Composition, Representation

Class outline:

- Composition
- Representation

Composition

Composition

An object can contain references to objects of other classes.

What examples of composition are in an animal conservatory?

- An animal has a mate.
- An animal has a mother.
- An animal has children.
- A conservatory has animals.

Referencing other instances

An instance variable can refer to another instance.

We can add this method to the base Animal class that adds a `mate` instance variable:

```
class Animal:

    def mate_with(self, other):
        if other is not self and other.species_name == self.species_name:
            self.mate = other
            other.mate = self
```

How would we call that method?

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            self.mate = other
            other.mate = self
```

How would we call that method?

```
mr_wabbit = Rabbit("Mister Wabbit", 3)
jane_doe = Rabbit("Jane Doe", 2)
mr_wabbit.mate_with(jane_doe)
```

Referencing a list of instances

An instance variable can also store a list of instances.

We can add this method to the Rabbit class that adds a `babies` instance variable.

```
class Rabbit(Animal):

    def reproduce_like_rabbits(self):
        if self.mate is None:
            print("oh no! better go on ZoOkCupid")
            return
        self.babies = []
        for _ in range(0, self.num_in_litter):
            self.babies.append(Rabbit("bunny", 0))
```

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How would we call that function?

```
mr_wabbit = Rabbit("Mister Wabbit", 3)
jane_doe = Rabbit("Jane Doe", 2)
mr_wabbit.mate_with(jane_doe)
jane_doe.reproduce_like_rabbits()
```

Relying on a common interface

If all instances implement a method with the same function signature, a program can rely on that method across instances of different subclasses.

```
def partytime(animals):
    """Assuming ANIMALS is a list of Animals, cause each
    to interact with all the others exactly once."""
    for i in range(len(animals)):
        for j in range(i + 1, len(animals)):
            animals[i].interact_with(animals[j])
```

How would we call that function?

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        for j in range(i + 1, len(animals)):
            animals[i].interact_with(animals[j])
```

How would we call that function?

```
jane_doe = Rabbit("Jane Doe", 2)
scar = Lion("Scar", 12)
elly = Elephant("Elly", 5)
pandy = Panda("PandeyBear", 4)
partytime([jane_doe, scar, elly, pandy])
```

Composition vs. Inheritance

Inheritance is best for representing "is-a" relationships

- Rabbit is a specific type of Animal
- So, Rabbit inherits from Animal

Composition is best for representing "has-a" relationships

- A conservatory has a collection of animals it cares for
- So, a conservatory has a list of animals as an instance variable

Objects everywhere

So many objects

What are the objects in this code?

```python
class Lamb:
    species_name = "Lamb"
    scientific_name = "Ovis aries"

    def __init__(self, name):
        self.name = name

    def play(self):
        self.happy = True

lamb = Lamb("Lil")
owner = "Mary"
had_a_lamb = True
fleece = {"color": "white", "fluffiness": 100}
kids_at_school = ["Billy", "Tilly", "Jilly"]
day = 1
```

