

## 61A Extra Lecture 6

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# Announcements

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Homework 1 due Monday 10/12 (today)

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Homework 1 due Monday 10/12 (today)

Homework 2 released next Monday 10/19 is due 11/2

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Homework 3 is to complete an extension to Project 4

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- Due at the same time as Project 4!

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Homework 1 due Monday 10/12 (today)

Homework 2 released next Monday 10/19 is due 11/2

Homework 3 is to complete an extension to Project 4

- Due at the same time as Project 4!

Homework 4 Released Monday 11/9, Due 11/23

# Implementing an Object System

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# Implementing an Object System

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**Today's topics:**

# Implementing an Object System

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## **Today's topics:**

- What is a class?

# Implementing an Object System

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- What is a class?
- What is an instance?

# Implementing an Object System

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- What is a class?
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- How do we write code for attribute look-up procedures?

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- What is a class?
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- How do we write code for attribute look-up procedures?

## **Tools we'll use:**

# Implementing an Object System

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## **Today's topics:**

- What is a class?
- What is an instance?
- How do we create inheritance relationships?
- How do we write code for attribute look-up procedures?

## **Tools we'll use:**

- Dispatch dictionaries

# Implementing an Object System

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## **Today's topics:**

- What is a class?
- What is an instance?
- How do we create inheritance relationships?
- How do we write code for attribute look-up procedures?

## **Tools we'll use:**

- Dispatch dictionaries
- Higher-order functions



# The OOP Abstraction Barrier (a.k.a. the Line)

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THE LINE

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Above the Line:

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Above the Line:

- Objects with **local state** & interact via **message passing**

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- Objects are **instantiated** by classes, which are also objects

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Below the Line:



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Below the Line:

- Objects have **mutable dictionaries** of attributes

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Below the Line:

- Objects have **mutable dictionaries** of attributes
- **Attribute look-up for instances** is a function

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THE LINE

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Below the Line:

- Objects have **mutable dictionaries** of attributes
- **Attribute look-up for instances** is a function
- **Attribute look-up for classes** is another function

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## THE LINE

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Below the Line:

- Objects have **mutable dictionaries** of attributes
- **Attribute look-up for instances** is a function
- **Attribute look-up for classes** is another function
- Object **instantiation** is another function

# Implementing the Object Abstraction

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**Fundamental OOP concepts:**

# Implementing the Object Abstraction

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## **Fundamental OOP concepts:**

- Object instantiation and initialization

# Implementing the Object Abstraction

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## **Fundamental OOP concepts:**

- Object instantiation and initialization
- Attribute look-up and assignment



# Implementing the Object Abstraction

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- Attribute look-up and assignment
- Method invocation

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- Attribute look-up and assignment
- Method invocation
- Inheritance

## **Not-so-fundamental issues (that we'll skip):**

# Implementing the Object Abstraction

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## **Fundamental OOP concepts:**

- Object instantiation and initialization
- Attribute look-up and assignment
- Method invocation
- Inheritance

## **Not-so-fundamental issues (that we'll skip):**

- Dot expression syntax

# Implementing the Object Abstraction

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## **Fundamental OOP concepts:**

- Object instantiation and initialization
- Attribute look-up and assignment
- Method invocation
- Inheritance

## **Not-so-fundamental issues (that we'll skip):**

- Dot expression syntax
- Multiple inheritance (on your homework)

# Implementing the Object Abstraction

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## **Fundamental OOP concepts:**

- Object instantiation and initialization
- Attribute look-up and assignment
- Method invocation
- Inheritance

## **Not-so-fundamental issues (that we'll skip):**

- Dot expression syntax
- Multiple inheritance (on your homework)
- Introspection (e.g., what class does this object have?)

# Instances

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Dispatch dictionary with messages 'get' and 'set'



# Instances

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Attributes stored in a local dictionary "attributes"

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Dispatch dictionary with messages 'get' and 'set'

Attributes stored in a local dictionary "attributes"

```
def make_instance(cls):
    """Return a new object instance."""

    def get_value(name):
        if name in attributes:
            return attributes[name]
        else:
            value = cls['get'](name)
            return bind_method(value, instance)

    def set_value(name, value):
        attributes[name] = value

    attributes = {}
    instance = {'get': get_value, 'set': set_value}
    return instance
```


# Instances

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Dispatch dictionary with messages 'get' and 'set'

Attributes stored in a local dictionary "attributes"

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The class of the instance

Match name against  
instance attributes

# Instances

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Dispatch dictionary with messages 'get' and 'set'

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        def set_value(name, value):  
            attributes[name] = value  
  
    attributes = {}  
    instance = {'get': get_value, 'set': set_value}  
    return instance
```

The class of the instance

Match name against instance attributes

Look up the name in the class

# Instances

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Dispatch dictionary with messages 'get' and 'set'

Attributes stored in a local dictionary "attributes"

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def make_instance(cls):  
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    attributes = {}  
    instance = {'get': get_value, 'set': set_value}  
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```

The class of the instance

Match name against  
instance attributes

Look up the name  
in the class

Assignment always  
creates/modifies  
instance attributes

# Bound Methods

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## Bound Methods

---

If looking up a name returns a class attribute value that is a function, `getattr` returns a bound method

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## Bound Methods

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## Bound Methods

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(Demo)

# Classes

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Dispatch dictionaries with messages 'get', 'set', and 'new'

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Dispatch dictionaries with messages 'get', 'set', and 'new'

