Object-Oriented Python

May 2, 2017

Overview

Overview

Recap of FP

Classes

Instances

Inheritance

Magic Methods

Exceptions

Recap from Last Week

Why Functional Programming?

Why avoid objects and side effects?

Formal Provability Line-by-line invariants

Modularity Encourages small independent functions

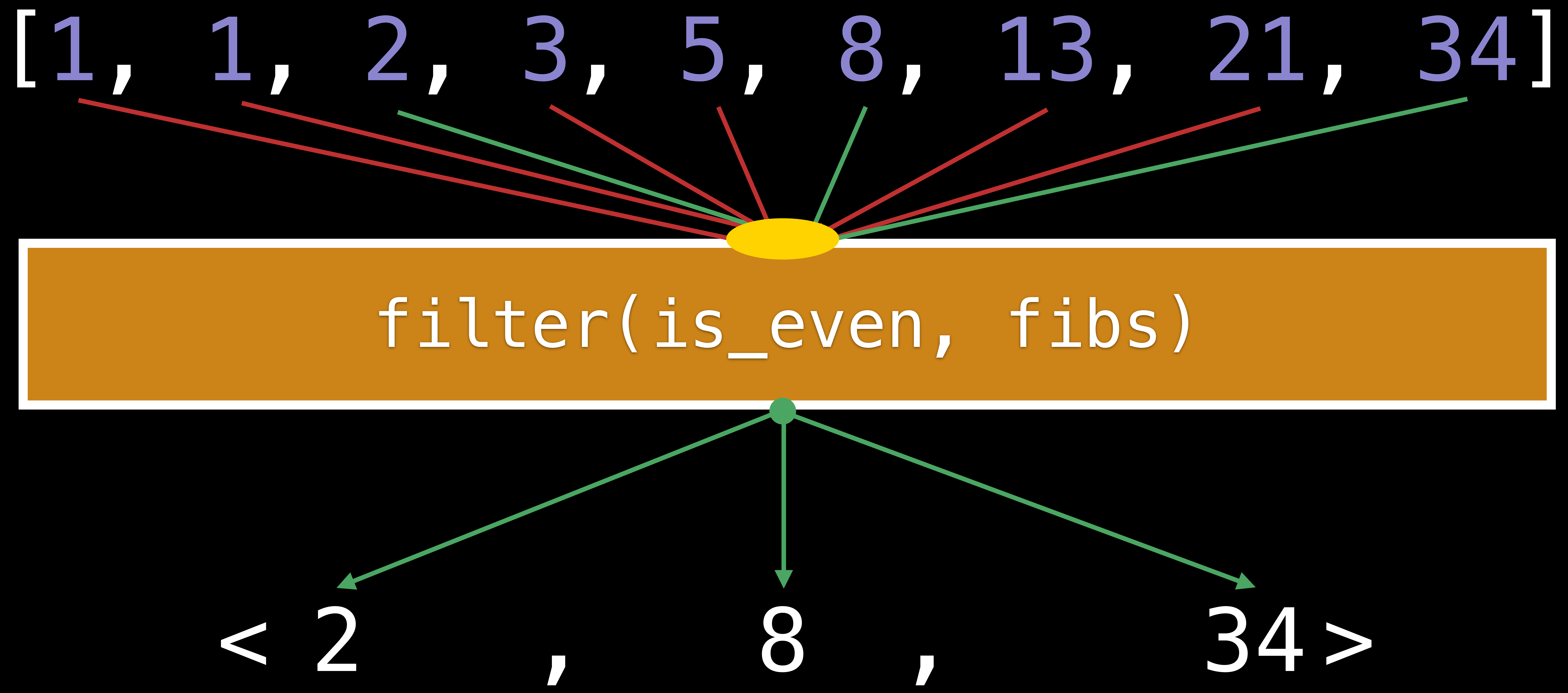
Composability Arrange existing functions for new goals

Easy Debugging Behavior depends only on input

Let's Get Started!

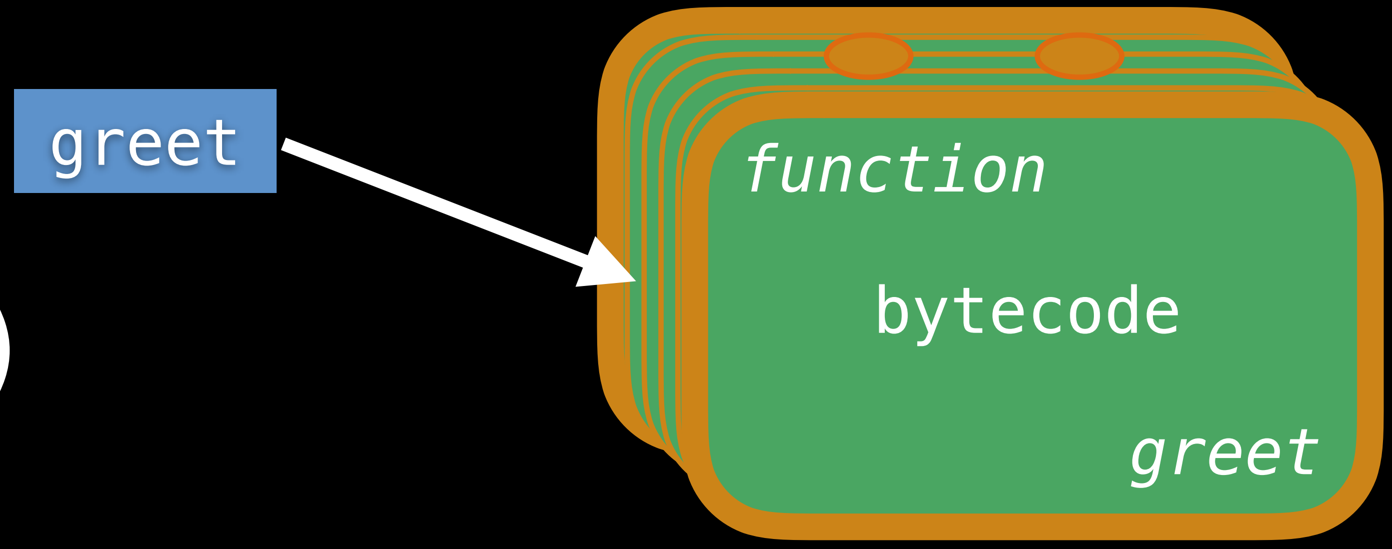
```
[len(s) for s in languages]
["python", "perl", "java", "c++"]

map(len, languages)

< 6 , 4 , 4, 3>
```

```
[num for num in fibs if is_even(num)]
```



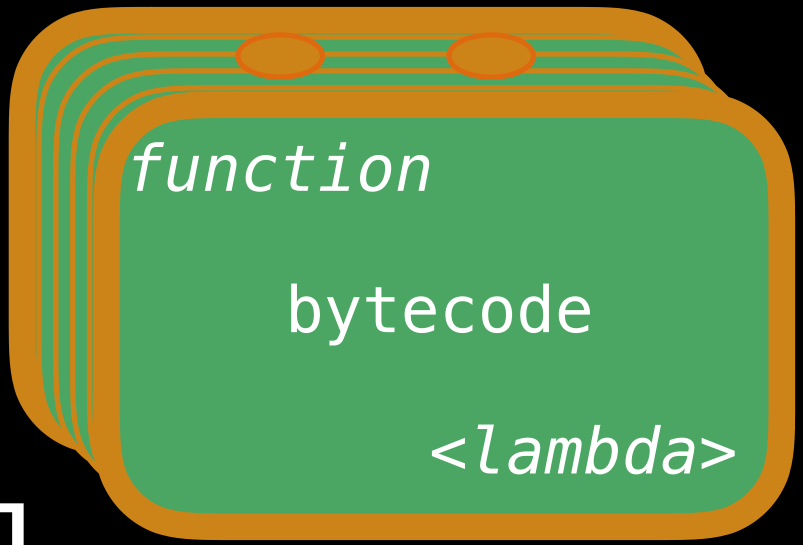
Function Definitions vs. Lambdas

```
def greet():
    print("Hi!")
```



def binds a function object to a name

```
lambda val: val ** 2
lambda x, y: x * y
lambda pair: pair[0] * pair[1]
```



lambda only creates a function object

```
(lambda x: x > 3)(4)  # => True
```

Decorators

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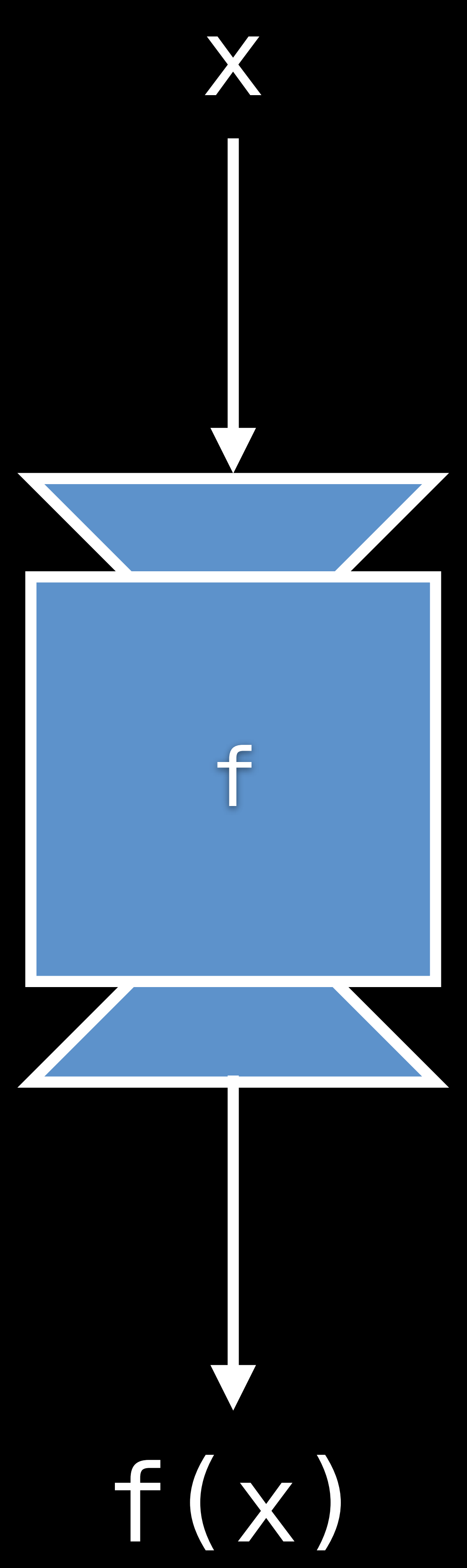

