

Using Inheritance

- Let's build an application that organizes info about people!
 - Person: name, birthday
 - Get last name
 - Sort by last name
 - Get age

Building a class

```
import datetime

class Person(object):
    def __init__(self, name):
        """create a person called name"""
        self.name = name
        self.birthday = None
        self.lastName = name.split(' ')[-1]

    def getLastName(self):
        """return self's last name"""
        return self.lastName

    # other methods

    def __str__(self):
        """return self's name"""
        return self.name
```

Building a class (more)

```
import datetime

class Person(object):
    def __init__(self, name):
        """create a person called name"""
        self.name = name
        self.birthday = None
        self.lastName = name.split(' ')[-1]

    def setBirthday(self, month, day, year):
        """sets self's birthday to birthDate"""
        self.birthday = datetime.date(year, month, day)

    def getAge(self):
        """returns self's current age in days"""
        if self.birthday == None:
            raise ValueError
        return (datetime.date.today() - self.birthday).days

# other methods
```

How `plist.sort()` works

- Python uses the timsort algorithm for sorting sequences
 - a highly-optimized combination of merge and insertion sorts that has very good average case performance
- The only knowledge needed about the objects being sorted is the result of a “less than” comparison between two objects
- Python interpreter translates `obj1 < obj2` into a method call on `obj1` \rightarrow `obj1.__lt__(obj2)`
- To enable sort operations on instances of a class, implement the `__lt__` special method

Building a class (more)

```
import datetime

class Person(object):
    def __init__(self, name):
        """create a person called name"""
        self.name = name
        self.birthday = None
        self.lastName = name.split(' ')[-1]

    def __lt__(self, other):
        """return True if self's ame is lexicographically
           less than other's name, and False otherwise"""
        if self.lastName == other.lastName:
            return self.name < other.name
        return self.lastName < other.lastName

# other methods

def __str__(self):
    """return self's name"""
    return self.name
```

Using Inheritance

- Let's build an application that organizes info about people!
 - Person: name, birthday
 - Get last name
 - Sort by last name
 - Get age
 - MITPerson: Person + ID Number
 - Assign ID numbers in sequence
 - Get ID number
 - Sort by ID number