So many objects

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    species_name = "Lamb"
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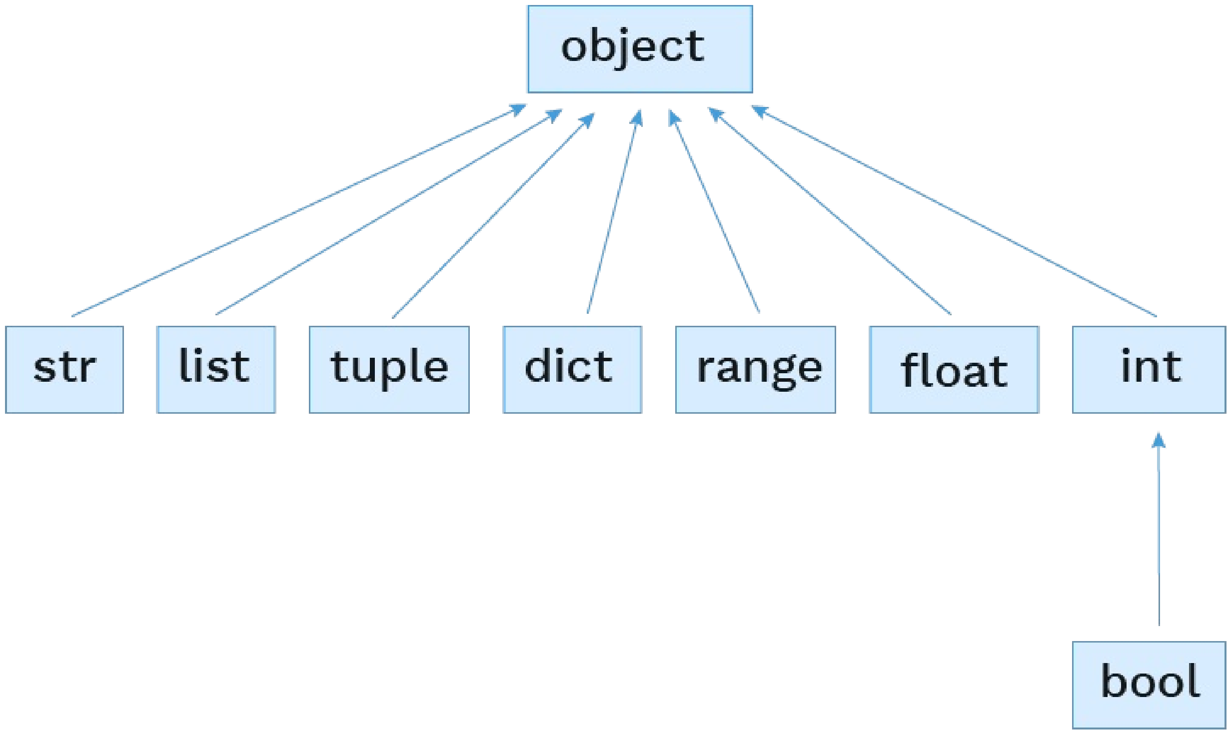
kids_at_school = ["Billy", "Tilly", "Jilly"]
day = 1
```

`lamb`, `owner`, `had_a_lamb`, `fleece`, `kids_at_school`, `day`, etc.
We can prove it by checking `object.__class__.__bases__`, which reports the base class(es) of the object's class.

It's all objects

All the built-in types inherit from `object`:



Built-in object attributes

If all the built-in types and user classes inherit from `object`, what are they inheriting?

Just ask `dir()`, a built-in function that returns a list of all the "interesting" attributes on an object.

```
dir(object)
```

Built-in object attributes

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```
dir(object)
```

- For string representation: `__repr__`, `__str__`, `__format__`
- For comparisons: `__eq__`, `__ge__`, `__gt__`, `__le__`, `__lt__`, `__ne__`
- Related to classes: `__bases__`, `__class__`, `__new__`, `__init__`, `__init_subclass__`, `__subclasshook__`, `__setattr__`, `__delattr__`, `__getattribute__`
- Others: `__dir__`, `__hash__`, `__module__`, `__reduce__`, `__reduce_ex__`

Python calls these methods behind these scenes, so we are often not aware when the "dunder" methods are being called.
Let us become enlightened!

String representation

__str__

The `__str__` method returns a human readable string representation of an object.

```
from fractions import Fraction

one_third = 1/3
one_half = Fraction(1, 2)
```

```
float.__str__(one_third)
Fraction.__str__(one_half)
```

__str__

The `__str__` method returns a human readable string representation of an object.

```
from fractions import Fraction

one_third = 1/3
one_half = Fraction(1, 2)
```

```
float.__str__(one_third)      # '0.3333333333333333'
Fraction.__str__(one_half)    # '1/2'
```

__str__ usage

The `__str__` method is used in multiple places by Python: `print()` function, `str()` constructor, f-strings, and more.

```
from fractions import Fraction

one_third = 1/3
one_half = Fraction(1, 2)
```

```
print(one_third)
print(one_half)

str(one_third)
str(one_half)

f"{one_half} > {one_third}"
```

__str__ usage

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```
from fractions import Fraction

one_third = 1/3
one_half = Fraction(1, 2)
```

```
print(one_third)              # '0.3333333333333333'
print(one_half)               # '1/2'

str(one_third)                # '0.3333333333333333'
str(one_half)                 # '1/2'

f"{one_half} > {one_third}"   # '1/2 > 0.3333333333333333'
```

Custom __str__ behavior

When making custom classes, we can override `__str__` to define our human readable string representation.