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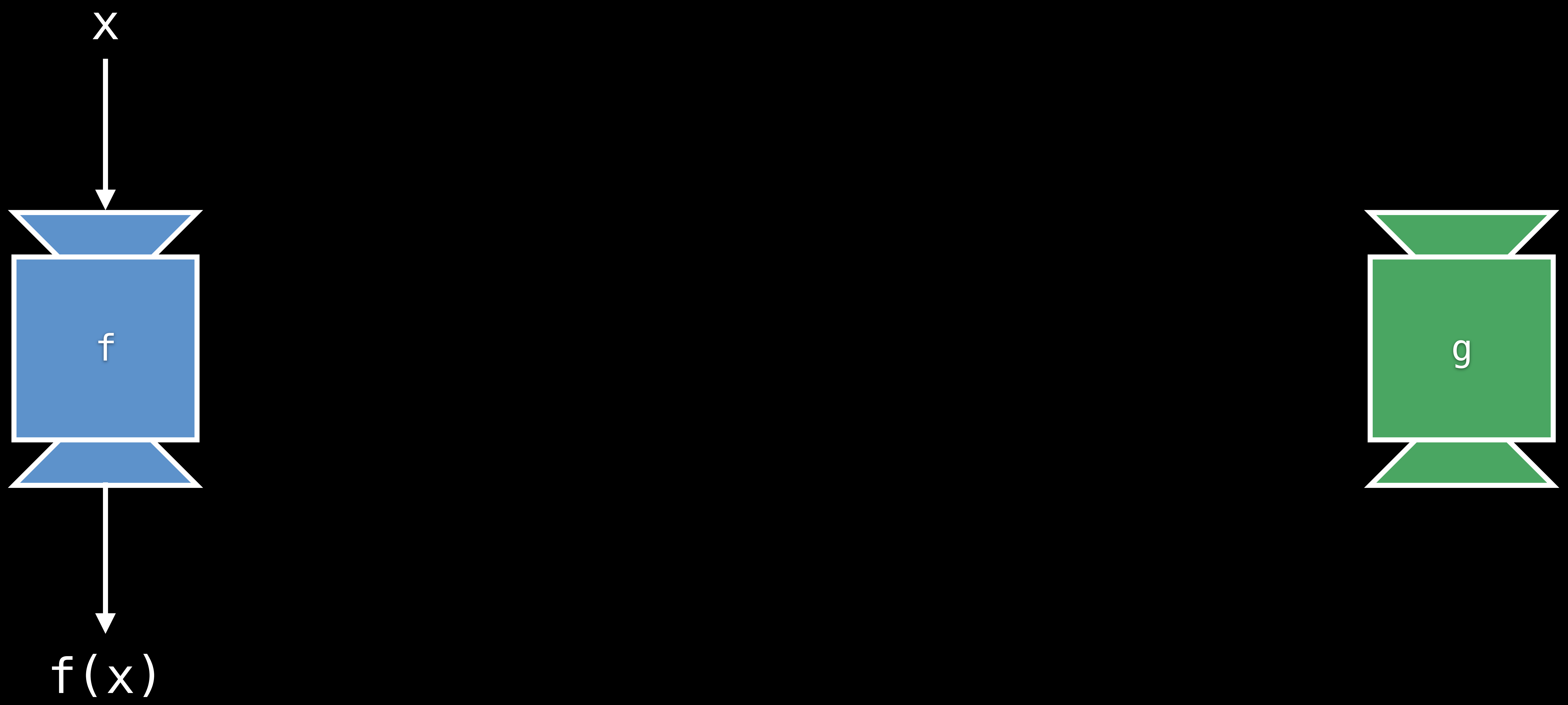

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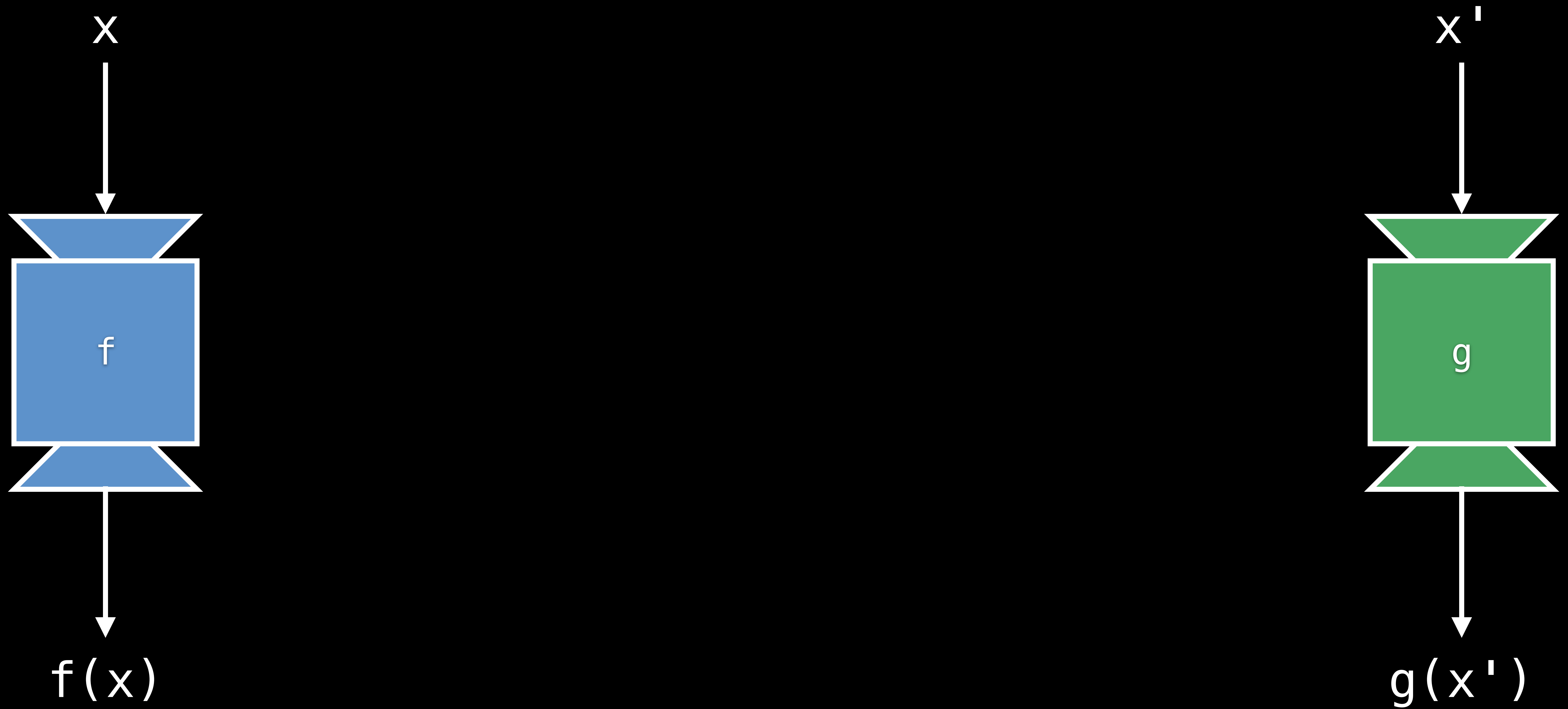

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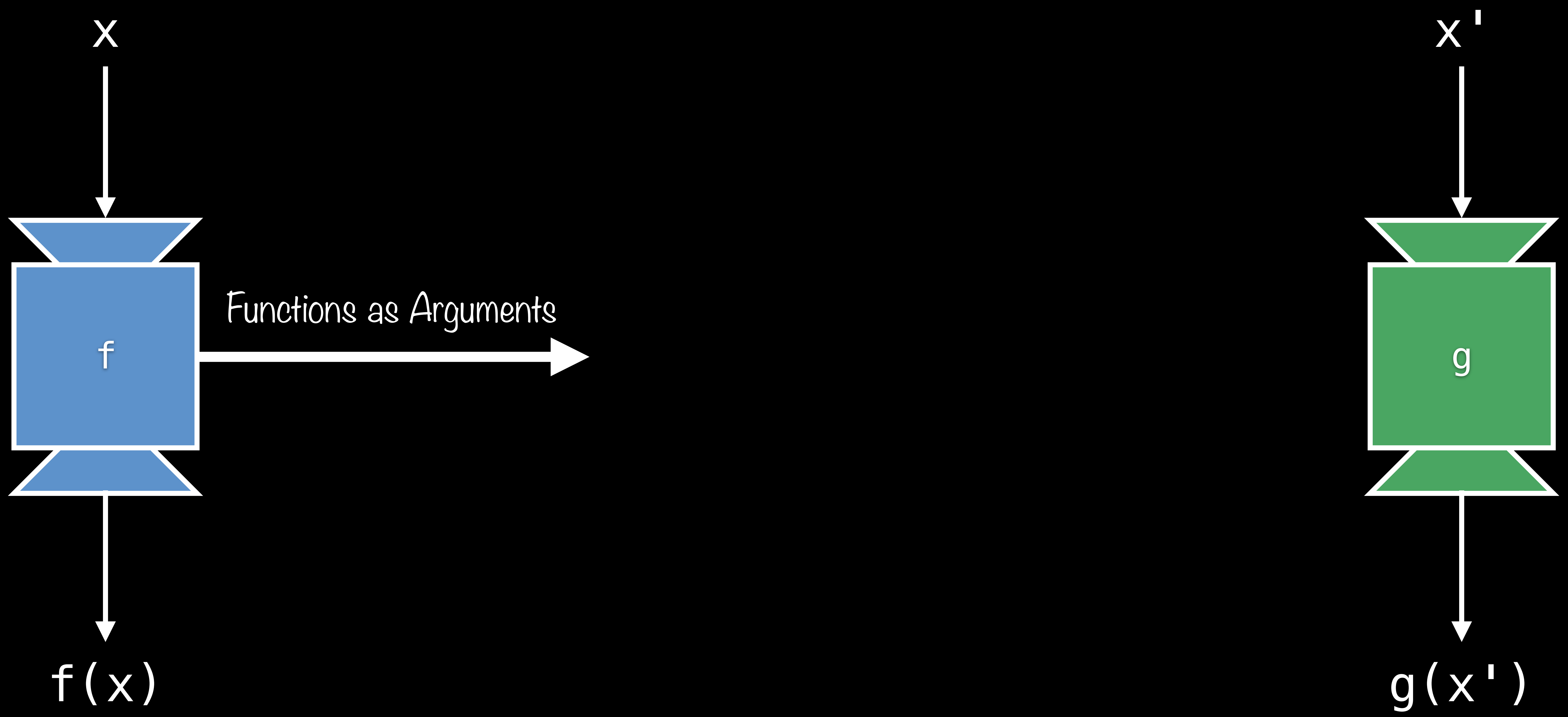