Building inheritance

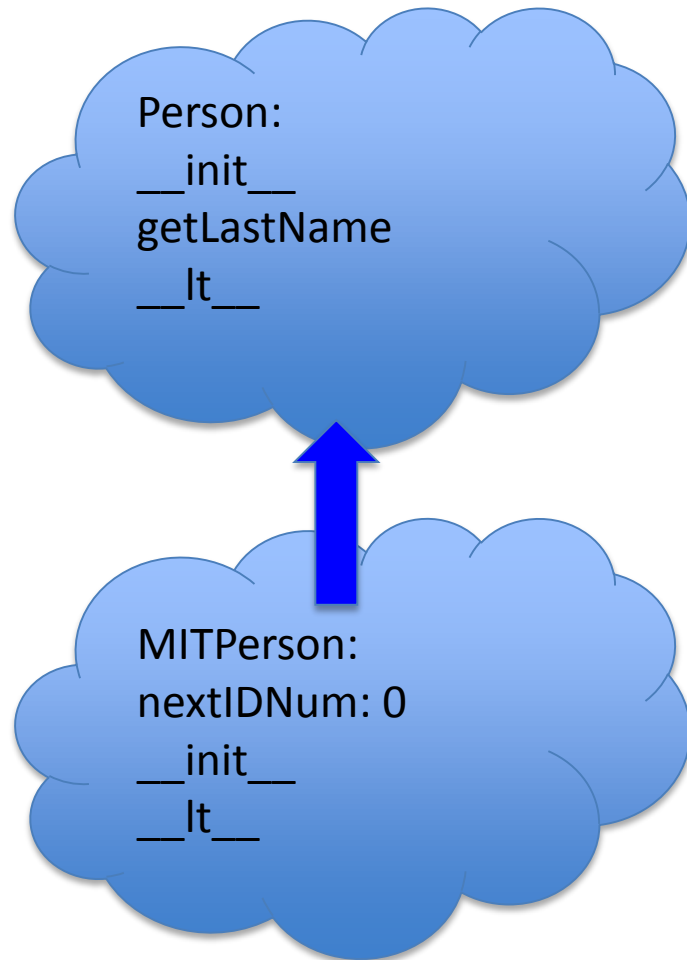
```
class MITPerson(Person):
    nextIdNum = 0 # next ID number to assign

    def __init__(self, name):
        Person.__init__(self, name) # initialize Person
attributes
        # new MITPerson attribute: a unique ID number
        self.idNum = MITPerson.nextIdNum
        MITPerson.nextIdNum += 1

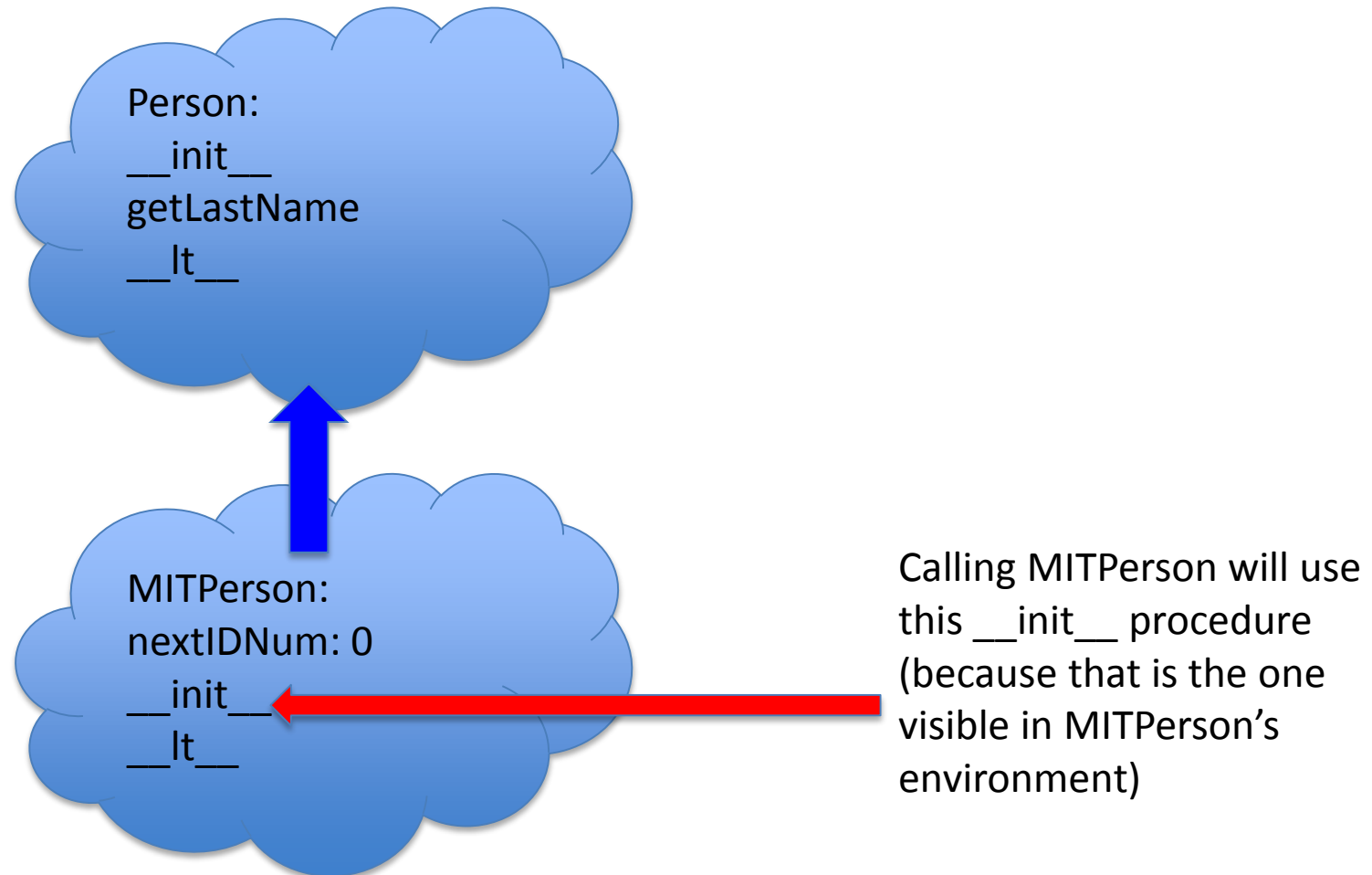
    def getIdNum(self):
        return self.idNum

# sorting MIT people uses their ID number, not name!
def __lt__(self, other):
    return self.idNum < other.idNum
```

