Inheritance

Inheritance, encapsulation, abstraction, and polymorphism are the four fundamental concepts of object-oriented programming.

Inheritance is a ***design pattern*** that enables new classes to receive—or *inherit*—the properties and methods of existing classes. You have seen that an object is a self-contained component that contains properties and methods needed to model a certain real-world object. You have also seen that a **class is a blueprint** or template to build a specific type of object and that every object is built from an associated class definition. You've also seen that you can use composition to define relationships between classes.

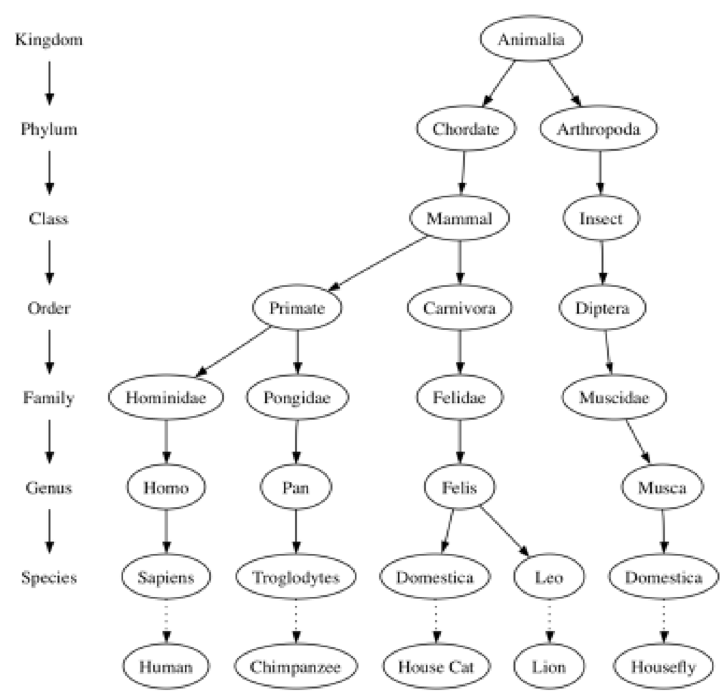
Inheritance is an alternate way to express a relationship between classes. It's a way of saying: I want to build a new class that contains all of the data and behaviors of an existing class, and instead of creating the new class from scratch, I want to reference the existing class in the new class' definition and simply indicate what's different.

Using the two basic concepts of inheritance

- subclassing (making a new class based on a previous one) and
- overriding (changing how a previous class works)

you can organize your objects into a hierarchy. Leveraging this hierarchy and overridden behaviors allows us to achieve polymorphism (we'll get to this). Using inheritance to make this hierarchy often creates easier to understand code, but most importantly it allows you to reuse and organize code more effectively.

In object-oriented programming, inheritance enables new objects to take on the properties of existing objects. A class that is used as the basis for inheritance is called a ***superclass*** or ***base class***. A class that inherits from a superclass is called a ***subclass*** or ***derived class***. The terms *parent* and *child* are also acceptable terms you may encounter and serve as somewhat accurate analogies for the concept of inheritance.



A child class inherits properties and methods from its parent similar to how human children inherit DNA code from their human parents. The hierarchies you can create in this fashion are similar to class hierarchies in the field of biological taxonomy, where the species in the lower levels of the hierarchy share characteristics with the species in the levels above. The items at the higher levels are ***more general*** (and may not even have concrete examples), while the items at the lower levels are more specific. Forks on the tree can happen at any level. In programming we use the term ***abstraction*** when talking about the higher levels of inheritance.

"Is a" vs "Has a" relationship

The composition design pattern exhibited "has a" relationships

- An Employee **has a** hired date
- A Patient **has a** primary physician
- A physician **has a** list of specialties
- An engine **has a** starter
- A Character **has a** collection of items
- A FoodTruck order **has a** Customer

The inheritance design pattern exhibits "is a" relationships. A subclass is a more specific instance of its superclass.

- A Doctor **is an** Employee
- A warlock **is a** character
- A sword **is a** weapon
- A lion **is a** mammal
- A rectangle **is a** polygon
- A square **is a** polygon

If the **is a** relationship does not exist between a subclass and superclass, you should not use inheritance. A sword **is a weapon**; so, it is okay to write a ***Sword*** class that is a subclass of a ***Weapon*** class. As a contrast, a kitchen **has a** sink. It would not make sense to say a kitchen **is a** sink or that a sink **is a** kitchen. The **has a** relationship indicates composition rather than inheritance.