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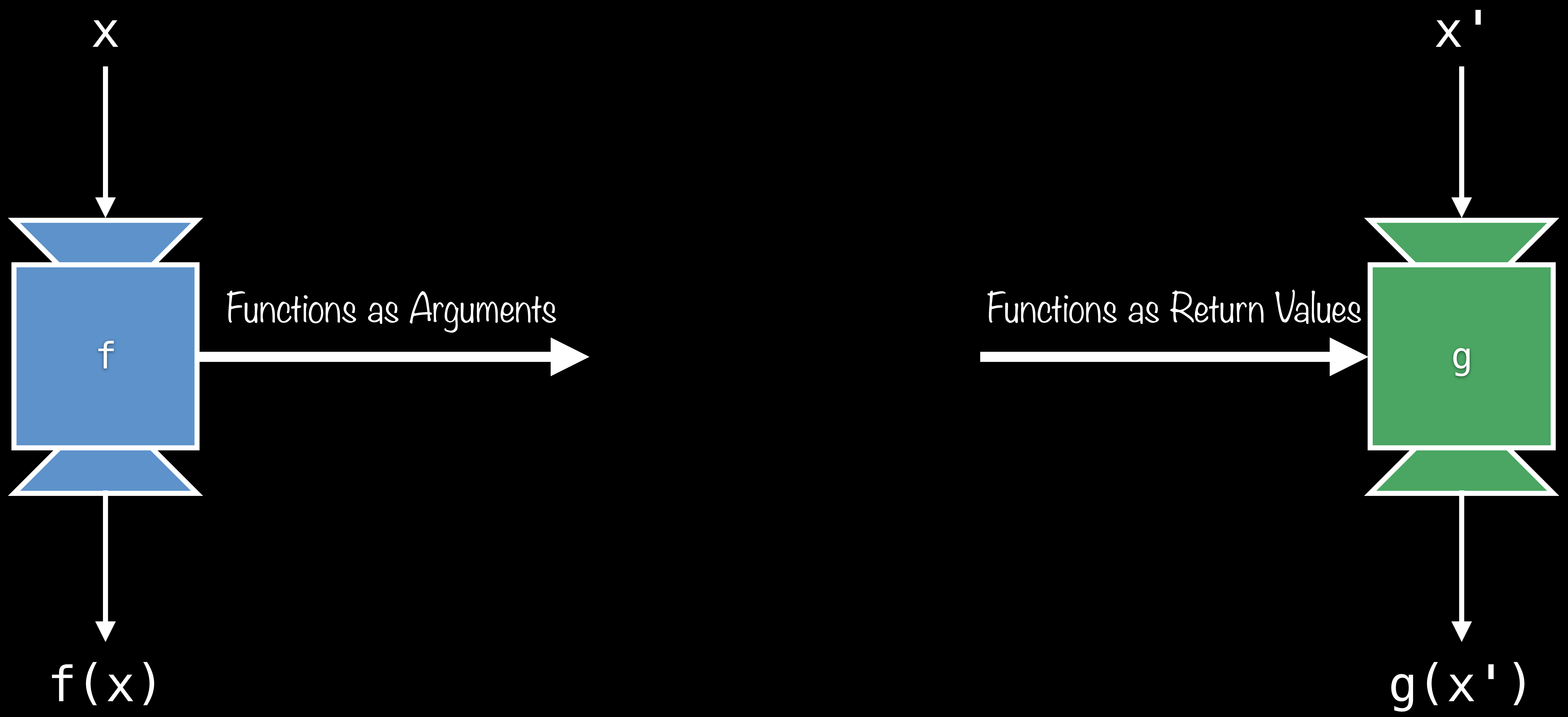
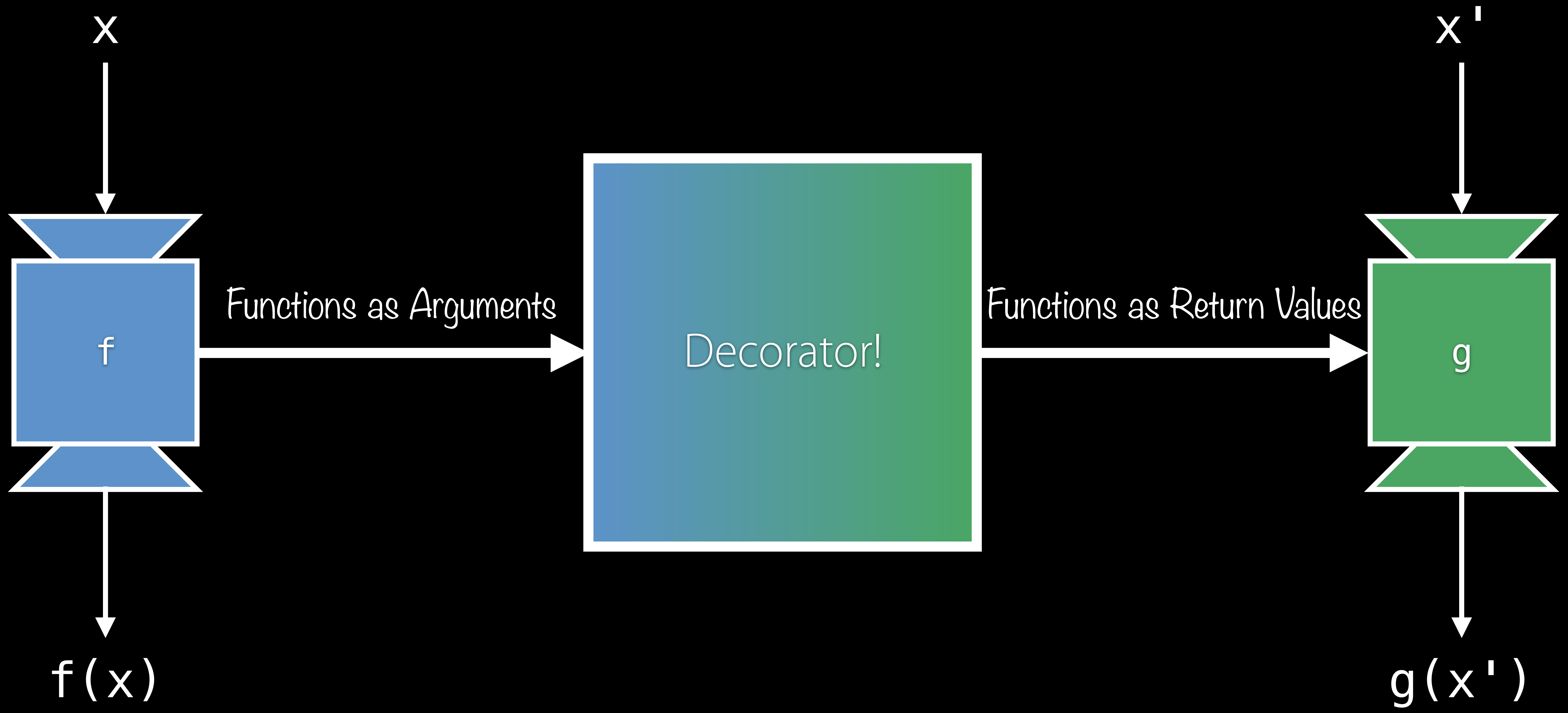

x
x'
f
Functions as Arguments
Functions as Return Values
g
f(x)
g(x')

Decorators


x
f
f(x)
Functions as Arguments
Decorator!
Functions as Return Values
x'
g
g(x')

Our First Decorator

```
def debug(function):
    def wrapper(*args, **kwargs):
        print("Arguments:", args, kwargs)
        return function(*args, **kwargs)
    return wrapper


@debug
def foo(a, b, c=1):
    return (a + b) * c
```

Object-Oriented Python

Recall: Programming Paradigms

Recall: Programming Paradigms

Procedural
Sequence of instructions that inform the computer what to do with the program's input

Examples
C
Pascal
Unix (sh)

Recall: Programming Paradigms

Procedural	**Declarative**
Sequence of instructions that inform the computer what to do with the program's input	Specification describes the problem to be solved, and language implementation figures out the details
Examples C Pascal Unix (sh)	*Examples* SQL Prolog

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Prolog

Object-Oriented
Deal with collections of objects which maintain internal state and support methods that query or modify this internal state in some way.

Examples
Java
Smalltalk

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Functional
Decomposes into a set of functions, each of which solely takes inputs and produces outputs with no internal state.

Examples
Haskell
OCaml
ML

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Sequence of instructions that inform the computer what to do with the program's input

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Specification describes the problem to be solved, and language implementation figures out the details

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Multi-Paradigm
Supports several different paradigms, to be combined freely

Examples
Scala
C++
Python

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Deal with collections of objects which maintain internal state and support methods that query or modify this internal state in some way.

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Decomposes into a set of functions, each of which solely takes inputs and produces outputs with no internal state.

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Objects, Names, Attributes

Recall: Some Definitions

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An *object* has identity

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A *name* is a reference to an object

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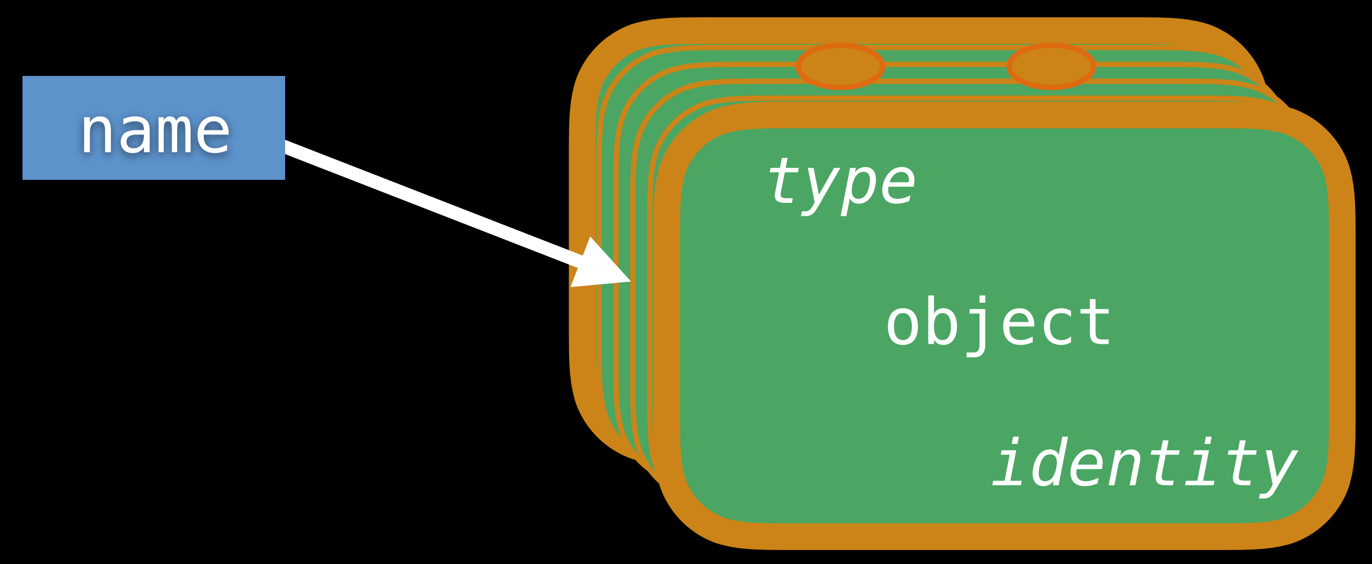
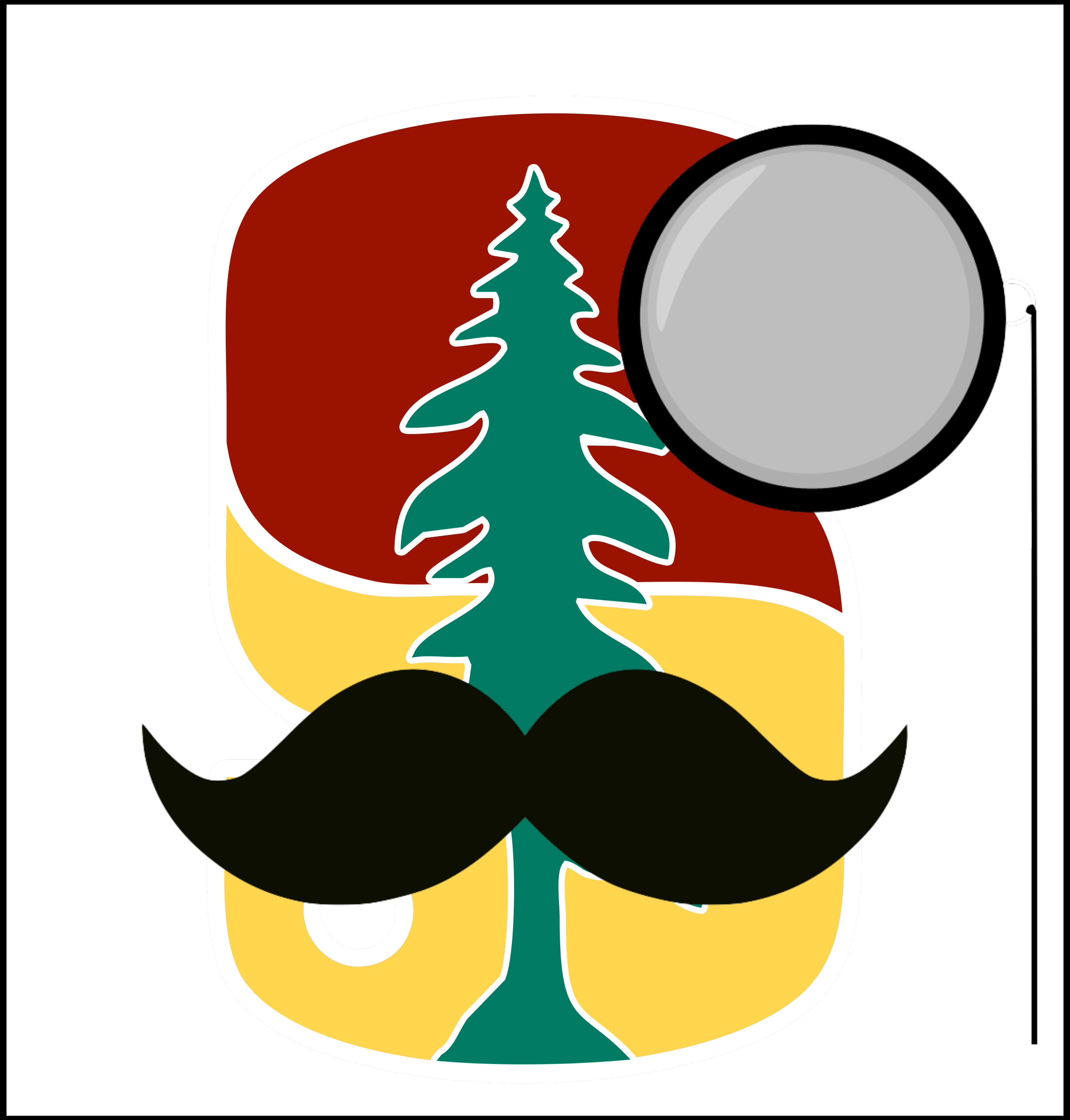