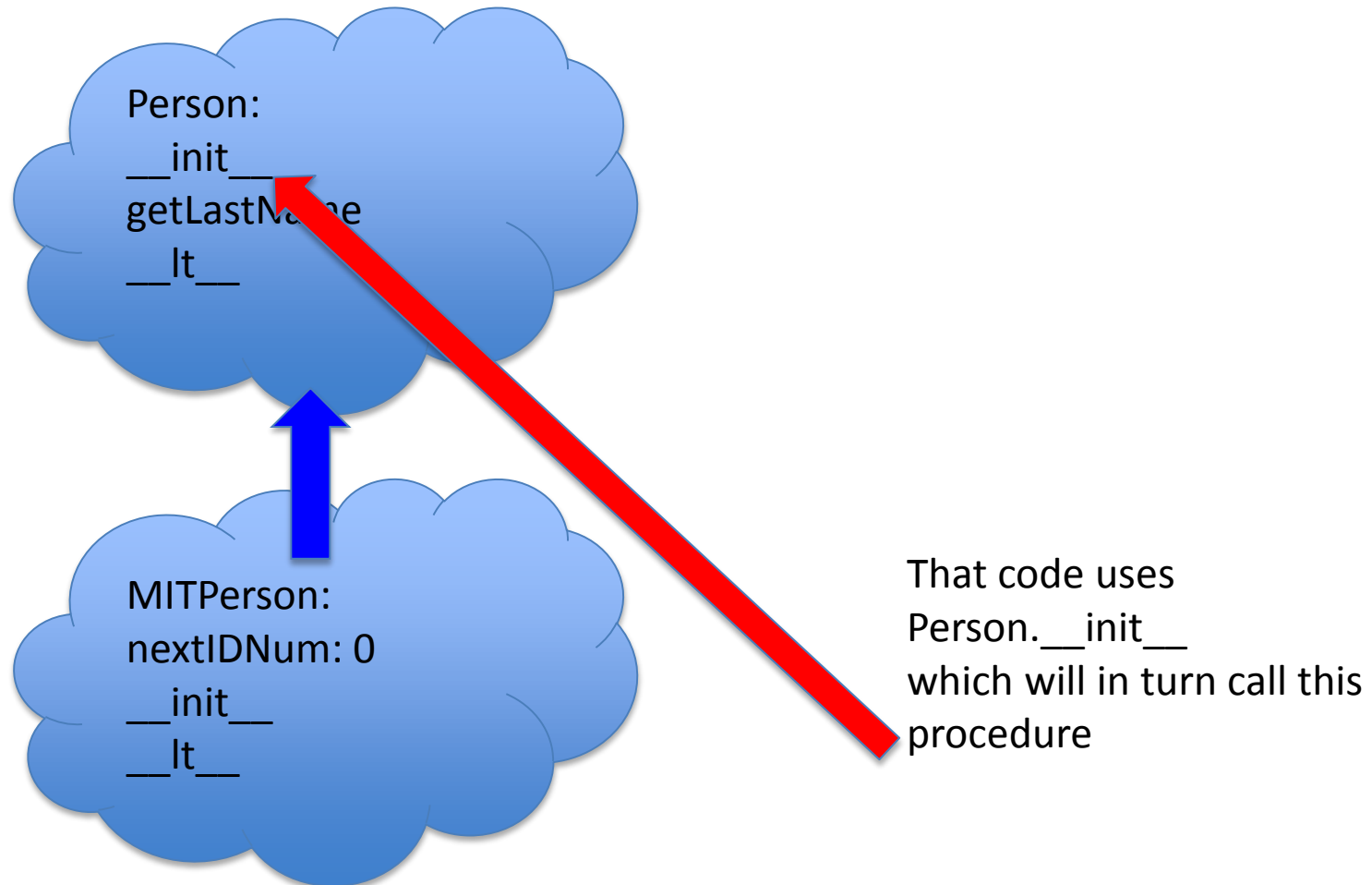
Visualizing the hierarchy



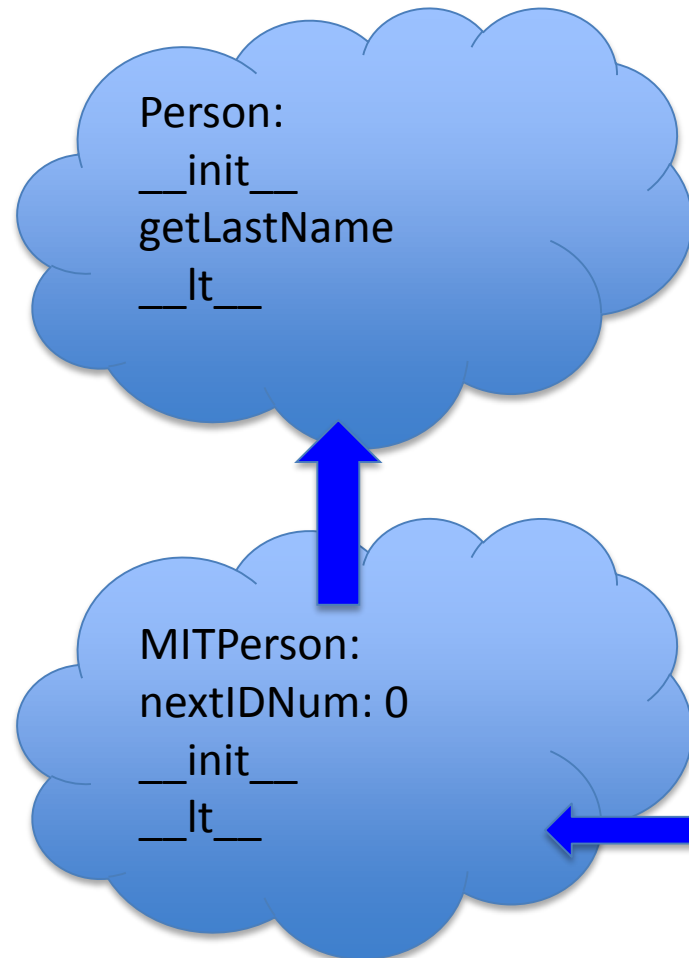
Visualizing the hierarchy



Visualizing the hierarchy



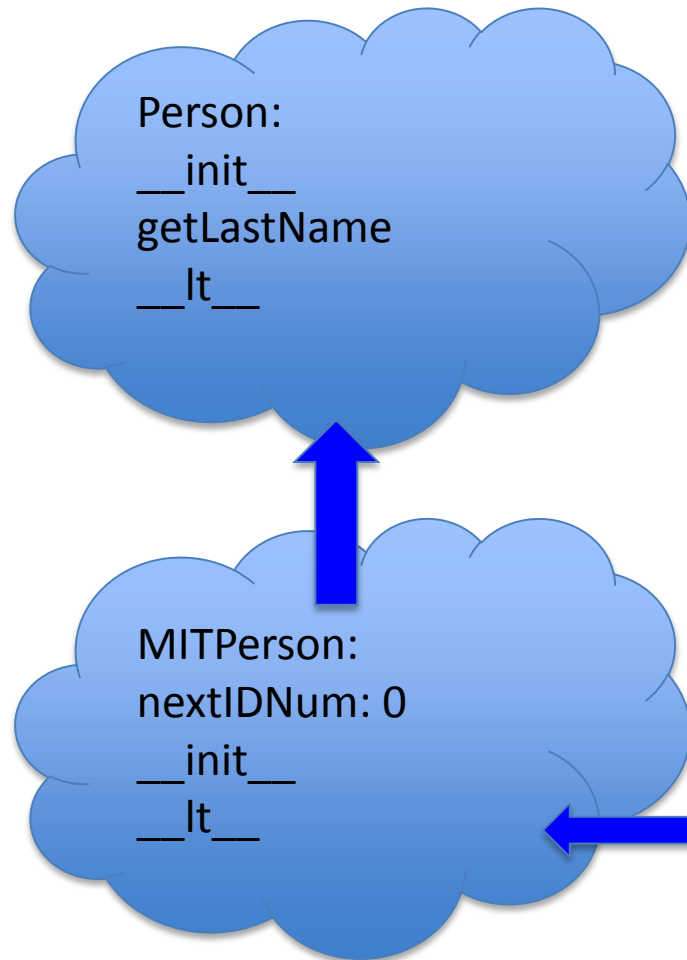
Visualizing the hierarchy



And that creates an instance of `MITPerson` (because of the first call, which inherits from the class definition) but with bindings set by the inherit `__init__` code

