Inheritance 1

- *Inheritance* allows us to reuse the code of an existing class `B` in creating a new class `C`
- Let's recap how the attribute lookup worked for classes
- When looking for an attribute, the lookup procedure starts with the instance dictionary, and continues with the class attributes
- If both fail, then the attribute is searched from the base classes and, recursively, from their base classes

Inheritance 2

- So, it may look like we access an attribute of a class `C`, when in reality we are accessing the attribute of its base class `B`
- In this case we say that the class `C` *inherits* the attribute from its base class `B`
- If we have attributes with the same name in both the class and its base class, the attribute of the base class is hidden
- We say that the class `C` *overrides* the attribute of the base class `B`
- Terminology: `B` is a *base class* and `C` is a *derived class*

Inheritance 3

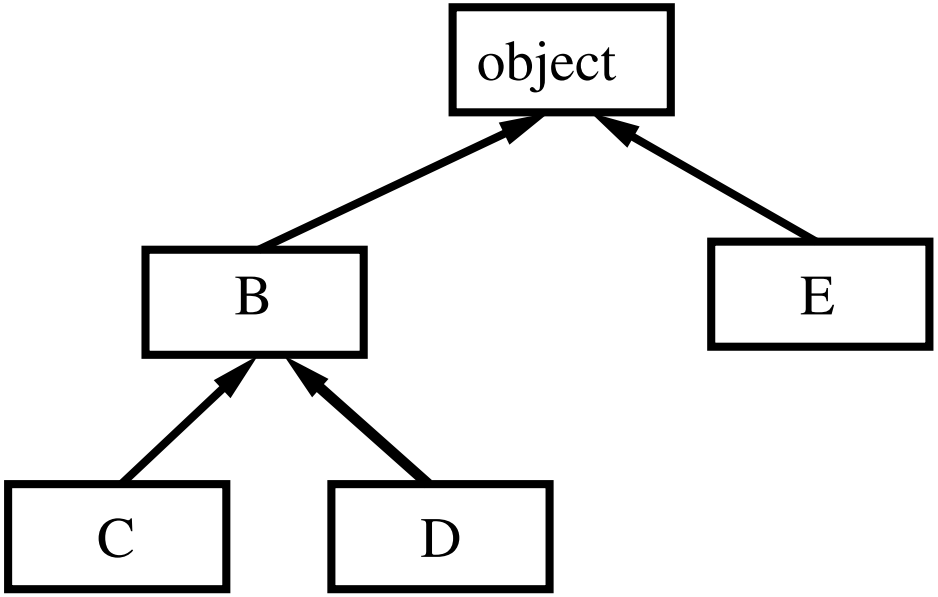
- Example:

```
class B(object):
    def f(self):
        print "Executing B.f"
    def g(self):
        print "Executing B.g"

class C(B):
    def g(self):
        print "Executing C.g"

x=C()
x.f()      # inherited from B
x.g()      # overridden by C
```

Relation of base and derived classes

- A derived class is sometimes also called a *subclass* and the base class is called *super class*
- The inheritance relation of two classes `B` and `C` can be tested with function `issubclass`: `issubclass(C,B)==True` but `issubclass(B,C)==False`
- Function `isinstance(obj, cls)` allows us to test whether an instance has type `cls` or has an *ancestor* class of type `cls`
- Let's create instances `x=C()` and `y=B()`
- Now we have `isinstance(x,B)==isinstance(x,C)==isinstance(y,B)==True`
- But `isinstance(y,C)==False`

Inheritance hierarchy



- object should be a base class or an ancestor class of every other class
- This means that `isinstance(x, object)==True` for all instances `x`

Use of inheritance

- By deriving from an existing class we can modify and/or extend its behaviour, without touching the original class
- For example, if we want to add one method to a `list` class, we can use inheritance. Therefore we have to only code the part that has changed and reuse the rest of the code of type list
- Another use of inheritance is to create conceptual *hierarchies*. For instance, later we will learn about the exception hierarchy of Python
- Third use would be to use classes to create *interfaces*. There can be several classes that have same interface (that is, they offer the same attributes), but their behaviour or implementation can be very different. This allows changing a part of your program with minimal changes required elsewhere in the code