Inheritance allows you to reuse data and behavior from the parent class. If you notice that several classes share the same data and/or behavior, you can pull that out into a parent class. This is called ***generalization***. For example, Customers and Employees are both people so it makes sense to use the general Person class as seen below.

Inheritance is also useful for ***specialization*** which is when you want most of the behavior of a parent class but want to do at least one thing differently and/or add more data. The example below can also be seen as specialization. An employee is a person but also has a unique id. A customer is a person, but also has a credit card.

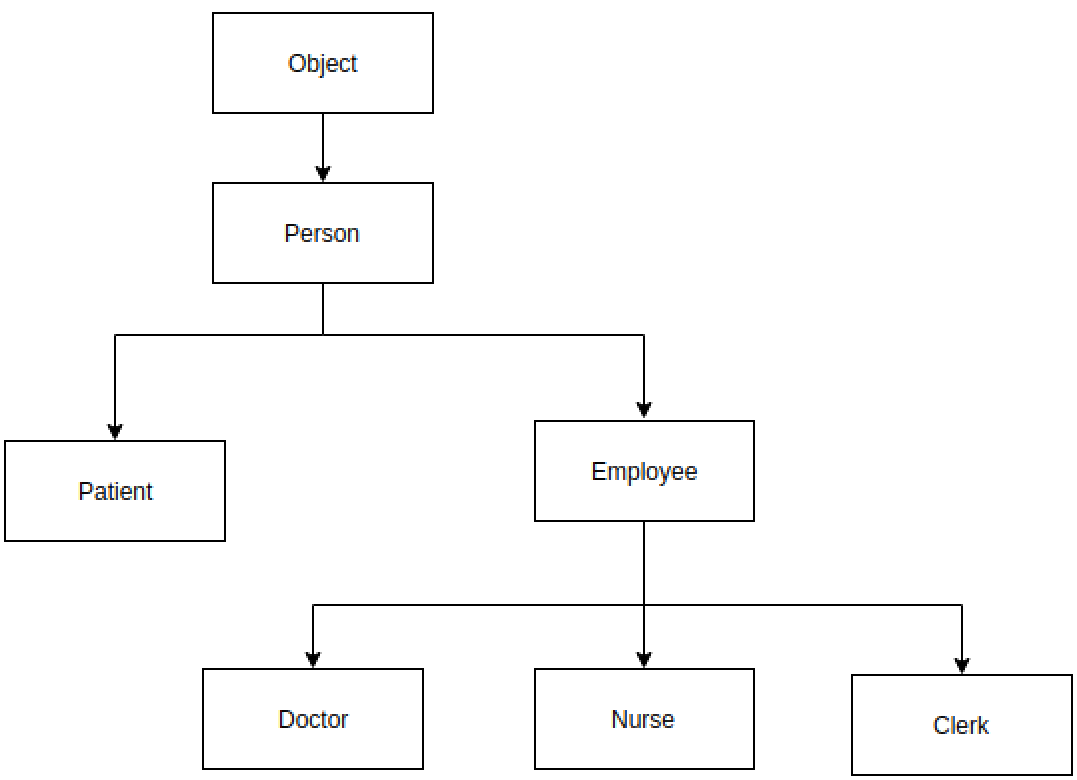
Example: Doctor's Appointments

You've been asked to design an application to track and process Doctor's Appointments. This application will track

- Patients and their symptoms
- The clerk who checked them in
- The nurse who took their vitals
- The Doctor they visited
- The invoice for the visit

We want to leverage the composition and inheritance design patterns in this application and generalize and reuse as much code as possible.

With this in mind, let's model the inheritance hierarchy for the classes ***Person, Patient, Employee, Clerk, Nurse and Doctor***. We want to focus on grouping shared attributes into classes and then extending those classes into specific sub classes when necessary.



Notice how the hierarchy begins with the class Object as the ***ultimate ancestor***. Every Java class extends Object ***even if this is not explicitly mentioned*** in the subclass. This association is provided by the Java compiler. You can see this relationship easily by creating a dummy class and calling toString on it.