name	
birthday	
lastName	

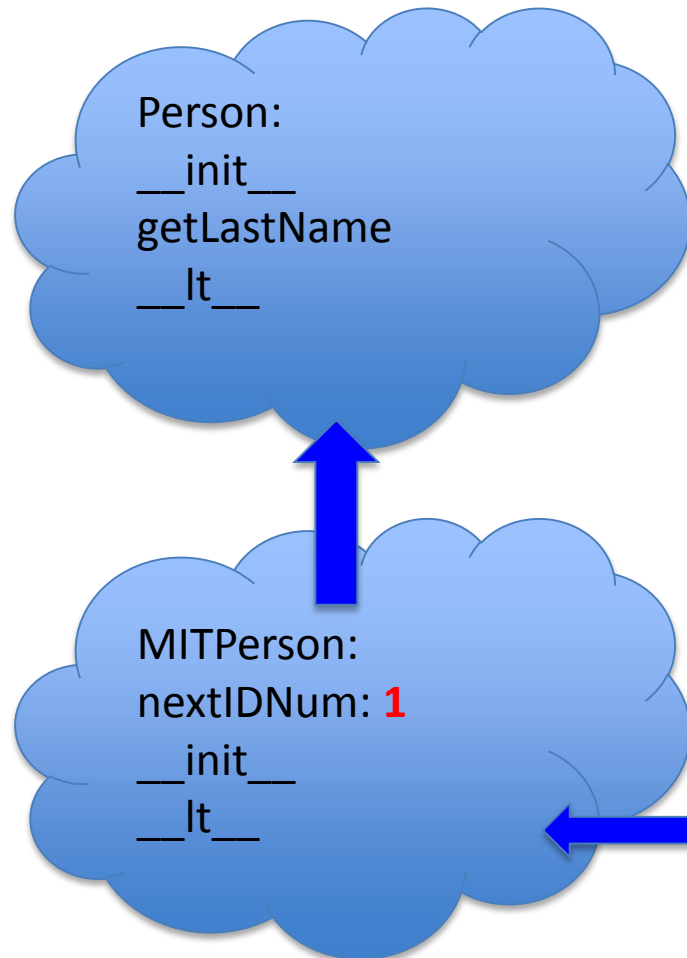
Visualizing the hierarchy



The rest of the original `__init__` code calls
`self.idNum = MITPerson.nextIDNum`
which looks up `nextIDNum` in the `MITPerson` environment, and creates a binding in `self` (i.e. the instance)

name	
birthday	
lastName	
idNum	0

Visualizing the hierarchy



The rest of the original `__init__` code calls
`self.idNum = MITPerson.nextIDNum`
which looks up `nextIDNum` in the MITPerson environment, and creates a binding in self (i.e. the instance)
And then updates `nextIDNum` in the MITPerson environment

name	
birthday	
lastName	
idNum	0

Examples of using this hierarchy

```
p1 = MITPerson( 'Eric' )
```

```
p2 = MITPerson( 'John' )
```

```
p3 = MITPerson( 'John' )
```

```
p4 = Person( 'John' )
```

Visualizing the hierarchy

p1	
p2	
p3	
p4	

name	Eric
birthday	
lastName	
idNum	0

name	John
birthday	
lastName	
idNum	1

name	John
birthday	
lastName	

name	John
birthday	
lastName	
idNum	2

Suppose we want to compare things

- Note that MITPerson has its own `__lt__` method
- This method “shadows” the Person method, meaning that if we compare an MITPerson object, since its environment inherits from the MITPerson class environment, Python will see this version of `__lt__` not the Person version
- Thus, `p1 < p2` will be converted into `p1.__lt__(p2)` which applies the method associated with the type of `p1`, or the MITPerson version

Who inherits

- Why does `p4 < p1` work, but `p1 < p4` doesn't?
 - `p4 < p1` is equivalent to `p4.__lt__(p1)`, which means we use the `__lt__` method associated with the type of `p4`, namely a `Person` (the one that compares based on name)
 - `p1 < p4` is equivalent to `p1.__lt__(p4)`, which means we use the `__lt__` method associated with the type of `p1`, namely an `MITPerson` (the one that compares based on `IDNum`) and since `p4` is a `Person`, it does not have an `IDNum`

Using Inheritance

- Let's build an application that organizes info about people!
 - Person: name, birthday
 - Get last name
 - Sort by last name
 - Get age
 - MITPerson: Person + ID Number
 - Assign ID numbers in sequence
 - Get ID number
 - Sort by ID number
 - Students: several types, all MITPerson
 - Undergraduate student: has class year
 - Graduate student

More classes for the hierarchy

```
class UG(MITPerson):  
    def __init__(self, name, classYear):  
        MITPerson.__init__(self, name)  
        self.year = classYear
```