Multiple inheritance

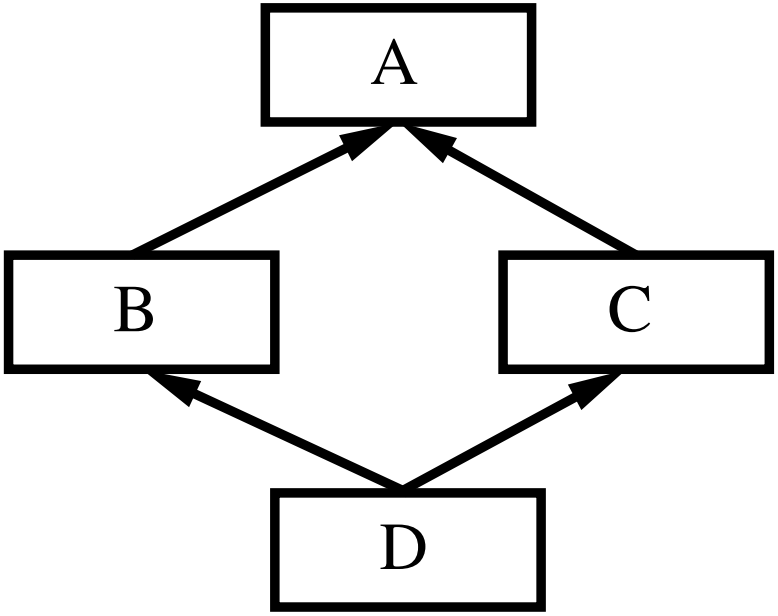
- A class can have several base classes:

  ```
  class Derived(Base1, Base2, ..., Basen):
  ```

- This is called *multiple inheritance*, which is sometimes useful but it also creates problems
- Your class can usually only inherit from one stardard type at the same time
- For instance, if you try to derive from both `list` and `dict` the result would be ambiguous
- Another problem is when the inheritance hierarchy is not tree-shaped

Diamond shaped inheritance graph 1

- The class `A` is now an ancestor of `D` through both `B` and `C` classes




```
class A(object):
    def f(self):
        print "A"
class B(A):
    pass
class C(A):
    def f(self):
        print "C"
class D(B, C):
    pass
x=D()
x.f()  # what will this print
```

Diamond shaped inheritance graph 2

- Will the call `x.f()` refer to `A.f` or `C.f`?
- The order in which base classes are visited is called *Method Resolution Order* (MRO)
- Normally the lookup proceeds in left-to-right, depth-first order
- But in the diamond case we would meet `A.f` before `C.f`
- Extra rule: if a base class can be reached through many paths, the right-most path is chosen
- Therefore we will first see `C.f` which hides `A.f`

Referring to base class attributes

- If in the definition of the method `C.f` we need to call the corresponding method of class `A`, we can use the fully qualified call `A.f(...)`
- This is called *delegation*
- It is useful, for instance, when you want to call the `__init__` method of the base class from the `__init__` of the derived class to initialise the base class attributes

Class-level methods 1

- Python provides two types of *class-level methods*. That is, methods that don't need to refer to any instance; they don't have `self` as the first parameter
- Usually all functions defined inside a class body are assumed to be normal methods
- A normal method can be turned into a *static method* by calling the builtin type `staticmethod`:

```
class C(object):
    def f():
        print "Executing static method"
    f=staticmethod(f)
x=C()
C.f()    # can be called without an instance
x.f()    # But also works through an instance
```

Class-level methods 2

- Another class-level method, in addition to static method, is called *class method*
- It can be created with the type call `classmethod`
- A class method will have a special first parameter, which refers to the class of the method. This parameter is usually named `cls`

```
class C(object):
    def f(cls):
        print ("Executing class method of class %s" %
               cls)
    f=classmethod(f)
x=C()
C.f()    # can be called without an instance
x.f()    # But also works through an instance
```