```
class Lamb:
    species_name = "Lamb"
    scientific_name = "Ovis aries"

    def __init__(self, name):
        self.name = name

    def __str__(self):
        return "Lamb named " + self.name
```

```
lil = Lamb("Lil lamb")

str(lil)

print(lil)
```

__repr__

The `__repr__` method returns a string that would evaluate to an object with the same values.

```
from fractions import Fraction

one_half = Fraction(1, 2)
Fraction.__repr__(one_half)           # 'Fraction(1, 2)'
```

If implemented correctly, calling `eval()` on the result should return back that same-valued object.

```
another_half = eval(Fraction.__repr__(one_half))
```

__repr__ usage

The `__repr__` method is used multiple places by Python: when `repr(object)` is called and when displaying an object in an interactive Python session.

```
from fractions import Fraction

one_third = 1/3
one_half = Fraction(1, 2)
```

```
one_third
one_half
repr(one_third)
repr(one_half)
```

Custom __repr__ behavior

When making custom classes, we can override `__repr__` to return a more appropriate Python representation.

```
class Lamb:
    species_name = "Lamb"
    scientific_name = "Ovis aries"

    def __init__(self, name):
        self.name = name

    def __str__(self):
        return "Lamb named " + self.name

    def __repr__(self):
        return f"Lamb({repr(self.name)})"
```

```
lil = Lamb("Lil lamb")
repr(lil)
lil
```

The rules of repr and str

When the `repr(obj)` function is called:

- Python calls the `ClassName.__repr__` method if it exists.
- If `ClassName.__repr__` does not exist, Python will look up the chain of parent classes until it finds one with `__repr__` defined.
- If all else fails, `object.__repr__` will be called.

When the `str(obj)` class constructor is called:

- Python calls the `ClassName.__str__` method if it exists.
- If no `__str__` method is found on that class, Python calls `repr()` on the object instead.
- ↑ See above!

Special methods

Special methods

Special methods have built-in behavior. Special method names always start and end with double underscores.

Name	Behavior
`__init__`	Method invoked automatically when an object is constructed
`__repr__`	Method invoked to display an object as a Python expression
`__str__`	Method invoked to stringify an object
`__add__`	Method invoked to add one object to another
`__bool__`	Method invoked to convert an object to True or False
`__float__`	Method invoked to convert an object to a float (real number)

See all special method names.

Special method examples

```
zero = 0
one = 1
two = 2
```

Standard approach	Dunder equivalent
`one + two # 3`	`one.__add__(two) # 3`
`bool(zero) # False`	`zero.__bool__() # False`
`bool(one)  # True`	`one.__bool__()  # True`

Adding together custom objects

Consider the following class:

```
from math import gcd

class Rational:
    def __init__(self, numerator, denominator):
        g = gcd(numerator, denominator)
        self.numer = numerator // g
        self.denom = denominator // g

    def __str__(self):
        return f"{self.numer}/{self.denom}"

    def __repr__(self):
        return f"Rational({self.numer}, {self.denom})"
```

Will this work?

```
Rational(1, 2) + Rational(3, 4)
```

Adding together custom objects

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class Rational:
    def __init__(self, numerator, denominator):
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    def __str__(self):
        return f"{self.numer}/{self.denom}"

    def __repr__(self):
        return f"Rational({self.numer}, {self.denom})"
```

Will this work?

```
Rational(1, 2) + Rational(3, 4)
```

TypeError: unsupported operand type(s) for +: 'Rational' and 'Rational'

Implementing dunder methods

We can make instances of custom classes addable by defining the `__add__` method:

```
class Rational:
    def __init__(self, numerator, denominator):
        g = gcd(numerator, denominator)
        self.numer = numerator // g
        self.denom = denominator // g

    def __add__(self, other):




    # The rest...
```