Take a look at the example below. Notice on line 15 that I am able to invoke the toString method on instance **T** even though there is no mention of a toString definition in the Toy class. This is due to the inheritance mechanism providing this definition via extending Object. The inherited toString does not do anything appropriate for our class because we never specified how we wanted toString to ***behave for our class*** (polymorphism foreshadowing!) All the inherited version of toString does is print the class type and the hash code.

Module java.base
Package java.lang

Class Object

java.lang.Object

`public class` **`Object`**

Class `Object` is the root of the class hierarchy. Every class has `Object` as a superclass. All objects, including arrays, implement the methods of this class.

Since:
1.0

```
1   public class Toy{
2
3       private String name;
4
5       public Toy(String name){
6           this.name = name;
7       }
8   }
9
10  class ToyDriver{
11
12      public static void main(String[] args){
13
14          Toy t = new Toy("Warlock Mini");
15          System.out.println(t.toString());
16
17      }
18  }
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac Toy.java
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ java ToyDriver
Toy@6ff3c5b5
```

The version of toString that we have been writing is called an ***over ridden method***. We will discuss this in more detail as we move through this module.

Java Object Orientation: We have the top of the class hierarchy provided for us by the language. Let’s define the root of our custom hierarchy by defining the Person class.

Design Considerations

When designing a class hierarchy, you want to place the generic attributes and behaviors toward the top. These attributes will then be passed down through the hierarchy to the subclasses. In our situation, the most general attributes would be very general personal data: name, address, sex and date of birth. These attributes are shared by Doctors, Nurses, Patients and clerks; any class that is a subset of Person. These should be defined as high up the hierarchy as possible . . . the Person class.

Also notice that we could use composition to handle the **Person has an address** association by defining Address as a class. An object like this could then be plugged in anytime an address needs to be tracked.

I have included a screen shot of a partial listing of this class. There are also toString and equals definitions. There are techniques in this equals method that will need some explanation, so I did not include it here.

```java
public class Address {

    private String  street;
    private String  city;
    private String  county;
    private String  state;
    private int     zip;

    public Address () {}

    public Address(Address toCopy) {
        this.street = toCopy.street;
        this.city   = toCopy.city;
        this.county = toCopy.county;
        this.state  = toCopy.state;
    }

    public Address(String street, String city, String county, String state, int zip) {
        this.street = street;
        this.city   = city;
        this.county = county;
        this.state  = state;
        this.zip    = zip;
    }

    public String getStreet() {
        return street;
    }

    public void setStreet(String street) {
        this.street = street;
    }

    public String getCity() {
        return city;
    }
```

Now let’s take a look at the listing for the Person class. Pay attention to the fields that could generate privacy leaks. These have been handled. If you are creating these classes as you work through this document be sure to write unit tests for the relevant features, particularly any fields dealing with object references and potential privacy leaks. You will have to do this from here on out.

```
public class Person {

    private String  firstName;
    private String  lastName;
    private Date    DOB;
    private char    sex;
    private String  phone;
    private Address address;

    public Person() {}

    public Person(Person toCopy) {
        this.firstName  = toCopy.firstName;
        this.lastName   = toCopy.lastName;
        this.DOB        = new Date(toCopy.DOB);
        this.sex        = toCopy.sex;
        this.phone      = toCopy.phone;
        this.address    = new Address(address);
    }

    public Person(String firstName, String lastName, Date dOB, char sex, String phone, Address address)
        super();
        this.firstName  = firstName;
        this.lastName   = lastName;
        this.DOB        = new Date(dOB);
        this.sex        = sex;
        this.phone      = phone;
        this.address    = new Address(address);
    }

```

```
    public void setAddress(Address address) {
        this.address = new Address(address);
    }

    public Date getDOB() {
        return new Date(DOB);
    }

    public void setDOB(Date dOB) {
        DOB = new Date(dOB);
    }
```

The “extends” keyword

Sub classes are considered an extension of the superclass. Defining a derived class from a base class is considered **extending the class**. We accomplish this with the keyword **extends.** Before we delve any further into the Doctor/Patient example I would like to create a small toy program that allows us to focus specifically on the details of extension.

Let’s start this demonstration with the definition of **class A**. Take a look at the feature access modifiers. These play an important role in what is accessible in the sub-class.