```
def make_class(attributes={}, base_class=None):
    """Return a new class."""

    def get_value(name):
        if name in attributes:
            return attributes[name]
        elif base_class is not None:
            return base_class['get'](name)

    def set_value(name, value):
        attributes[name] = value

    def new(*args):
        return init_instance(cls, *args)

    cls = {'get': get_value, 'set': set_value, 'new': new}
    return cls
```



# Classes

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Dispatch dictionaries with messages 'get', 'set', and 'new'

```
def make_class(attributes={}, base_class=None):  
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    def get_value(name):  
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            return attributes[name]  
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            return base_class['get'](name)  
  
    def set_value(name, value):  
        attributes[name] = value  
  
    def new(*args):  
        return init_instance(cls, *args)  
  
    cls = {'get': get_value, 'set': set_value, 'new': new}  
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```

The class attribute  
look-up procedure

# Classes

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Dispatch dictionaries with messages 'get', 'set', and 'new'

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The class attribute  
look-up procedure

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    def set_value(name, value):  
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```
    def new(*args):  
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    cls = {'get': get_value, 'set': set_value, 'new': new}  
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# Classes

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Dispatch dictionaries with messages 'get', 'set', and 'new'

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    def get_value(name):  
        if name in attributes:  
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        elif base_class is not None:  
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The class attribute  
look-up procedure

```
    def set_value(name, value):  
        attributes[name] = value
```

Common dispatch  
dictionary pattern

```
    def new(*args):  
        return init_instance(cls, *args)
```

```
    cls = {'get': get_value, 'set': set_value, 'new': new}  
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```

# Instantiation and Initialization

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## Instantiation and Initialization

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First makes a new instance, then invokes the `__init__` method

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def make_class(attributes={}, base_class=None):  
    ...  
    def new(*args):  
        return init_instance(cls, *args)  
    ...  
  
def init_instance(cls, *args):
```

# Instantiation and Initialization

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First makes a new instance, then invokes the `__init__` method

```
def make_class(attributes={}, base_class=None):
    ...
    def new(*args):
        return init_instance(cls, *args)
    ...

def init_instance(cls, *args):
    """Return a new instance of cls, initialized with args."""
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# Instantiation and Initialization

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First makes a new instance, then invokes the `__init__` method

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def make_class(attributes={}, base_class=None):  
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    def new(*args):  
        return init_instance(cls, *args)  
    ...
```

```
def init_instance(cls, *args):  
    """Return a new instance of cls, initialized with args."""  
    instance = make_instance(cls)
```

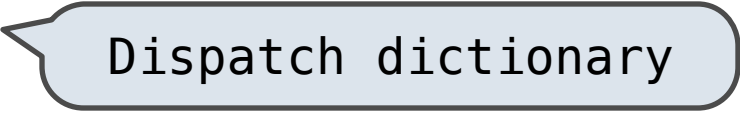
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# Instantiation and Initialization

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First makes a new instance, then invokes the `__init__` method

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    ...  
    def new(*args):  
        return init_instance(cls, *args)  
    ...
```

```
def init_instance(cls, *args):  
    """Return a new instance of cls, initialized with args."""  
    instance = make_instance(cls)  
    init = cls['get']('__init__')
```



Dispatch dictionary

# Instantiation and Initialization

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First makes a new instance, then invokes the `__init__` method

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def make_class(attributes={}, base_class=None):  
    ...  
    def new(*args):  
        return init_instance(cls, *args)  
    ...
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```
def init_instance(cls, *args):  
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Dispatch dictionary

The constructor name  
is fixed here

# Instantiation and Initialization

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First makes a new instance, then invokes the `__init__` method

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def make_class(attributes={}, base_class=None):  
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    def new(*args):  
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```

```
def init_instance(cls, *args):  
    """Return a new instance of cls, initialized with args."""  
    instance = make_instance(cls)  
    init = cls['get']('__init__')  
    if init is not None:
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Dispatch dictionary

The constructor name  
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# Instantiation and Initialization

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First makes a new instance, then invokes the `__init__` method

```
def make_class(attributes={}, base_class=None):  
    ...  
    def new(*args):  
        return init_instance(cls, *args)  
    ...
```

```
def init_instance(cls, *args):  
    """Return a new instance of cls, initialized with args."""  
    instance = make_instance(cls)  
    init = cls['get']('__init__')  
    if init is not None:  
        init(instance, *args)
```

The code snippet for `init_instance` has two callouts:

- A blue dashed box around `make_instance(cls)` points to a callout box containing the text "Dispatch dictionary".
- A blue dashed box around `'__init__'` points to a callout box containing the text "The constructor name is fixed here".