Controlling attribute access

- *Descriptors* are a way to control the access to attributes
- Instead of using a normal attribute, we can use an instance of a descriptor class in place of the attribute
- When we access the descriptor attribute, we are actually calling certain methods of the descriptor.
- The methods for reading, setting, and deleting an attribute are `__get__`, `__set__`, and `__delete__`, respectively

Descriptors 1

- The following descriptor class makes sure that we don't assign a negative value to the corresponding attribute:

```
class Nonnegative(object):
    def __get__(self, x, C):
        print "Executing get"
        return x._v
    def __set__(self, x, value):
        print "Executing set"
        if value < 0:
            raise ValueError
        x._v=value
```

Descriptors 2

- Let's make the attribute a for a class C using the Nonnegative descriptor and then try to use it:

```
class C(object):
    _v = 2
    v = Nonnegative()
x = C()
y = C()
x.v = 3  # will execute the __set__ method
y.v = 5
x.v      # will execute the __get__ method
y.v
x.v = -2 # will cause an error
```

Properties

- A *property* is an attribute of an instance that triggers special function calls when the attribute is read, set or deleted
- One can create properties with the type call `property(fget, fset, fdel, doc)` and binding the return value to an attribute name
- The functions `fget`, `fset` and `fdel` will be called when corresponding operations, reading, setting, or deleting the attribute are tried
- Properties are actually more user friendly versions of descriptors: we don't have to create a separate descriptor class

Creating a property

- An example of creating a property a for the class C

```
class C(object):
    def __init__(self, value):
        self.a_ = value
    def seta(self, value):
        if value < 0:
            raise ValueError
        self.a_ = value
    def geta(self):
        return self.a_
    a = property(geta, seta)
```

Accessing a property

- Let's try to access the attribute a of an instance x:

```
>>> x=C(2)
>>> x.a
2
>>> x.a=5
>>> x.a
5
>>> x.a = -2    # this will cause an error
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "property.py", line 8, in seta
    def geta(self):
ValueError
```

Properties with synthetic attributes 1

- An example of an attribute whose value is computed when needed

```
class Rectangle(object):
    def __init__(self, w, h):
        self.width = w
        self.height = h

    def getarea(self):
        print "Executing getarea"
        return self.width * self.height
    area = property(getarea,
                    doc="Computes the area on the fly")
```

Properties with synthetic attributes 2

- Let's try to access this attribute:

```
>>> r=Rectangle(4,5)
>>> r.area
20
>>> Rectangle.area.__doc__
'Computes the area on the fly'
```

Special methods

- We have already encountered one *special method*, namely the `__init__` method
- This method sets the instance attributes to some initial value
- Its first parameter is the `self`, and the subsequent parameters are the ones that were passed to the call of the class
- The `__init__` method should return no value
- In the following slides the main general purpose special methods are introduced
- They are executed when certain operations on objects are performed

General purpose special methods 1

- In the following, `C` is a class and `x` and `y` are its instances
- `__hash__` returns an `int` value, with the following requirement: `x==y` implies `x.__hash__() == y.__hash__()`. The value is used in storing objects in dictionaries and sets. The instances `x` and `y` must be immutable
- A class with `__call__` method makes its instances *callable*. I.e. the call `x(a,b, ...)` will result in calling this special method with the given parameters
- The method `__del__` gets called when the corresponding instance gets deleted
- Method `__new__` is used to control the creation of new instances. It can be used, for example, to create classes that have only one instance.

General purpose special methods 2

- The method `__str__` is called when the print statement needs to print the value of an instance. It returns a string. The print-format expression calls this for conversion `%s`
- The method `__repr__` is called when the interactive interpreter prints the value of an evaluated expression, and when the conversion `%r` for print-format expression is used. Returns a canonical representation string that (at least in theory) can be used to recreate the original object.
- Special methods `__eq__`, `__ge__`, `__gt__`, `__le__`, `__lt__`, and `__ne__` get called when the corresponding operators `x==y`, `x>=y`, `x>y`, `x<=y`, `x<y`, and `x!=y` are used