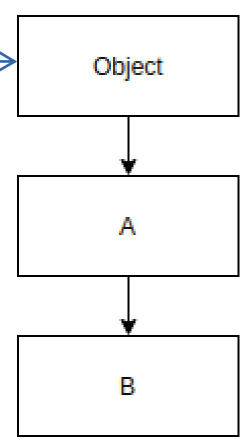
```
public class A{
    private String name;
    public A(String name){
        this.name = name;
    }
    public String getName(){
        return name;
    }
    private void helper(){
        System.out.println("Do something helpful");
    }
    public String toString(){
        return "Class A --> Name is: " + name;
    }
} // end of A
```

To extend a class in Java the superclass must reside somewhere in the CLASSPATH, which allows us to import; or be in the same directory as the subclass, which requires no import. For simplicity’s sake I am defining these classes in the same working directory.

We can define class B as an extension of A with the class header (this class is not public because I have it defined in the same source code file as class A and there can only be a single public class in a source file.)

```
class B extends A{
```

Now we have the following inheritance hierarchy



- A implicitly extends Object
- B explicitly extends A
- Instances of class B now have 3 associated data types {Object, A, B}

Here is the full listing of class B

```
class B extends A{
    private double weight;
    public B(String name, double weight){
        super(name);            // pass name to superclass A
        this.weight = weight;   // weight stays with "this"
    }
    public String toString(){
        // call the super class toString, concatenate to "this" toString
        return super.toString() + " Class B --> weight is: " + weight;
    }
} // end of B
```

Important Concepts

- A is the ***super class*** (or base class); B is the ***sub class*** (or derived class). A Java class can only have a single direct super class via extension.
- Private features in A stay private, and B cannot access those features directly. ***They exist but cannot be accessed.***
- Public features in A can be accessed directly by B
- The constructor for class B accepts both **name** and **weight** attributes. There is no public setName method in A so we need to pass **name** through the A constructor. You refer to superclass constructors via the **super** keyword. Notice that you do not say **A(name)** it is **super(name).** Calls to ***super*** in a constructor must be the first line!
- The name variable gets passed up the hierarchy to the super class, while the weight variable gets assigned locally to **this.weight**
- The over ridden toString definition in B includes the result from the super class definition of toString. Notice the syntax **super.ToString().** You have to prefix **super** to this method call because there are three definitions: one in Object, one in A and one in B (working up to polymorphism!). You cannot say **super.super.toString()** to access the Object's version of toString. Notice the output that B's toString gives.

```
class InheritanceDriver{
    public static void main(String[] args){
        B b = new B("warlock mini", 5);
        System.out.println(b);
    }
}
```

```
PROBLEMS    OUTPUT    DEBUG CONSOLE    TERMINAL

kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ java InheritanceDriver
Class A --> Name is: warlock mini Class B --> weight is: 5.0
```

Notice that we can invoke methods defined in class A as long as they are public

```java
class InheritanceDriver{
    public static void main(String[] args){
        B b = new B("warlock mini", 5);
        System.out.println(b);

        String n = b.getName();
        System.out.println("Name is: " + n);
    }
```

Invoke inherited method

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ java InheritanceDriver
Class A --> Name is: warlock mini Class B --> weight is: 5.0
Name is: warlock mini
```

You cannot invoke private methods of the super class. These methods exist in memory but are private, and that restricts access ***even to subclasses***.

```java
class InheritanceDriver{
    public static void main(String[] args){
        B b = new B("warlock mini", 5);
        System.out.println(b);

        String n = b.getName();
        System.out.println("Name is: " + n);

        b.helper();
    }
}
```

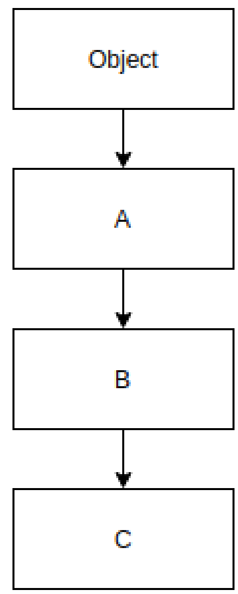
Method “helper” is private in super class

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
A.java:48: error: cannot find symbol
        b.helper();
         ^
  symbol:   method helper()
  location: variable b of type B
1 error
```

```java
class C extends B{
    private String color;
    public C(String name, double weight, String color){
        super(name, weight);    // pass name and weight to superclass B
        this.color = color;     // color stays with "this"
    }
    public String toString(){
        return super.toString() + " Class C --> color is: " + color;
    }
} // end of C
```

This is our class hierarchy now



- C is an instance of B
- B is an instance of A
- Therefore, C is an instance of A
- A, B and C are all instances of Object

In the code below, notice how the toString invocation on **c** includes the results from **B.toString** and **A.ToString**.