Classes

First Look at Classes



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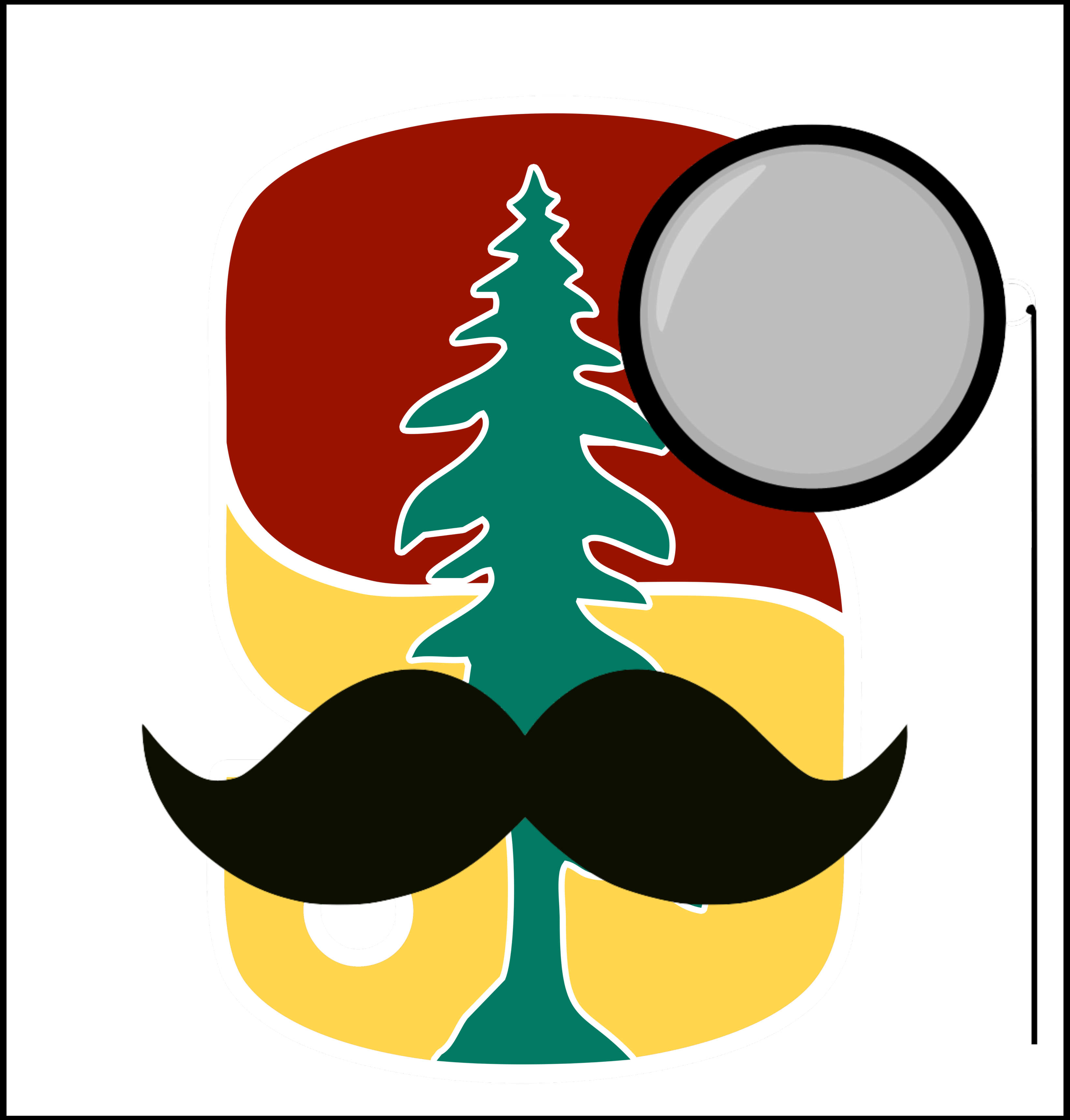
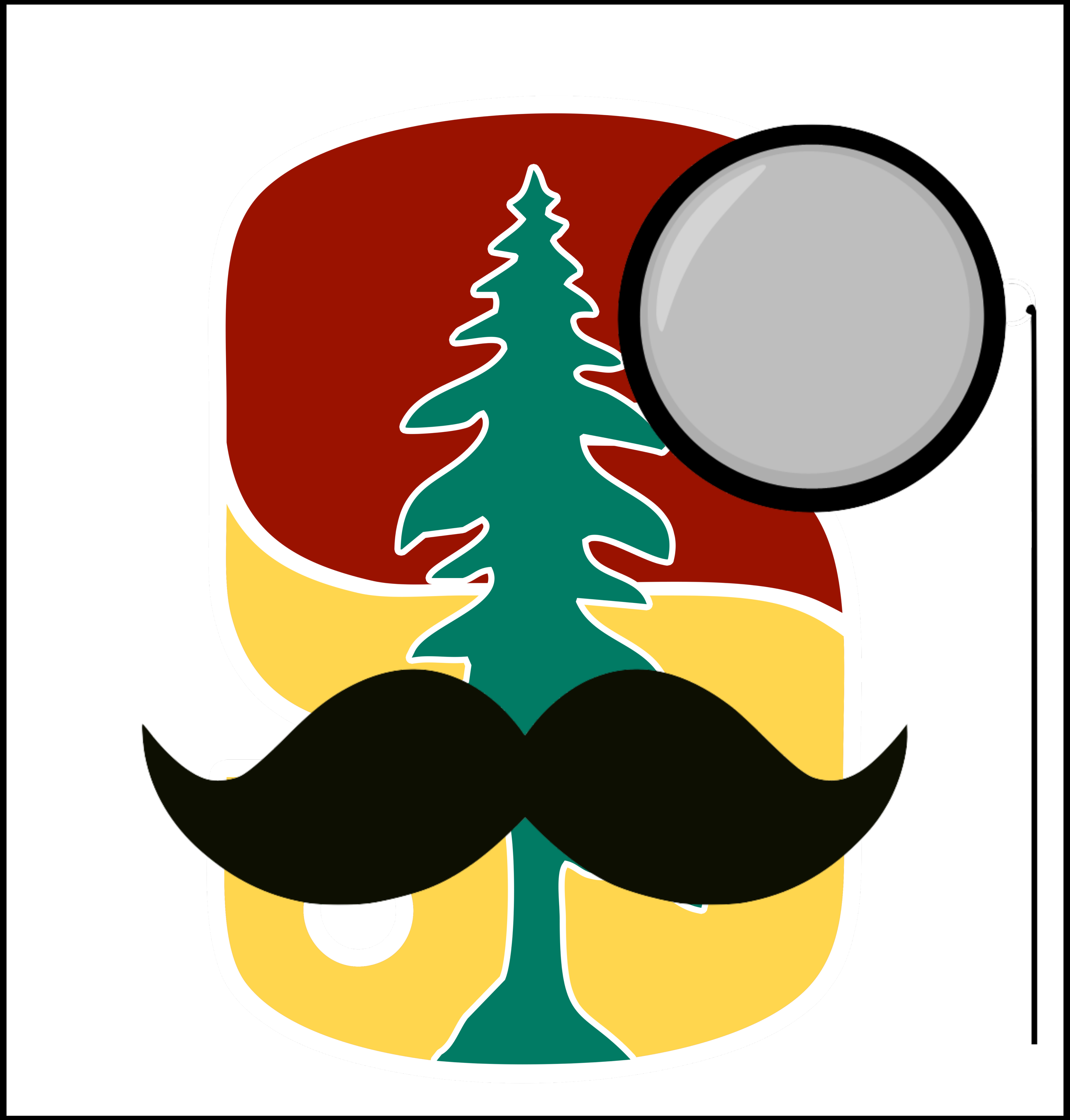


