python
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:

```
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]
    """
    return list(map(term, range(n + 1)))
```

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).

    >>> termified(5, lambda x: 2 ** x)
    [1, 2, 4, 8, 16, 32]
    """
    return list(map(term, range(n + 1)))
```

Compare to list comprehension version:

```python
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)
```

```python
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.

```
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)
```

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

```
filtered = list(is_fourletterword, ["braid", "bode", "brand", "band"]))

evens = list(filter(lambda x: x % 2 == 0, [1, 2, 3, 4]))
```

Exercise: Divisors

Let's implement this without using a list comprehension.

```
def divisors(n):
    """Returns all the divisors of N.

    >>> divisors(12)
    [1, 2, 3, 4, 6]
    """
```

Exercise: Divisors (solution)

Using filter:

```
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)))
```

Exercise: Divisors (solution)

Using filter:

```
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:

```
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

```
# 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

```
# From:                    # To:
["one", "two", "three"]    --> ("one", "uno")  ("two", "dos")  ("three", "tres")
["uno", "dos", "tres"]
```

```
english_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()`

```
zipped = list(zip(english_nums, spanish_nums))
```

Exercise: matches

List comprehensions are allowed for this one...

```
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
    """
```

Exercise: List of lists

```
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]]
    """
```

Exercise: List of lists (solution)

```python
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)]
```

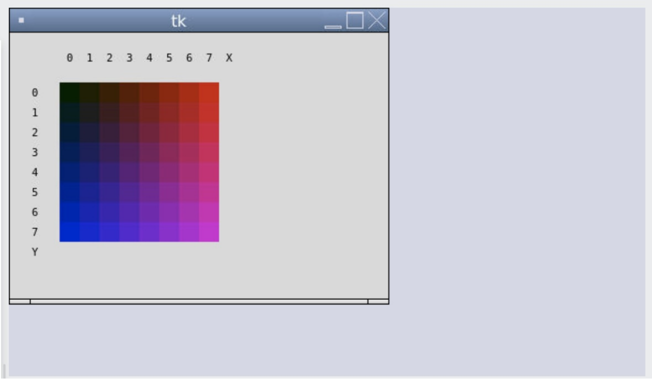
Exercise: Palindrome

```
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
    """
```

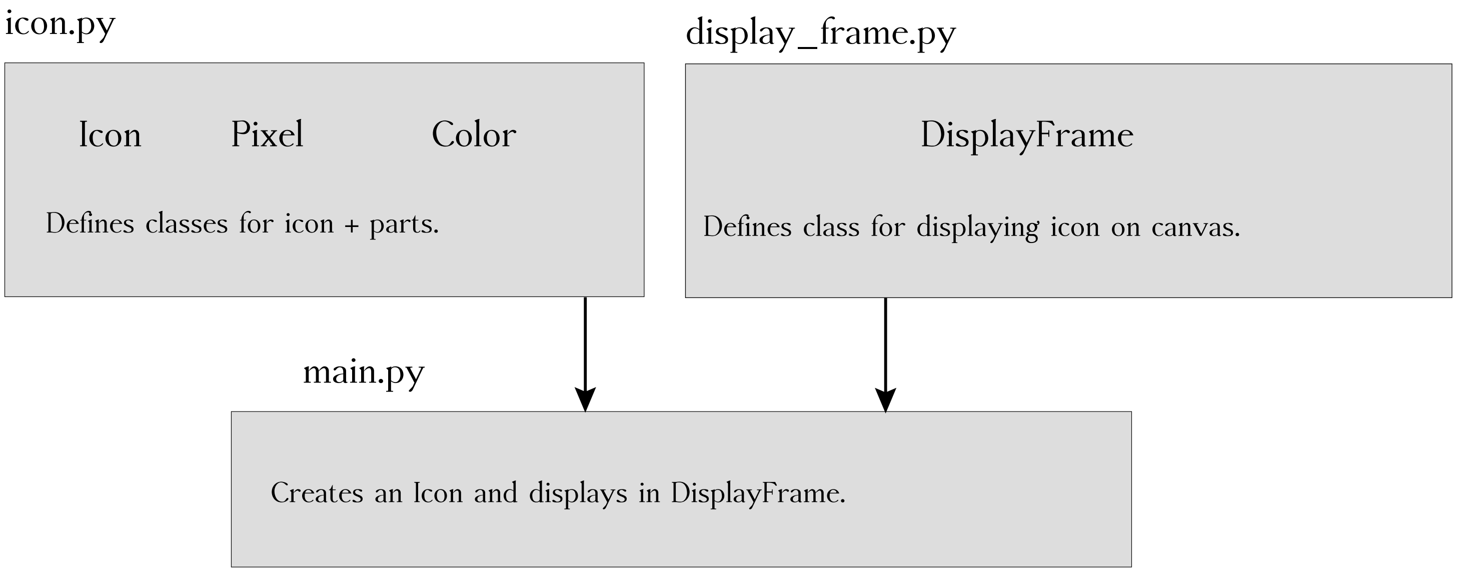
Exercise: Palindrome (solution)

```
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
    """
    return all([a == b for a, b in zip(s, reversed(s))])
    # OR
    return list(s) == list(reversed(s))
```

Icon project



Icon design



icon.py

Icon Pixel Color

Defines classes for icon + parts.

display_frame.py

DisplayFrame

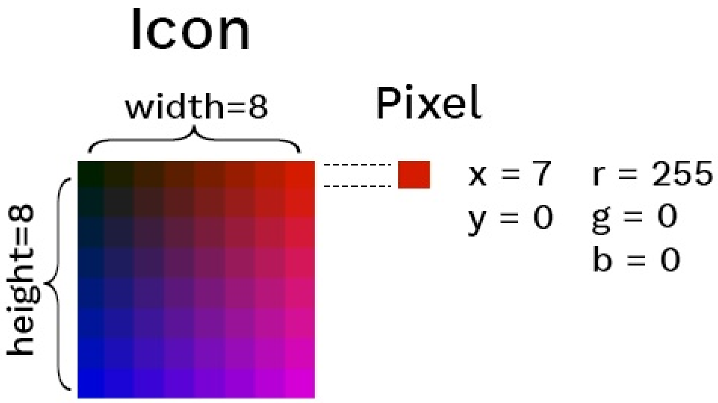
Defines class for displaying icon on canvas.

main.py

Creates an Icon and displays in DisplayFrame.

An OOP Icon

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



The Color class

```python
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}"
```

```python
red = Color(255, 0, 0)
print(red.to_hex())
```

The Pixel class

```python
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})"
```

```python
pixel = Pixel(0, 7, 255, 0, 0)
print(pixel.color.to_hex())
```

The Icon class

```
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
```

The DisplayFrame class

```
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

```
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?

```
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?

```
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?

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

Iterable-processing functions

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```
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```

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:

```
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)
```