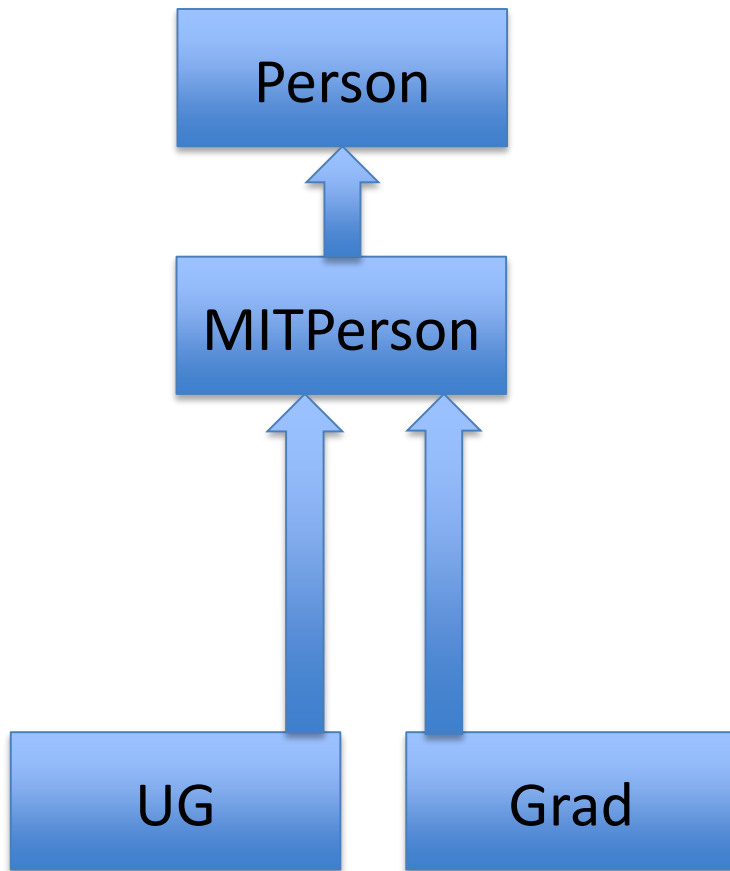
```
    def getClass(self):  
        return self.year
```

```
class Grad(MITPerson):  
    pass
```

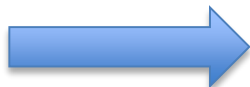
```
def isStudent(obj):  
    return isinstance(obj, UG) or  
    isinstance(obj, Grad)
```

Class Hierarchy & Substitution Principle

- Here's a diagram showing our class hierarchy



Subclass



Superclass

Cleaning up the hierarchy

```
class UG(MITPerson):  
    def __init__(self, name, classYear):  
        MITPerson.__init__(self, name)  
        self.year = classYear
```

```
    def getClass(self):  
        return self.year
```