# Instantiation and Initialization

---

First makes a new instance, then invokes the `__init__` method

```
def make_class(attributes={}, base_class=None):  
    ...  
    def new(*args):  
        return init_instance(cls, *args)  
    ...
```

```
def init_instance(cls, *args):  
    """Return a new instance of cls, initialized with args."""  
    instance = make_instance(cls)  
    init = cls['get']('__init__')  
    if init is not None:  
        init(instance, *args)  
    return instance
```

Dispatch dictionary

The constructor name  
is fixed here

# Example: Defining an Account Class

---



# Example: Defining an Account Class

---

(Demo)

## Example: Defining an Account Class

---

```
def make_account_class():          (Demo)

    interest = 0.02

    def __init__(self, account_holder):
        self['set']('holder', account_holder)
        self['set']('balance', 0)

    def deposit(self, amount):
        new_balance = self['get']('balance') + amount
        self['set']('balance', new_balance)
        return self['get']('balance')

    def withdraw(self, amount):
        balance = self['get']('balance')
        if amount > balance:
            return 'Insufficient funds'
        self['set']('balance', balance - amount)
        return self['get']('balance')

    return make_class(locals())

Account = make_account_class()
```

## Example: Defining an Account Class

---

```
def make_account_class():          (Demo)

    interest = 0.02

    def __init__(self, account_holder):
        self['set']('holder', account_holder)
        self['set']('balance', 0)

    def deposit(self, amount):
        new_balance = self['get']('balance') + amount
        self['set']('balance', new_balance)
        return self['get']('balance')

    def withdraw(self, amount):
        balance = self['get']('balance')
        if amount > balance:
            return 'Insufficient funds'
        self['set']('balance', balance - amount)
        return self['get']('balance')

    return make_class(locals())

Account = make_account_class()
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## Example: Using the Account Class

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The Account class is instantiated and stored, then messaged

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The Account class is instantiated and stored, then messaged

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
```

## Example: Using the Account Class

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The Account class is instantiated and stored, then messaged

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['get']('holder')
'Jim'
```

## Example: Using the Account Class

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The Account class is instantiated and stored, then messaged

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['get']('holder')
'Jim'
>>> jim_acct['get']('interest')
0.02
```



## Example: Using the Account Class

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The Account class is instantiated and stored, then messaged

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['get']('holder')
'Jim'
>>> jim_acct['get']('interest')
0.02
>>> jim_acct['get']('deposit')(20)
20
```

## Example: Using the Account Class

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The Account class is instantiated and stored, then messaged

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['get']('holder')
'Jim'
>>> jim_acct['get']('interest')
0.02
>>> jim_acct['get']('deposit')(20)
20
>>> jim_acct['get']('withdraw')(5)
15
```

## Example: Using the Account Class

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The Account class is instantiated and stored, then messaged

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['get']('holder')
'Jim'
>>> jim_acct['get']('interest')
0.02
>>> jim_acct['get']('deposit')(20)
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>>> jim_acct['get']('withdraw')(5)
15
```

How can we also use getattr and setattr style syntax?

# Class and Instance Attributes

---

Instance attributes and class attributes can share names

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```
>>> Account = make_account_class()
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# Class and Instance Attributes

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# Class and Instance Attributes

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Instance attributes and class attributes can share names

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['set']('interest', 0.08)
```

# Class and Instance Attributes

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Instance attributes and class attributes can share names

```
>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['set']('interest', 0.08)
>>> Account['get']('interest')
0.02
```



# Class and Instance Attributes

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Instance attributes and class attributes can share names

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>>> Account = make_account_class()
>>> jim_acct = Account['new']('Jim')
>>> jim_acct['set']('interest', 0.08)
>>> Account['get']('interest')
0.02
```

(Demo)

## Example: Using Inheritance

---

CheckingAccount is a special case of Account

## Example: Using Inheritance

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CheckingAccount is a special case of Account

(Demo)

## Example: Using Inheritance

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CheckingAccount is a special case of Account

```
def make_checking_account_class():  
    interest = 0.01  
    withdraw_fee = 1  
  
    def withdraw(self, amount):  
        fee = self['get']('withdraw_fee')  
        return Account['get']('withdraw')(self, amount + fee)  
  
    return make_class(locals(), Account)  
  
CheckingAccount = make_checking_account_class()
```

(Demo)

## Example: Using Inheritance

---

CheckingAccount is a special case of Account

```
def make_checking_account_class():  
    interest = 0.01  
    withdraw_fee = 1  
  
    def withdraw(self, amount):  
        fee = self['get']('withdraw_fee')  
        return Account['get']('withdraw')(self, amount + fee)  
  
    return make_class(locals(), Account)  
CheckingAccount = make_checking_account_class()
```

(Demo)

## Relationship to the Python Object System

---

Object attributes are stored as dictionaries

Some "magic" names, `__<name>__`, require special handling

An object has an "attribute" called `__dict__` that is a dictionary of its user-defined instance attributes

(Demo)

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(Demo)

In Python, classes have classes too

The equivalent of `init_instance` can be customized (metaclass)