New Syntax

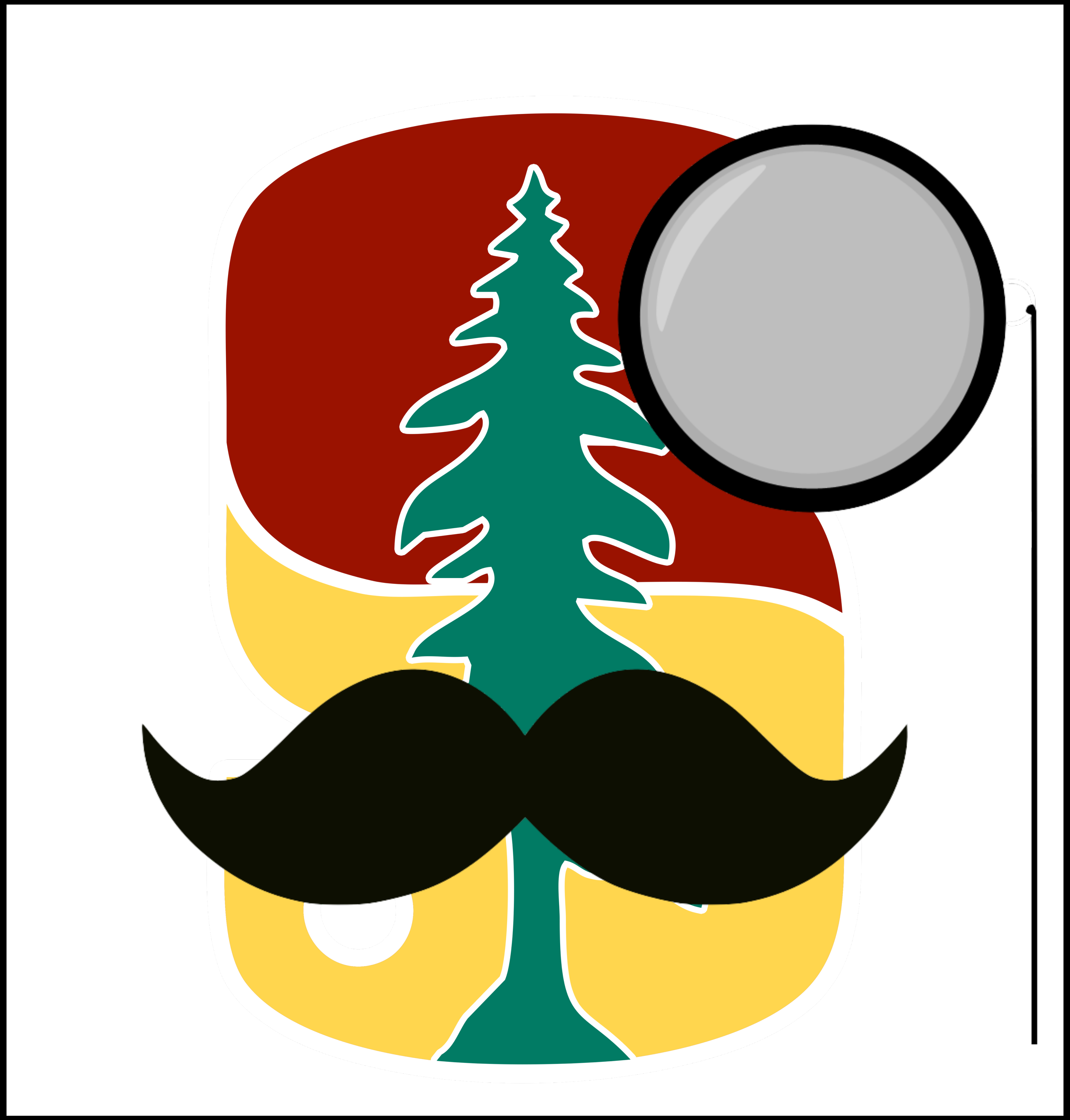
First Look at Classes



New Syntax

Class Objects

First Look at Classes



New Syntax

Class Objects

Instance Objects

First Look at Classes

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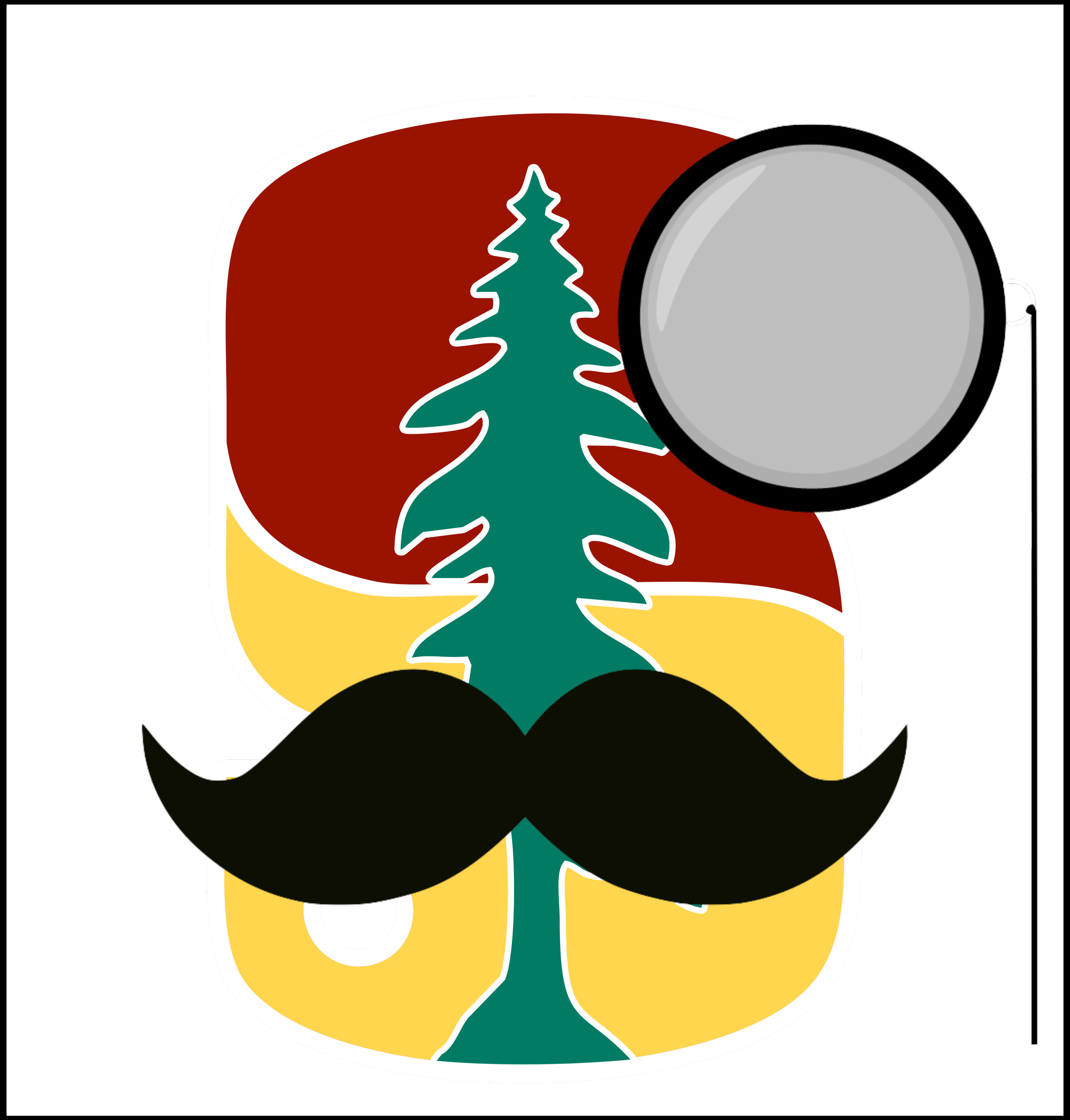
Instance Objects

Methods vs. Functions

First Look at Classes



- New Syntax
- Class Objects
- Instance Objects
- Methods vs. Functions

Who says Python isn't classy?

Class Definition Syntax

```
class ClassName:
    <statement>
    <statement>
    ...
```

The `class` keyword introduces a new class defintion

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Must be executed to have effect (like def)

Class Definitions

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- Defining a class **==** creating a class object (like `int`, `str`)

Class Definitions

- Statements are usually assignments or function definitions
- Entering a class definition creates a new "namespace"-ish
  - Really, a special `__dict__` attribute where others live
- Exiting a class definition creates a class object
  - Defining a class `==` creating a class object (like `int`, `str`)
  - Defining a class `!=` instantiating a class

Wait, What?

Class Objects vs. Instance Objects

Class Objects vs. Instance Objects

Defining a class creates a *class object*

- Supports attribute reference and instantiation

Class Objects vs. Instance Objects

Defining a class creates a *class object*

- Supports attribute reference and instantiation

Instantiating a class object creates an *instance object*

- Only supports attribute reference

Class Objects

Support (1) attribute references and (2) instantation

Class Attribute References

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```python
class MyClass:
    """A simple example class"""
    num = 12345
    def greet(self):
        return "Hello world!"
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MyClass.num    # => 12345          (int object)
MyClass.greet  # => <function f> (function object)
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Warning! Class attributes can be written to by the client

Class Instantiation

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```
x = MyClass(args)
```

Class Instantiation

No new

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Classes are instantiated using parentheses and an optional argument list

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Class Instantiation

No `new`

Classes are instantiated using parentheses and an optional argument list

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```

"Instantiating" a class constructs an instance object of that class object.
In this case, `x` is an instance object of the `MyClass` class object

Custom Constructor using `__init__`

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```
class Complex:
    def __init__(self, realpart=0, imagpart=0):
        self.real = realpart
        self.imag = imagpart
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# Make an instance object `c`!
c = Complex(3.0, -4.5)
```

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c.real, c.imag  # => (3.0, -4.5)
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c = Complex(3.0, -4.5)
c.real, c.imag  # => (3.0, -4.5)
```

You can't overload `__init__`!
Use keyword arguments or factory methods

Instance Objects

Only support attribute references

Data Attributes

Data Attributes

= "instance variables"

= "data members"

Data Attributes

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```
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Data Attributes

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c.real, c.imag  # => (3.0, -4.5)
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Data Attributes

= "instance variables"
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c = Complex(3.0, -4.5)

# Get attributes
c.real, c.imag  # => (3.0, -4.5)

# Set attributes
c.real = -9.2
c.imag = 4.1
```

Instance Attribute Reference Resolution

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```python
class MyOtherClass():
    num = 12345
    def __init__(self):
        self.num = 0
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print(x.num)  # 0 or 12345?
```

Instance Attribute Reference Resolution

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class MyOtherClass():
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print(x.num)  # 0 or 12345?
del x.num
```

Instance Attribute Reference Resolution

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Instance Attribute Reference Resolution

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print(x.num)  # 0 or 12345?
del x.num
print(x.num)  # 0 or 12345?
```

Attribute references first search the instance's `__dict__` attribute, then the class object's

Setting Data Attributes

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# You can set attributes on instance (and class) objects
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c.counter = 1
```

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# You can set attributes on instance (and class) objects
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c.counter = 1
while c.counter < 10:
    c.counter = x.counter * 2
    print(c.counter)
del c.counter  # Leaves no trace
```

Setting Data Attributes

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# prints 1, 2, 4, 8
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Setting Data Attributes

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# on the fly (we used this in the constructor!)
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while c.counter < 10:
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del c.counter  # Leaves no trace

# prints 1, 2, 4, 8
```

Setting attributes actually inserts into the instance object's `__dict__` attribute

Recall: A Sample Class

```python
class MyClass:
    """A simple example class"""
    num = 12345
    def greet(self):
        return "Hello world!"
```

Calling Methods

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x.greet()  # 'Hello world!'
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print(type(x.greet))        # method
print(type(MyClass.greet))  # function
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print(x.num is MyClass.num)  # True
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print(type(x.greet))          # method
print(type(MyClass.greet))  # function

print(x.num is MyClass.num)  # True
print(x.greet is MyClass.greet)  # False
```

Methods vs. Functions

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A *method* is a function bound to an object

```
method ≈ (object, function)
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Methods vs. Functions

A *method* is a function bound to an object

```
method ≈ (object, function)
```

Methods calls invoke special semantics

```
object.method(arguments) = function(object, arguments)
```

Example: 🍕🍕🍕

Pizza

Pizza

```python
class Pizza:
```

Pizza

```python
class Pizza:
    def __init__(self, radius, toppings, slices=8):
        self.radius = radius
        self.toppings = toppings
        self.slices_left = slices
```

Pizza

```
class Pizza:
    def __init__(self, radius, toppings, slices=8):
        self.radius = radius
        self.toppings = toppings
        self.slices_left = slices

    def eat_slice(self):
        if self.slices_left > 0:
            self.slices_left -= 1
        else:
            print("Oh no! Out of pizza")
```

Pizza

```python
class Pizza:
    def __init__(self, radius, toppings, slices=8):
        self.radius = radius
        self.toppings = toppings
        self.slices_left = slices

    def eat_slice(self):
        if self.slices_left > 0:
            self.slices_left -= 1
        else:
            print("Oh no! Out of pizza")

    def __repr__(self):
        return '{}" pizza'.format(self.radius)
```

Pizza

Pizza

```
p = Pizza(14, ("Pepperoni", "Olives"), slices=12)
```

Pizza

```
p = Pizza(14, ("Pepperoni", "Olives"), slices=12)
print(Pizza.eat_slice)
# => <function Pizza.eat_slice>
```

Pizza

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print(p.eat_slice)
# => <bound method Pizza.eat_slice of 14" Pizza>
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method = p.eat_slice
```

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method = p.eat_slice
method.__self__  # => 14" Pizza
```

Pizza

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p = Pizza(14, ("Pepperoni", "Olives"), slices=12)
print(Pizza.eat_slice)
# => <function Pizza.eat_slice>

print(p.eat_slice)
# => <bound method Pizza.eat_slice of 14" Pizza>

method = p.eat_slice
method.__self__  # => 14" Pizza
method.__func__  # => <function Pizza.eat_slice>
```

Pizza

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p = Pizza(14, ("Pepperoni", "Olives"), slices=12)
print(Pizza.eat_slice)
# => <function Pizza.eat_slice>

print(p.eat_slice)
# => <bound method Pizza.eat_slice of 14" Pizza>

method = p.eat_slice
method.__self__  # => 14" Pizza
method.__func__  # => <function Pizza.eat_slice>

p.eat_slice()  # Implicitly calls Pizza.eat_slice(p)
```

Class and Instance Attributes

🐶🐶🐶

Class and Instance Variables

Class and Instance Variables

```
class Dog:
```

Class and Instance Variables

```
class Dog:
    kind = 'Canine'          # class variable shared by all instances
```

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class Dog:
    kind = 'Canine'         # class variable shared by all instances

    def __init__(self, name):
        self.name = name    # instance variable unique to each instance
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a = Dog('Astro')
pb = Dog('Mr. Peanut Butter')
```

Class and Instance Variables

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    def __init__(self, name):
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a = Dog('Astro')
pb = Dog('Mr. Peanut Butter')

a.kind   # 'Canine' (shared by all dogs)
pb.kind  # 'Canine' (shared by all dogs)
a.name   # 'Astro' (unique to a)
pb.name  # 'Mr. Peanut Butter' (unique to pb)
```

Warning

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```

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class Dog:
    tricks = []
```

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Warning

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class Dog:
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    def __init__(self, name):
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    def add_trick(self, trick):
        self.tricks.append(trick)
```

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```

What could go wrong?