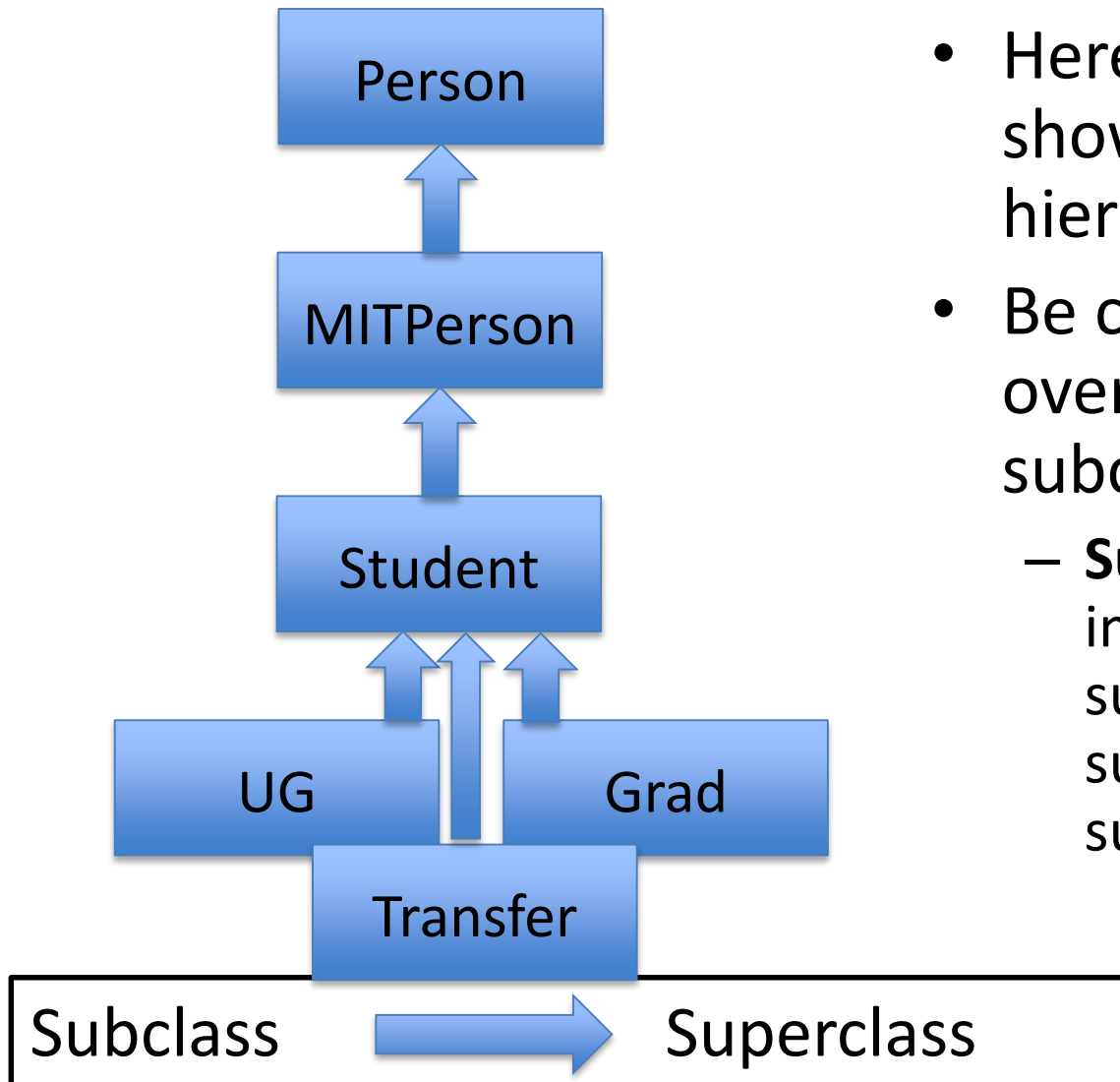
```
class Grad(MITPerson):  
    pass
```

```
class TransferStudent(MITPerson):  
    pass
```

```
def isStudent(obj):  
    return isinstance(obj, UG) or isinstance(obj, Grad)
```

Now I have to rethink
isStudent

Class Hierarchy & Substitution Principle



- Here's a diagram showing our class hierarchy
- Be careful when overriding methods in a subclass!
 - **Substitution principle:** important behaviors of superclass should be supported by all subclasses

Cleaning up the hierarchy

```
class Student(MITPerson):  
    pass  
  
class UG(Student):  
    def __init__(self, name, classYear):  
        MITPerson.__init__(self, name)  
        self.year = classYear  
  
    def getClass(self):  
        return self.year  
  
class Grad(Student):  
    pass  
  
class TransferStudent(Student):  
    pass  
  
def isStudent(obj):  
    return isinstance(obj, Student)
```

Better is to create a superclass that covers all students

In general, creating a class in the hierarchy that captures common behaviors of subclasses allows us to concentrate methods in a single place, and lets us think about subclasses as a coherent whole

Example class: A Gradebook

- Create class that includes instances of other classes within it
- Concept:
 - Build a data structure that can hold grades for students
 - Gather together data and procedures for dealing with them in a single structure, so that users can manipulate without having to know internal details

Example: A Gradebook

```
class Grades(object):
    """A mapping from students to a list of grades"""
    def __init__(self):
        """Create empty grade book"""
        self.students = [] # list of Student objects
        self.grades = {} # maps idNum -> list of grades
        self.isSorted = True # true if self.students is
sorted
                                sorted

    def addStudent(self, student):
        """Assumes: student is of type Student
        Add student to the grade book"""
        if student in self.students:
            raise ValueError('Duplicate student')
        self.students.append(student)
        self.grades[student.getIdNum()] = []
        self.isSorted = False
```

Example: A Gradebook

```
class Grades(object):

    def addGrade(self, student, grade):
        """Assumes: grade is a float
           Add grade to the list of grades for student"""
        try:
            self.grades[student.getIdNum()].append(grade)
        except KeyError:
            raise ValueError('Student not in grade book')

    def getGrades(self, student):
        """Return a list of grades for student"""
        try:    # return copy of student's grades
            return self.grades[student.getIdNum()][:]
        except KeyError:
            raise ValueError('Student not in grade book')
```