We can easily call any public method that exists **above "this"** in the inheritance hierarchy. See line 46 below

This arrangement does not work the other way around. A cannot call B methods, B cannot call C methods!!

```java
40  class InheritanceDriver{
41      public static void main(String[] args){
42          C c = new C("warlock mini", 5, "Red");
43          System.out.println(c);
44
45          // call an A method
46          String n = c.getName();
47          System.out.println("The name is: " + n);
48      }
49  }
```

PROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ java InheritanceDriver
Class A --> Name is: warlock mini Class B --> weight is: 5.0 Class C --> color is: Red
The name is: warlock mini
```

The instanceof Operator

Java provides the boolean operator ***instanceof*** to test an object's lineage. Use this operator whenever you are interested in where an object falls in an inheritance hierarchy. This operator will return true if the object in question is a direct instance or a subclass of the specified class. Here is an example with the A, B, C hierarchy.

```java
class InheritanceDriver{
    public static void main(String[] args){
        C c = new C("warlock mini", 5, "Red");

        System.out.println("Is C an instance of B? " +      (c instanceof B));
        System.out.println("Is C an instance of A? " +      (c instanceof A));
        System.out.println("Is C an instance of Object? " + (c instanceof Object));
    }
}
```

PROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ java InheritanceDriver
Is C an instance of B? true
Is C an instance of A? true
Is C an instance of Object? true
```

Notice how this returns true for each class above C in the hierarchy. If you want to know exactly which class defines an instance use the inherited method **getClass().** This method is defined in the Object class. You can think of this method as telling you the specific constructor that was used when the object was instantiated . . . ie. Which constructor was called with **new?**

```java
class InheritanceDriver{
    public static void main(String[] args){
        C c = new C("warlock mini", 5, "Red");
        B b = new B("wizard mini", 3);
        A a = new A("halfling mini");

        System.out.println("Is C an instance of B? " +      (c instanceof B));
        System.out.println("Is C an instance of A? " +      (c instanceof A));
        System.out.println("Is C an instance of Object? " + (c instanceof Object));
;
        System.out.println("Was the B constructor called? " + (c.getClass() == b.getClass()));
        System.out.println("Was the A constructor called? " + (c.getClass() == a.getClass()));
    }
}
```

PROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL   1: bash

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ java InheritanceDriver
Is C an instance of B? true
Is C an instance of A? true
Is C an instance of Object? true
Was the B constructor called? false
Was the A constructor called? false
```

instanceof tests hierarchy membership, ***getClass()*** returns exact type identity.

Super Class Constructor Chaining

It is important to understand how this inheritance hierarchy is instantiated. If an instance of C is created using the following snippet

```
C c = new C("warlock mini", 5, "Red");
```

Then the constructors are called in this order: ***C* → *B* → *A* → *Object*** We can trace our user defined constructor chain as there are explicit calls to the super class. Notice that there is no ***super()*** call in the constructor for A even though its super class is Object. When you omit this, the compiler will insert a

```
public class A{
    private String name;
    public A(String name){
        this.name = name;
    }
    public String getName(){
        return name;
    }
    private void helper(){
        System.out.println("Do something helpful");
    }
    public String toString(){
        return "Class A --> Name is: " + name;
    }
} // end of A

class B extends A{
    private double weight;
    public B(String name, double weight){
        super(name);                // pass name to superclass A
        this.weight = weight;       // weight stays with "this"
    }
    public String toString(){
        // call the super class toString, concatenate to "this" toString
        return super.toString() + " Class B --> weight is: " + weight;
    }
} // end of B

