Representation

Class outline:

- String formatting
- repr/str representation
- Special method names
- Polymorphism
- Generics

String formatting

String concatenation

So far, we've been using the + operator for combining string literals with the results of expressions.

```
artist = "Lil Nas X"
song = "Industry Baby"
place = 2

print("Debuting at #" + str(place) + ": '" + song + "' by " + artist)
```

But that's not ideal:

- Easy to bungle up the + signs
- Hard to grok what the final string will be
- Requires explicitly `str()`ing non-strings

String interpolation

String interpolation is the process of combining string literals with the results of expressions.

Available since Python 3.5, **f strings** (formatted string literals) are the best way to do string interpolation.

Just put an `f` in front of the quotes and then put any valid Python expression in curly brackets inside:

```
artist = "Lil Nas X"
song = "Industry Baby"
place = 2

print(f"Debuting at #{place}: '{song}' by {artist}")
```

😍😍😍😍😍😍

Expressions in f strings

Any valid Python expression can go inside the parentheses, and will be executed in the current environment.

```
greeting = 'Ahoy'
noun = 'Boat'

print(f"{greeting.lower()}, {noun.upper()}yMc{noun}Face")

print(f"{greeting*3}, {noun[0:3]}yMc{noun[-1]}Face")
```

Objects

So many objects

What are the objects in this code?

```
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
```

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    species_name = "Lamb"
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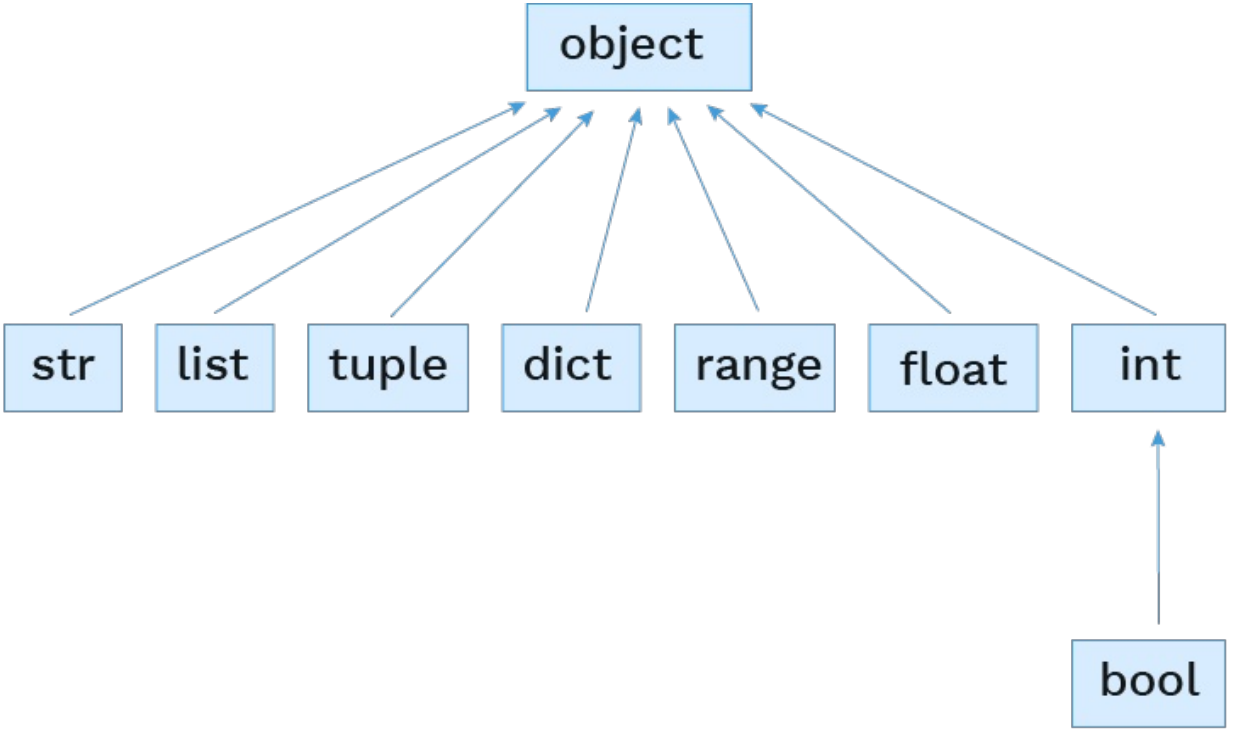
fleece = {"color": "white", "fluffiness": 100}
kids_at_school = ["Billy", "Tilly", "Jilly"]
day = 1
```

`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 attributes on an object.

```
dir(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 attributes on an object.

```
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

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)              # '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
```

Special methods

Special methods

Certain names are special because they have built-in behavior. Those 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
```

Syntactic sugar	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

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)
```

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...
```

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

    # The rest...
```

Implementing dunder methods

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```
class Rational:
    def __init__(self, numerator, denominator):
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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` invokes a zero-argument method __repr__ on its argument:

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

`str` invokes a zero-argument method __str__ on its argument:

```
one_half = Rational(1, 2)
one_half.__str__() # '1/2'
```

Implementing repr and str

The behavior of `repr` is slightly more complicated than invoking `__repr__` on its argument:

- An instance attribute called `__repr__` is ignored! Only class attributes are found
- Poll: How could we implement this behavior?

Implementing repr and str

The behavior of `repr` is slightly more complicated than invoking `__repr__` on its argument:

- An instance attribute called `__repr__` is ignored! Only class attributes are found
- Poll: How could we implement this behavior?

The behavior of `str` is also complicated:

- An instance attribute called `__str__` is ignored
- If no `__str__` attribute is found, uses `repr` string
- (By the way, `str` is a class, not a function)
- Demo: How would we implement this behavior?

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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    starting with a value of INITIAL_VALUE."""
    sum = initial_value
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        sum += item
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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, str) and len(str) == 1:
        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`.

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):
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    if isinstance(month, int):
        return month >= 1 and month <= 12
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        return month in ["January", "February", "March", "April",
                         "May", "June", "July", "August", "Septembe
                         "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`.

Type coercion

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

```
def sum_numbers(nums):
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    sum = Rational(0, 0)
    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`.

Python Project of The Day!

ASCIIfy

ASCIIfy: A Python script to turn an image into an ASCII string, using the Python pillow library.