Warning

Warning

```
d = Dog('Fido')
e = Dog('Buddy')
```

Warning

```
d = Dog('Fido')
e = Dog('Buddy')
d.add_trick('roll over')
e.add_trick('play dead')
```

Warning

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d = Dog('Fido')
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d.add_trick('roll over')
e.add_trick('play dead')
d.tricks  # => ['roll over', 'play dead'] (shared value)
```

Did we Solve It?

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```
class Dog:
```

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```python
class Dog:
    # Let's try a default argument!
    def __init__(self, name='', tricks=[]):
        self.name = name
        self.tricks = tricks
```

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class Dog:
    # Let's try a default argument!
    def __init__(self, name='', tricks=[]):
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```

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```

Solution

```python
class Dog:
    def __init__(self, name):
        self.name = name
        self.tricks = []  # New list for each dog
```

Solution

```
class Dog:
    def __init__(self, name):
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        self.tricks = []  # New list for each dog

    def add_trick(self, trick):
```

Solution

```python
class Dog:
    def __init__(self, name):
        self.name = name
        self.tricks = []  # New list for each dog

    def add_trick(self, trick):
        self.tricks.append(trick)
```

Solution

Solution

```
d = Dog('Fido')
e = Dog('Buddy')
```

Solution

```
d = Dog('Fido')
e = Dog('Buddy')
d.add_trick('roll over')
e.add_trick('play dead')
```

Solution

```
d = Dog('Fido')
e = Dog('Buddy')
d.add_trick('roll over')
e.add_trick('play dead')
d.tricks  # => ['roll over']
e.tricks  # => ['play dead']
```

Privacy and Style

Keep an Eye Out!

Keep an Eye Out!

Nothing is truly private!

Keep an Eye Out!

Nothing is truly private!

Clients can modify *anything*

Keep an Eye Out!

Nothing is truly private!

Clients can modify *anything*

"With great power…"

Stylistic Conventions

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A method's first parameter should always be `self`

Stylistic Conventions

- A method's first parameter should always be **`self`**
  - Why? Explicitly differentiate instance and local variables

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  - Why? Explicitly differentiate instance and local variables
  - Method calls already provide the calling object as the first argument to the class function

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- A method's first parameter should always be `self`
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- Attribute names prefixed with a leading underscore are intended to be private (e.g. _spam)

Stylistic Conventions

- A method's first parameter should always be `self`
  - Why? Explicitly differentiate instance and local variables
  - Method calls already provide the calling object as the first argument to the class function
- Attribute names prefixed with a leading underscore are intended to be private (e.g. _spam)
- Use verbs for methods and nouns for data attributes

Time Out for Announcements

Logistics

Logistics

Assignment 1 Recap

Logistics

Assignment 1 Recap

- Great work finishing a hard assignment!

Logistics

- Assignment 1 Recap
  - Great work finishing a hard assignment!
- Late Day Policy Review

Logistics

Assignment 1 Recap

- Great work finishing a hard assignment!

Late Day Policy Review

"Too Much Work" Policy Review

Logistics

Assignment 1 Recap

- Great work finishing a hard assignment!

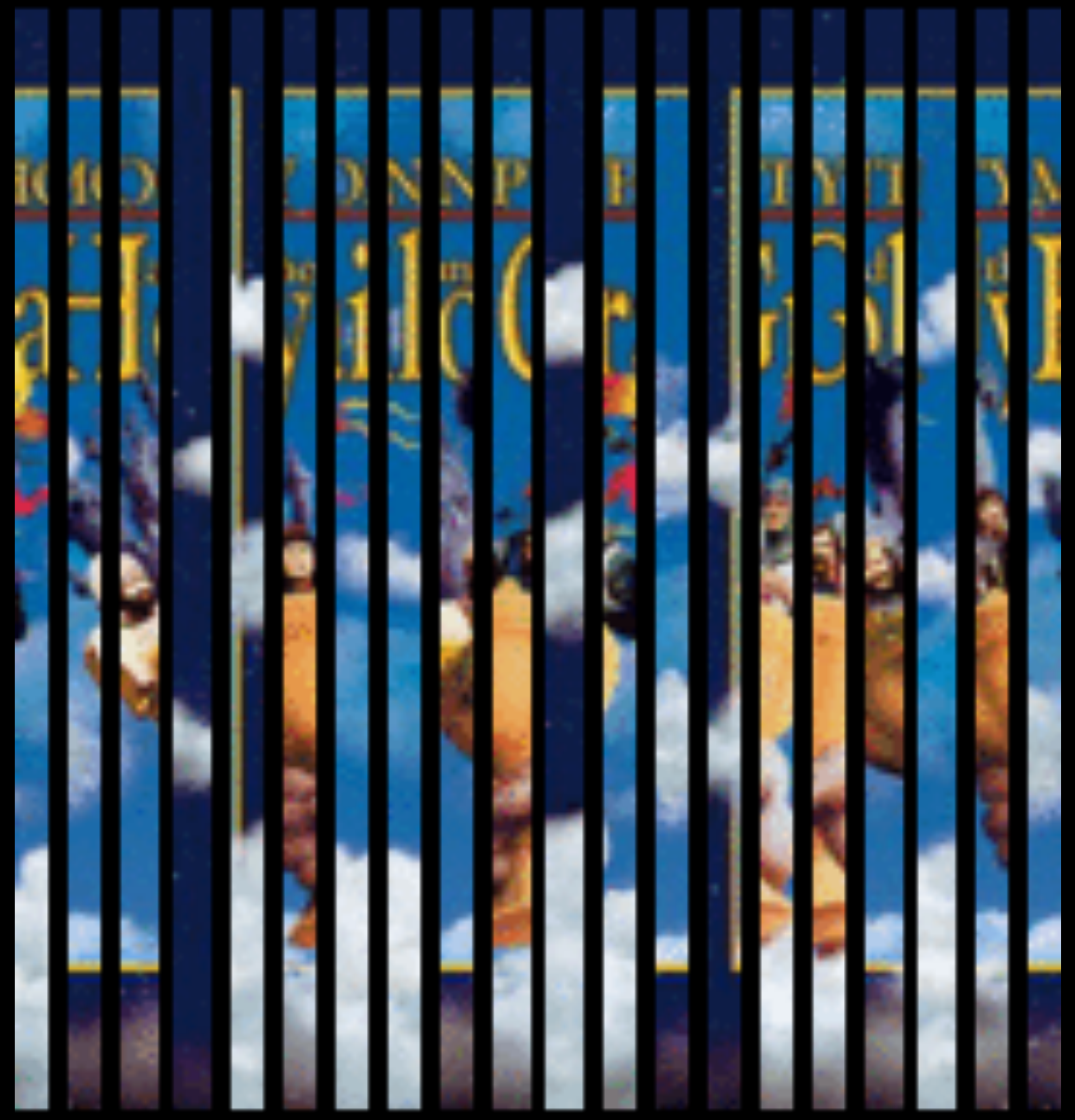
Late Day Policy Review

"Too Much Work" Policy Review

Grading this week

The Quest for the Holy Grail

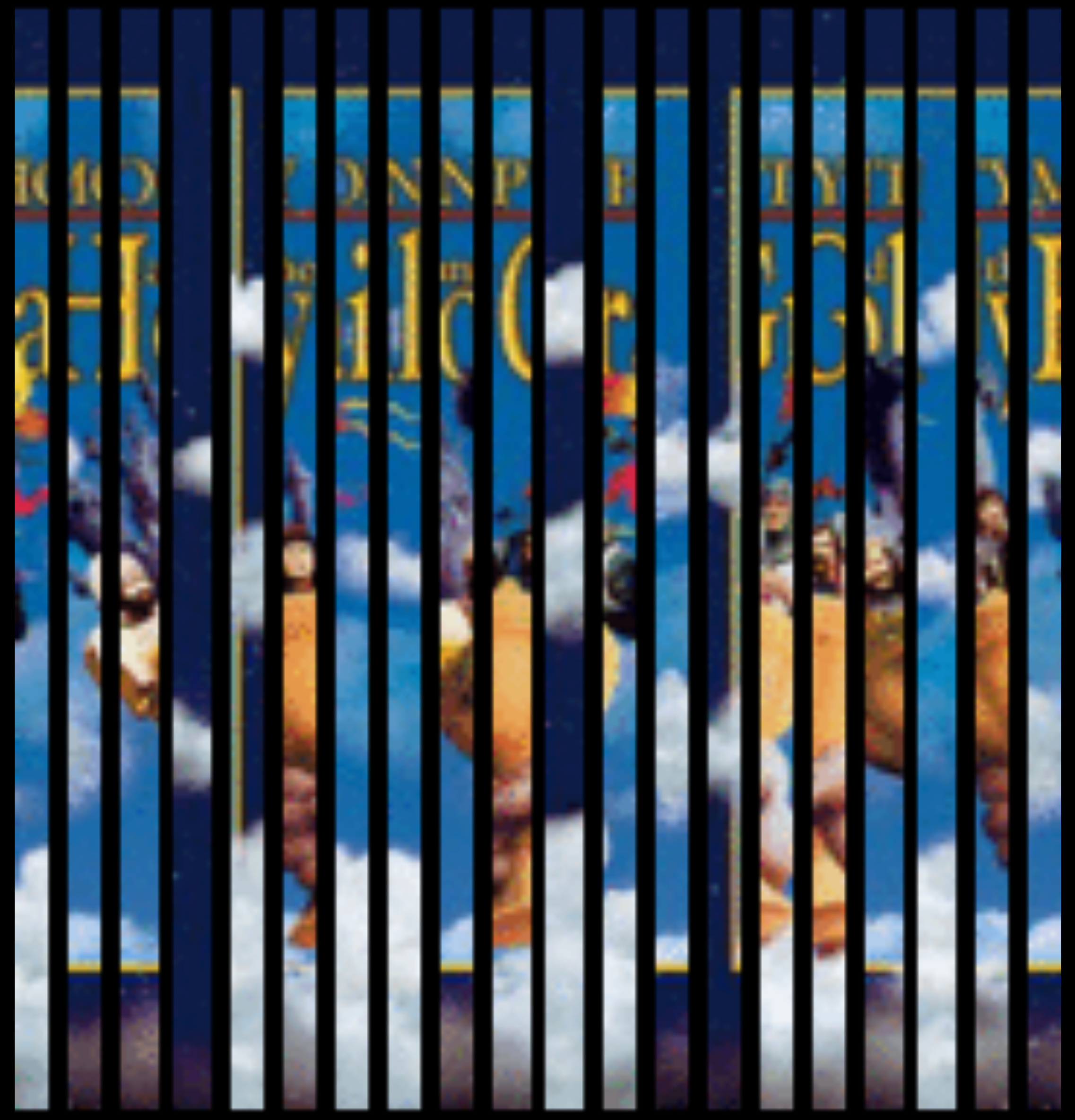
The Quest for the Holy Grail



The Quest for the Holy Grail

Three Parts

- Train a dragon, learn to fight
- Make potions
- Reassemble the map to the grail!*

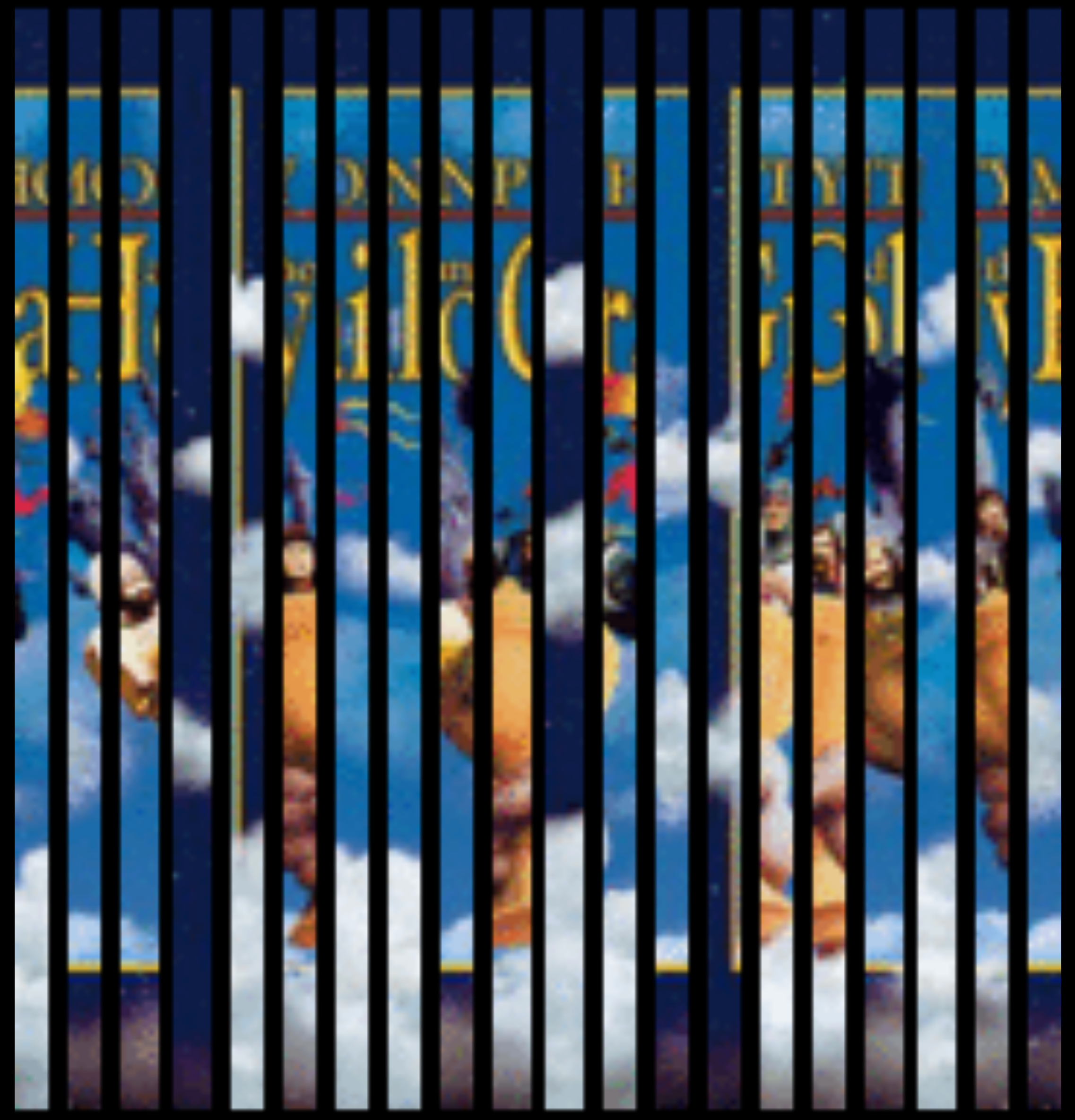


The Quest for the Holy Grail

- Three Parts
  - Train a dragon, learn to fight
  - Make potions
  - Reassemble the map to the grail!*
- If you get stuck, **ask us for hints**
  - Piazza is your friend

The Quest for the Holy Grail

- Three Parts
  - Train a dragon, learn to fight
  - Make potions
  - Reassemble the map to the grail!*
- If you get stuck, **ask us for hints**
  - Piazza is your friend
- Prizes for the first team (1-3) to complete the quest!



Back to Python!

Inheritance