class C extends B{
    private String color;
    public C(String name, double weight, String color){
        super(name, weight);        // pass name and weight to superclass B
        this.color = color;         // color stays with "this"
    }
    public String toString(){
        return super.toString() + " Class C --> color is: " + color;
    }
} // end of C
```

no argument call to ***super( );*** This concept is important to understand and remember.

Method over riding

Method overriding is similar to method overloading in that we are allowed to define multiple method definitions with the same name. The details differ though.

- An overloaded method can be in the same class or a sub class and the definitions are identified by the differing signatures
  - public void setMonth(int m)
  - public void setMonth(String m)
  - The compiler can tell the difference between these two method signatures based on the call to the method.
    - setMonth(12); // calls setMonth(int)
    - setMonth("January"); // calls setMonth(String)
- An over ridden method meets the following criteria
  - Must be in a sub class
  - Must have the same signature
    - public String toString(); // in super class
    - public String toString(); // in the sub class
  - All the compiler cares about is that the syntax is correct and that there is a definition of the method available to the instance that is calling the method. It could be anywhere in the inheritance hierarchy as long as it is public.
  - The run-time environment (JVM) is then responsible for binding the call to the appropriate method definition. This is determined by the result you would get from running ***getClass()*** on that instance.

We have been defining over ridden methods each time we wrote our own ***toString().*** The definitions we write ***override the definition*** that is inherited from the Object class. This is a crucial foundational concept to polymorphism.

You can see this by reading the Object API spec.

Method Summary

All Methods | Instance Methods | Concrete Methods | Deprecated Methods

Modifier and Type	Method	Description
protected Object	clone()	Creates and returns a copy of this object.
boolean	equals(Object obj)	Indicates whether some other object is "equal to" this one.
protected void	finalize()	**Deprecated.** The finalization mechanism is inherently problematic.
Class<?>	getClass()	Returns the runtime class of this Object.
int	hashCode()	Returns a hash code value for the object.
void	notify()	Wakes up a single thread that is waiting on this object's monitor.
void	notifyAll()	Wakes up all threads that are waiting on this object's monitor.
String	toString()	Returns a string representation of the object.
void	wait()	Causes the current thread to wait until it is awakened, typically by being *notified* or *interrupted*.
void	wait(long timeoutMillis)	Causes the current thread to wait until it is awakened, typically by being *notified* or *interrupted*, or until a certain amount of real time has elapsed.
void	wait(long timeoutMillis, int nanos)	Causes the current thread to wait until it is awakened, typically by being *notified* or *interrupted*, or until a certain amount of real time has elapsed.

The @Override annotation

If you are attempting to override a method, you can add the ***@Override*** annotation to communicate your intention to the compiler. The compiler will then perform checks to ensure that your method is properly over ridden. Here is an example demonstrating this annotation with the toString method.

```
class C extends B{
    private String color;
    public C(String name, double weight, String color){
        super(name, weight);    // pass name and weight to superclass B
        this.color = color;     // color stays with "this"
    }
    @Override
    public String toString(){
        return super.toString() + " Class C --> color is: " + color;
    }
} // end of C
```

Take a look at what happens when we add this annotation and do not properly override a method. Notice that I added a parameter to toString which overloads instead of overrides. The compiler complains.

```
    @Override
    public String toString(int x){
        return super.toString() + " Class C --> color is: " + color;
    }
} // end of C
```

PROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
A.java:38: error: method does not override or implement a method from a supertype
    @Override
    ^
1 error
```

Overriding the equals() Method

Here is the equals method signature from the object class

`boolean`	`equals(Object obj)`	Indicates whether some other object is "equal to" this one.

Notice that the parameter type is ***Object***. Up until now we have been defining our equals methods as accepting **"this"** type, which technically ***overloads instead of overrides***. This has worked fine for our purposes, but it is not in line with the rules of over ridden methods and the Java design specification. If we attempted to override the equals method in class A using A as the parameter type, the compiler would complain when we add the @Override annotation

```java
public class A{
    private String name;
    public A(String name){
        this.name = name;
    }
    public String getName(){
        return name;
    }
    private void helper(){
        System.out.println("Do something helpful");
    }
    @Override
    public String toString(){
        return "Class A --> Name is: " + name;
    }

    @Override
    public boolean equals(A a){
        return this.name == a.name;
    }
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
A.java:17: error: method does not override or implement a method from a supertype
    @Override
    ^
1 error
```

To properly override this method the parameter type needs to be Object. Remember that any Java class is a sub class of Object, which further means that instances of these classes **are Objects,** and as such can be assigned to a variable of type Object.

```java
    @Override
    public boolean equals(Object obj){
        return this.name == obj.name;
    }
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL

```
kenneth@dragonborn:~/OneDrive/Spring2020/165/examples/inheritance$ javac A.java
A.java:19: error: cannot find symbol
        return this.name == obj.name;
                               ^
  symbol:   variable name
  location: variable obj of type Object
1 error
```

Changing the parameter type to Object removes the error with the @Override annotation but now we have a different error. Attempting to reference the **name** field in Class A through a variable of type Object is not allowed as **there is no field "name"** in the Object class.

This brings up an important aspect of inheritance. A subclass object has multiple types and can be treated as an instance of any of the types above it in the hierarchy. You can pass an object of a sub-class type into a method that accepts arguments of a super class type. This is due to the ***"is a"*** relationship between the levels. Because C is also an instance of B you can assign instances of type C to variables of type B. You can also assign instances of type C to variables of type A . . . and by extension you can also assign instances of ***any Java class*** to variables of type Object, as Object is the ultimate ancestor. This is called automatic type promotion, or colloquially an ***upstream cast.***

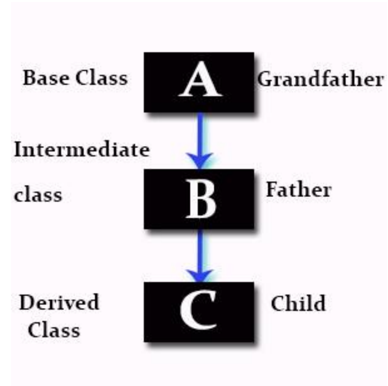
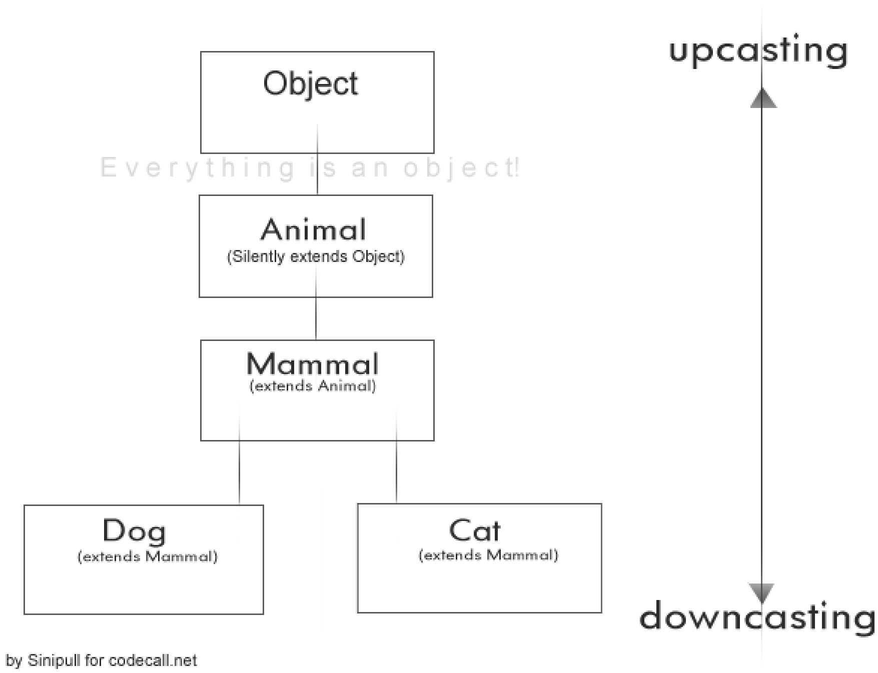


Fig: Multilevel Inheritance



Up-cast can happen automatically.

Down-cast must be explicit

When an up-cast happens the instance of the sub-class type ***becomes*** an instance of the super-class type and ***"forgets"*** that it once was a sub-class type. In practice this means that **you can no longer call sub-class methods from the super-class variable unless the method signatures are shared (overridden).** This is what is happening with our argument to the equals method. An instance of any Java class can be passed into a method that accepts an object, but now it can only be treated as an Object, unless we down-cast it back to its original type. Down casting is a tricky operation and must be handled with precision and care.

Rule: You can only down cast an object if it was originally an instance of the target type.

Instance Of vs Get Class

Before you downcast something you need to test to see if it can in fact be down casted. There are two ways to check an instances origin: ***instanceof*** and ***getClass()***. These were described and demonstrated above. Which one should we use?

instanceof: Will return true if the instance in question fits anywhere within an inheritance hierarchy

getClass(): Will tell you which class was used to build the original instance. Essentially, which type constructor was used to build the object.

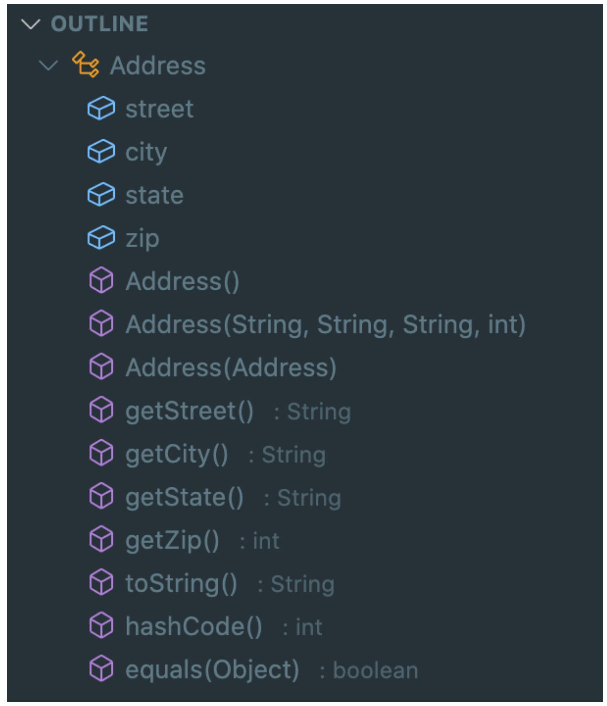
```java
@Override
public boolean equals(Object obj) {
    // identity check. Are the references equal
    if (this == obj)                    return true;
    // null check. Is the parameter null?
    if (obj == null)                    return false;
    // origin check. Does obj share the same class as "this"
    if (getClass() != obj.getClass())   return false;