Example: A Gradebook

```
class Grades(object):  
  
    def allStudents(self):  
        """Return a list of the students in the grade book"""  
        if not self.isSorted:  
            self.students.sort()  
            self.isSorted = True  
        return self.students[:]  
        #return copy of list of students
```

Using a gradebook without knowing internal details

```
def gradeReport(course):  
    """Assumes: course if of type grades"""  
    report = []  
    for s in course.allStudents():  
        tot = 0.0  
        numGrades = 0  
        for g in course.getGrades(s):  
            tot += g  
            numGrades += 1  
        try:  
            average = tot/numGrades  
            report.append(str(s) + '\ 's mean grade is '  
                          + str(average))  
        except ZeroDivisionError:  
            report.append(str(s) + ' has no grades')  
    return '\n'.join(report)
```

Setting up an example

```
ug1 = UG('Jane Doe', 2014)
ug2 = UG('John Doe', 2015)
ug3 = UG('David Henry', 2003)
g1 = Grad('John Henry')
g2 = Grad('George Steinbrenner')

six00 = Grades()
six00.addStudent(g1)
six00.addStudent(ug2)
six00.addStudent(ug1)
six00.addStudent(g2)

for s in six00.allStudents():
    six00.addGrade(s, 75)
six00.addGrade(g1, 100)
six00.addGrade(g2, 25)

six00.addStudent(ug3)
```

Using this example

- I could list all students using

```
for s in six00.allStudents():  
    print s
```
- This prints out the list of student names sorted by idNum
- Why not just do

```
for s in six00.students:  
    print s
```
- This violates the data hiding aspect of an object, and exposes internal representation
 - If I were to change how I want to represent a grade book, I should only need to change the methods within that object, not external procedures that use it

Comments on the example

- Nicely separates collection of data from use of data
- Access is through methods associated with the gradebook object
- But current version is inefficient – to get a list of all students, I create a copy of the internal list
 - Let's me manipulate without change the internal structure
 - But expensive in a MOOC with 100,000 students

Generators

- Any procedure or method with a `yield` statement is called a **generator**

```
def genTest():  
    yield 1  
    yield 2
```

- `genTest()` → `<generator object genTest at 0x201b878>`
- Generators have a `next()` method which starts/resumes execution of the procedure. Inside of generator:
 - `yield` suspends execution and returns a value
 - Returning from a generator raises a `StopIteration` exception

Using a generator

```
>>> foo = genTest()
```

```
>>> foo.next()  
1
```

Execution will proceed in body of foo, until reaches first yield statement; then returns value associated with that statement

```
>>> foo.next()  
2
```

Execution will resume in body of foo at point where stop, until reaches next yield statement; then returns value associated with that statement

```
>>> foo.next()
```

Results in a StopIteration exception

Using generators

- We can use a generator inside a looping structure, as it will continue until it gets a `StopIteration` exception:

```
>>> for n in genTest():  
        print n
```

```
1
```

```
2
```

```
>>>
```

A fancier example:

```
def genFib():  
    fibn_1 = 1 #fib(n-1)  
    fibn_2 = 0 #fib(n-2)  
    while True:  
        # fib(n) = fib(n-1) + fib(n-2)  
        next = fibn_1 + fibn_2  
        yield next  
        fibn_2 = fibn_1  
        fibn_1 = next
```

A fancier example

- Evaluating

```
fib = genFib()
```

- creates a generator object

- Calling

```
fib.next()
```

- will return the first Fibonacci number, and subsequence calls will generate each number in sequence

- Evaluating

```
for n in genFib():  
    print n
```

- will produce all of the Fibonacci numbers (an infinite sequence)

Why generators?

- A generator separates the concept of computing a very long sequence of objects, from the actual process of computing them explicitly
- Allows one to generate each new objects as needed as part of another computation (rather than computing a very long sequence, only to throw most of it away while you do something on an element, then repeating the process)

Fix to Grades class

```
def allStudents(self):  
    if not self.isSorted:  
        self.students.sort()  
        self.isSorted = True  
    return self.students[:]  
    #return copy of list of students
```

Before

```
def allStudents(self):  
    if not self.isSorted:  
        self.students.sort()  
        self.isSorted = True  
    for s in self.students:  
        yield s
```

After