```python
class DerivedClassName(BaseClassName):
    pass
```

Parentheses indicate inheritance

```
class DerivedClassName(BaseClassName):
    pass
```

Parentheses indicate inheritance

```
class DerivedClassName(BaseClassName):
    pass
```

Any expression is valid

Facts about Single Inheritance

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A class object 'remembers' its base class

Facts about Single Inheritance

A class object 'remembers' its base class

Python 3 class objects inherit from `object` (by default)

Facts about Single Inheritance

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Method and attribute lookup begins in the derived class

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Python 3 class objects inherit from `object` (by default)

Method and attribute lookup begins in the derived class

- Proceeds down the chain of base classes

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A class object 'remembers' its base class

Python 3 class objects inherit from `object` (by default)

Method and attribute lookup begins in the derived class

- Proceeds down the chain of base classes

Derived methods override (shadow) base methods

Facts about Single Inheritance

A class object 'remembers' its base class

Python 3 class objects inherit from `object` (by default)

Method and attribute lookup begins in the derived class

- Proceeds down the chain of base classes

Derived methods override (shadow) base methods

- Like `virtual` in C++

Multiple Inheritance

"The Dreaded Diamond Pattern"

Multiple Inheritance

```
class Derived(Base1, Base2, …, BaseN):
    pass
```

Multiple Inheritance

Base classes are separated by commas

```
class Derived(Base1, Base2, …, BaseN):
    pass
```

Multiple Inheritance

Base classes are separated by commas

```
class Derived(Base1, Base2, …, BaseN):
    pass
```

Order matters!

Attribute Resolution

Attribute Resolution

Attribute lookup is (almost) depth-first, left-to-right

- Officially, "C3 superclass linearization" (Wikipedia)

Attribute Resolution

Attribute lookup is (almost) depth-first, left-to-right

- Officially, "C3 superclass linearization" (Wikipedia)

Class objects have a (hidden) function attribute `.mro()`

- Shows linearization of base classes

Attribute Resolution In Action

```python
class A: pass
class B: pass
class C: pass
class D: pass
class E: pass
class K1(A, B, C): pass
class K2(D, B, E): pass
class K3(D, A): pass
class Z(K1, K2, K3): pass

Z.mro()  # [Z, K1, K2, K3, D, A, B, C, E, object]
```

Magic Methods

Magic Methods

Magic Methods

Python uses `__init__` to build classes

Magic Methods

- Python uses `__init__` to build classes
  - Overriding `__init__` lets us hook into the language

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  - sets? dictionaries?

Magic Methods

- Python uses `__init__` to build classes
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  - iterators? lists?
  - sets? dictionaries?
  - numbers?

Magic Methods

- Python uses `__init__` to build classes
  - Overriding `__init__` lets us hook into the language
- What else can we do? Can we define classes that act like:
  - iterators? lists?
  - sets? dictionaries?
  - numbers?
  - comparables?

Implementing Magic Methods

Implementing Magic Methods

```python
class MagicClass:
    def __init__(self): ...
    def __contains__(self, key): ...
    def __add__(self, other): ...
    def __iter__(self): ...
    def __next__(self): ...
    def __getitem__(self, key): ...
    def __len__(self): ...
    def __lt__(self, other): ...
    def __eq__(self, other): ...
    def __str__(self): ...
    def __repr__(self): ...  # And even more...
```

Some Magic Methods

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
```

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
str(x)   # => x.__str__()
x == y   # => x.__eq__(y)
```

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
str(x)   # => x.__str__()
x == y   # => x.__eq__(y)

x < y    # => x.__lt__(y)
```

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
str(x)   # => x.__str__()
x == y   # => x.__eq__(y)

x < y    # => x.__lt__(y)
x + y    # => x.__add__(y)
```

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
str(x)   # => x.__str__()
x == y   # => x.__eq__(y)

x < y    # => x.__lt__(y)
x + y    # => x.__add__(y)
iter(x)  # => x.__iter__()
```

Some Magic Methods

```python
x = MagicClass()
y = MagicClass()
str(x)   # => x.__str__()
x == y   # => x.__eq__(y)

x < y    # => x.__lt__(y)
x + y    # => x.__add__(y)
iter(x)  # => x.__iter__()
next(x)  # => x.__next__()
```

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
str(x)    # => x.__str__()
x == y    # => x.__eq__(y)

x < y     # => x.__lt__(y)
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iter(x)   # => x.__iter__()
next(x)   # => x.__next__()
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```

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
str(x)    # => x.__str__()
x == y    # => x.__eq__(y)

x < y     # => x.__lt__(y)
x + y     # => x.__add__(y)
iter(x)   # => x.__iter__()
next(x)   # => x.__next__()
len(x)    # => x.__len__()
el in x   # => x.__contains__(el)
```

Some Magic Methods

```
x = MagicClass()
y = MagicClass()
str(x)    # => x.__str__()
x == y    # => x.__eq__(y)

x < y     # => x.__lt__(y)
x + y     # => x.__add__(y)
iter(x)   # => x.__iter__()
next(x)   # => x.__next__()
len(x)    # => x.__len__()
el in x   # => x.__contains__(el)
```

Many, many more

Link 1

Link 2

Link 3

Example: Point

Example: Point

```
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y
```

Example: Point

```
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y

    def rotate_90_CC(self):
        self.x, self.y = -self.y, self.x
```

Example: Point

```
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y

    def rotate_90_CC(self):
        self.x, self.y = -self.y, self.x

    def __add__(self, other):
        return Point(self.x + other.x, self.y + other.y)
```

Example: Point

```python
class Point:
    def __init__(self, x=0, y=0):
        self.x = x
        self.y = y

    def rotate_90_CC(self):
        self.x, self.y = -self.y, self.x

    def __add__(self, other):
        return Point(self.x + other.x, self.y + other.y)

    def __str__(self):
        return "Point({0}, {1})".format(self.x, self.y)
```

Example

Example

```
o = Point()
print(o)          # Point(0, 0)
```

Example

```
o = Point()
print(o)            # Point(0, 0)

p1 = Point(3, 5)
p2 = Point(4, 6)
print(p1, p2)       # Point(3, 5) Point(4, 6)
```

Example

```
o = Point()
print(o)          # Point(0, 0)

p1 = Point(3, 5)
p2 = Point(4, 6)
print(p1, p2)     # Point(3, 5) Point(4, 6)

p1.rotate_90_CC()
print(p1)         # Point(-5, 3)
```

Example

```
o = Point()
print(o)          # Point(0, 0)

p1 = Point(3, 5)
p2 = Point(4, 6)
print(p1, p2)     # Point(3, 5) Point(4, 6)

p1.rotate_90_CC()
print(p1)         # Point(-5, 3)

print(p1 + p2)    # Point(-1, 9)
```

OOP Case Study: Errors and Exceptions

Syntax Errors

"Errors before execution"

Syntax Errors

"Errors before execution"