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    def __init__(self, numerator, denominator):
        g = gcd(numerator, denominator)
        self.numer = numerator // g
        self.denom = denominator // g

    def __add__(self, other):
        new_numer = self.numer * other.denom + other.numer * self.denom
        new_denom = self.denom * other.denom
        return Rational(new_numer, new_denom)

    # The rest...
```

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    def __add__(self, other):
        new_numer = self.numer * other.denom + other.numer * self.denom
        new_denom = self.denom * other.denom
        return Rational(new_numer, new_denom)

    # The rest...
```

Now try...

```
Rational(1, 2) + Rational(3, 4)
```

Polymorphism

Polymorphic functions

Polymorphic function: A function that applies to many (poly) different forms (morph) of data

`str` and `repr` are both polymorphic; they apply to any object.

```
repr(1/3)            # '0.3333333333333333'
repr(Rational(1, 3)) # 'Rational(1, 3)'
```

```
str(1/3)            # '0.3333333333333333'
str(Rational(1, 3)) # '1/3'
```

The class of that object can customize the per-object behavior using `__str__` and `__repr__`.

Generic functions

A **generic function** can apply to arguments of different types.

```
def sum_two(a, b):
    return a + b
```

What could `a` and `b` be?

The function `sum_two` is **generic** in the type of `a` and `b`.

Generic functions

A **generic function** can apply to arguments of different types.

```
def sum_two(a, b):
    return a + b
```

What could `a` and `b` be? Anything summable!

The function `sum_two` is **generic** in the type of `a` and `b`.

Generic function #2

```
def sum_em(items, initial_value):
    """Returns the sum of ITEMS,
    starting with a value of INITIAL_VALUE."""
    sum = initial_value
    for item in items:
        sum += item
    return sum
```

What could `items` be?

What could `initial_value` be?

The function `sum_em` is **generic** in the type of `items` and the type of `initial_value`.

Generic function #2

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def sum_em(items, initial_value):
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```

What could `items` be? Any iterable with summable values.

What could `initial_value` be?

The function `sum_em` is **generic** in the type of `items` and the type of `initial_value`.

Generic function #2

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def sum_em(items, initial_value):
    """Returns the sum of ITEMS,
    starting with a value of INITIAL_VALUE."""
    sum = initial_value
    for item in items:
        sum += item
    return sum
```

What could `items` be? Any iterable with summable values.

What could `initial_value` be? Any value that can be summed with the values in iterable.

The function `sum_em` is **generic** in the type of `items` and the type of `initial_value`.

Type dispatching

Another way to make generic functions is to select a behavior based on the type of the argument.

```
def is_valid_month(month):
    if isinstance(month, int):
        return month >= 1 and month <= 12
    elif isinstance(month, str):
        return month in ["January", "February", "March", "April",
                         "May", "June", "July", "August", "Septembe
                         "October", "November", "December"]
    return false
```

What could `month` be?

The function `is_valid_month` is **generic** in the type of `month`.

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```
def is_valid_month(month):
    if isinstance(month, int):
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    elif isinstance(month, str):
        return month in ["January", "February", "March", "April",
                         "May", "June", "July", "August", "September
                         "October", "November", "December"]
    return false
```

What could `month` be? Either an int or string.

The function `is_valid_month` is **generic** in the type of `month`.

Type coercion

Another way to make generic functions is to coerce an argument into the desired type.

```
def sum_numbers(nums):
    """Returns the sum of NUMS"""
    sum = Rational(0, 0)
    for num in nums:
        if isinstance(num, int):
            num = Rational(num, 1)
        sum += num
    return sum
```

What could `nums` be?

The function `sum_numbers` is **generic** in the type of `nums`.

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    for num in nums:
        if isinstance(num, int):
            num = Rational(num, 1)
        sum += num
    return sum
```

What could `nums` be? Any iterable with ints or Rationals.

The function `sum_numbers` is **generic** in the type of `nums`.