```
>>>
```

Syntax Errors

"Errors before execution"

```
>>> while True print('Hello world')
```

Syntax Errors

"Errors before execution"

```
>>> while True print('Hello world')
  File "<stdin>", line 1
    while True print('Hello world')
                   ^
SyntaxError: invalid syntax
```

Syntax Errors

"Errors before execution"

```
>>> while True print('Hello world')
  File "<stdin>", line 1
    while True print('Hello world')
                   ^
SyntaxError: invalid syntax
```

Error is detected at the token preceding the arrow

Exceptions

"Errors during execution"

Exceptions

"Errors during execution"

```
>>> 10 * (1/0)
```

Exceptions

"Errors during execution"

```
>>> 10 * (1/0)
Traceback (most recent call last):
    File "<stdin>", line 1
ZeroDivisionError: division by zero
```

Exceptions

"Errors during execution"

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>>> 10 * (1/0)
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>>> 4 + spam*3
```

Exceptions

"Errors during execution"

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>>> 10 * (1/0)
Traceback (most recent call last):
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ZeroDivisionError: division by zero

>>> 4 + spam*3
Traceback (most recent call last):
    File "<stdin>", line 1
NameError: name 'spam' is not defined
```

Exceptions

"Errors during execution"

```
>>> 10 * (1/0)
Traceback (most recent call last):
    File "<stdin>", line 1
ZeroDivisionError: division by zero

>>> 4 + spam*3
Traceback (most recent call last):
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NameError: name 'spam' is not defined

>>> '2' + 2
```

Exceptions

"Errors during execution"

```
>>> 10 * (1/0)
Traceback (most recent call last):
    File "<stdin>", line 1
ZeroDivisionError: division by zero

>>> 4 + spam*3
Traceback (most recent call last):
    File "<stdin>", line 1
NameError: name 'spam' is not defined

>>> '2' + 2
Traceback (most recent call last):
    File "<stdin>", line 1
TypeError: Can't convert 'int' object to str implicitly
```

And More

And More

KeyboardInterrupt

UnboundLocalError

SystemExit

StopIteration

SyntaxError

ZeroDivisionError

AttributeError

KeyError

IndexError

NotImplementedError

TypeError

OSError

NameError

```
BaseException
├── SystemExit
├── KeyboardInterrupt
├── GeneratorExit
└── Exception
    ├── StopIteration
    ├── ArithmeticError
    │   ├── FloatingPointError
    │   ├── OverflowError
    │   └── ZeroDivisionError
    ├── AssertionError
    ├── AttributeError
    ├── BufferError
    ├── EOFError
    ├── ImportError
    ├── LookupError
    │   ├── IndexError
    │   └── KeyError
    ├── MemoryError
    ├── NameError
    │   └── UnboundLocalError
    ├── OSError
```

```
├── OSError
│   ├── BlockingIOError
│   ├── ChildProcessError
│   ├── ConnectionError
│   │   ├── BrokenPipeError
│   │   ├── ConnectionAbortedError
│   │   ├── ConnectionRefusedError
│   │   └── ConnectionResetError
│   ├── FileExistsError
│   ├── FileNotFoundError
│   ├── InterruptedError
│   ├── IsADirectoryError
│   ├── NotADirectoryError
│   ├── PermissionError
│   ├── ProcessLookupError
│   └── TimeoutError
├── ReferenceError
├── RuntimeError
│   └── NotImplementedError
├── SyntaxError
│   └── IndentationError
│       └── TabError
```

```
├── SystemError
├── TypeError
├── ValueError
│   └── UnicodeError
│       ├── UnicodeDecodeError
│       ├── UnicodeEncodeError
│       └── UnicodeTranslateError
└── Warning
    ├── DeprecationWarning
    ├── PendingDeprecationWarning
    ├── RuntimeWarning
    ├── SyntaxWarning
    ├── UserWarning
    ├── FutureWarning
    ├── ImportWarning
    ├── UnicodeWarning
    ├── BytesWarning
    └── ResourceWarning
```

And Even More

Inheritance in Action!

Handling Exceptions

What's Wrong?

```python
def read_int():
    """Reads an integer from the user (broken)"""
    return int(input("Please enter a number: "))
```

What's Wrong?

```
def read_int():
    """Reads an integer from the user (broken)"""
    return int(input("Please enter a number: "))
```

What happens if the user enters a nonnumeric input?

Solution

Solution

```python
def read_int():
    """Reads an integer from the user (fixed)"""
```

Solution

```
def read_int():
    """Reads an integer from the user (fixed)"""
    while True:
```

Solution

```
def read_int():
    """Reads an integer from the user (fixed)"""
    while True:
        try:
```

Solution

```
def read_int():
    """Reads an integer from the user (fixed)"""
    while True:
        try:
            x = int(input("Please enter a number: "))
```

Solution

```
def read_int():
    """Reads an integer from the user (fixed)"""
    while True:
        try:
            x = int(input("Please enter a number: "))
            break
```

Solution

```
def read_int():
    """Reads an integer from the user (fixed)"""
    while True:
        try:
            x = int(input("Please enter a number: "))
            break
        except ValueError:
```

Solution

```
def read_int():
    """Reads an integer from the user (fixed)"""
    while True:
        try:
            x = int(input("Please enter a number: "))
            break
        except ValueError:
            print("Oops! Invalid input. Try again...")
```

Solution

```
def read_int():
    """Reads an integer from the user (fixed)"""
    while True:
        try:
            x = int(input("Please enter a number: "))
            break
        except ValueError:
            print("Oops! Invalid input. Try again...")
    return x
```

Mechanics of `try` statement

Mechanics of `try` statement

1) Attempt to execute the try clause

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2a) If no exception occurs, skip the except clause. Done!

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2b) If an exception occurs, skip the rest of the try clause.

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1) Attempt to execute the try clause

2a) If no exception occurs, skip the except clause. Done!

2b) If an exception occurs, skip the rest of the try clause.

2bi) If the exception's type matches (/ is a subclass of) that named by except, then execute the except clause. Done!

Mechanics of `try` statement

1) Attempt to execute the try clause

2a) If no exception occurs, skip the except clause. Done!

2b) If an exception occurs, skip the rest of the try clause.

2bi) If the exception's type matches (/ is a subclass of) that named by except, then execute the except clause. Done!

2bii) Otherwise, hand off the exception to any outer try statements. If unhandled, halt execution. Done!

Conveniences

Conveniences

```
try:
    distance = int(input("How far? "))
    time = car.speed / distance
    car.drive(time)
```

Conveniences

```
try:
    distance = int(input("How far? "))
    time = car.speed / distance
    car.drive(time)
except ValueError as e:
    print(e)
```

Bind a name to the exception instance

Conveniences

```
try:
    distance = int(input("How far? "))
    time = car.speed / distance
    car.drive(time)
except ValueError as e:
    print(e)
except ZeroDivisionError:
    print("Division by zero!")
```

Bind a name to the exception instance

Conveniences

```python
try:
    distance = int(input("How far? "))
    time = car.speed / distance
    car.drive(time)
except ValueError as e:
    print(e)
except ZeroDivisionError:
    print("Division by zero!")
except (NameError, AttributeError):
    print("Bad Car")
```

Bind a name to the exception instance

Catch multiple exceptions

Conveniences

```
try:
    distance = int(input("How far? "))
    time = car.speed / distance
    car.drive(time)
except ValueError as e:
    print(e)
except ZeroDivisionError:
    print("Division by zero!")
except (NameError, AttributeError):
    print("Bad Car")
except:
    print("Car unexpectedly crashed!")
```

Bind a name to the exception instance

Catch multiple exceptions

"Wildcard" catches everything

Good Python:
Don't Be a Pokemon Trainer

Solution?

```
def read_int():
    """Reads an integer from the user (fixed?)"""
    while True:
        try:
            x = int(input("Please enter a number: "))
            break
        except:
            print("Oops! Invalid input. Try again...")
    return x
```

"I'll just catch 'em all!"

Solution?

```python
def read_int():
    """Reads an integer from the user (fixed?)"""
    while True:
        try:
            x = int(input("Please enter a number: "))
            break
        except:
            print("Oops! Invalid input. Try again...")
    return x
```

"I'll just catch 'em all!"

Oops! Now we can't CTRL+C to escape

Raising Exceptions

The `raise` keyword

The `raise` keyword

```
>>> raise NameError('Why hello there!')
```

The `raise` keyword

```
>>> raise NameError('Why hello there!')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
NameError: Why hello there!
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The `raise` keyword

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>>> raise NameError('Why hello there!')
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>>> raise NameError
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
NameError
```

The raise keyword

```
>>> raise NameError('Why hello there!')
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
NameError: Why hello there!
```

You can raise either instance objects or class objects

```
>>> raise NameError
Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
NameError
```

`raise` within `except` clause

raise within except clause

```
try:
    raise NotImplementedError("TODO")
except NotImplementedError:
    print('Looks like an exception to me!')
    raise
```

Re-raises the currently active exception

raise within except clause

```
try:
    raise NotImplementedError("TODO")
except NotImplementedError:
    print('Looks like an exception to me!')
    raise
# Looks like an exception to me!
# Traceback (most recent call last):
#   File "<stdin>", line 2, in <module>
# NotImplementedError: TODO
```

Re-raises the currently active exception

Good Python: Using `else`

```
try:
    ...
except ...:
    ...
else:
    do_something()
```

```
try:
    ...
except ...:
    ...
else:
    do_something()
```

Code that executes if the try clause does not raise an exception

```
try:
    ...
except ...:
    ...
else:
    do_something()
```

Code that executes if the try clause does not raise an exception

Why? Avoid accidentally catching an exception raised by something other than the code being protected

Example: Database Transactions

```
try:
    update_the_database()
except TransactionError:
    rollback()
    raise
else:
    commit()
```

If the commit raises an exception, we might actually *want* to crash

Aside: Python Philosophy

Coding for the Common Case

Coding for the Common Case

Don't check if a file exists, then open it.

Coding for the Common Case

Don't check if a file exists, then open it.

- Just try to open it!

Coding for the Common Case

Don't check if a file exists, then open it.

- Just try to open it!
- Handle exceptional cases with an except clause (or two)

Coding for the Common Case

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You can define an __init__ method to be fancy

Clean-Up Actions

The `finally` clause

Executed upon leaving the try/except/else block

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# Goodbye, world!
# Traceback (most recent call last):
#   File "<stdin>", line 2, in <module>
# NotImplementedError
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Also executed "on the way out" (break, continue, return)

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# This is what enables us to use with ... as ...
with open(filename) as f:
    raw = f.read()
# is (almost) equivalent to
f = open(filename)
f.__enter__()
try:
    raw = f.read()
finally:
    f.__exit__()  # Closes the file
```

Surprisingly useful and flexible!

The Road Ahead

Behind Us - The Python Language

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Week 1 Python Fundamentals

Week 2 Data Structures

Week 3 Functions

Week 4 Functional Programming

Week 5 Object-Oriented Python

The Road Ahead - Python Tools

The Road Ahead - Python Tools

Week 6 Standard Library

Week 7 Third-Party Tools

Week 8 Ecosystem

Week 9 Advanced Topics

Week 10 Projects!

Next Time

Lab Time

Lab Time

Building Basic Classes

Lab Time

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Fun with Inheritance

Lab Time

Building Basic Classes

Fun with Inheritance

Magic Methods a.k.a. 007