    // We know we have a "non null" instance of class A
    A other = (A) obj;                  // down cast Object to A

    // compare name fields. Avoid potential null pointer exception
    if (name == null) {                 // null checks on fields
        if (other.name != null)
            return false;
    } else if (!name.equals(other.name))
        return false;
    return true;
}
```

Now that you have seen an explanation of the concepts in a properly defined equals method you can use VS Code's ***source action*** tool to generate equals methods. This will also generate a ***hashCode*** method as these two are normally found together.

Doctor/Patient Continued

Now that we have fully covered the technical details of inheritance we can continue with the Doctor/Patient example described earlier. At this point we have done the following.

- Defined the Person class to encapsulate all generic attributes of a Person. Here is the outline
- I used ***composition*** for the pattern: A Person ***has a*** first and last name by including instances of the String class for both first and last.
- I used ***composition*** for the pattern: A Person ***has an*** Address by including an instance of the Address class
- I also used ***composition*** for the pattern: A Person ***has a*** Date of Birth by including an instance of the Date class.



At this point the Person class is ready to be extended into some specialized cases. In the Doctor's office visit scenario, we can make the statements:

- A Doctor ***is a*** Person
- A Patient ***is a*** Person
- A Nurse ***is a*** Person

We could further organize our code base around the following design.

- An Employee at the Doctor's office ***is a*** Person
- A Doctor ***is an*** Employee
- A Nurse ***is an*** Employee
- A Patient is not an Employee, just a Person.

What would be some information that a hospital or doctor's office would want to track about their Employees? Let's keep is simple.

- An Employee ***is a*** Person
- An Employee ***has a*** Date of Hire
- An Employee ***has an*** assigned ID

This design is communicated with the following class specification

```java
public class Employee extends Person {

    private Date   hireDate;
    private int    id;
    private String  department;
```

Here are the Employee Constructors. Notice how they pass the data that ***belongs*** to Person through a call to the super class constructors.

```java
    // no argument
    public Employee() {}

    // overloaded constructor
    public Employee(Person p, Date hired, int id, String dept) {
        super(p);           // call to super class copy constructor
        setHireDate(hired);
        setId(id);
        setDepartment(dept);
    }

    // copy constructor
    public Employee(Employee toCopy){
        super(toCopy);  // up cast the Employee object to a Person object
        setHireDate(toCopy.hireDate);
        setId(toCopy.id);
        setDepartment(toCopy.department);
    }
```

Important Concept: The Employee copy constructor contains an ***upstream cast to Person.*** The signature of the Person copy constructor is

```java
public Person(Person copy)
```

When the Employee constructor calls

```java
super(toCopy);
```

it is passing the ***Employee instance "toCopy"*** to a variable of type ***Person.*** Because an Employee is a sub class of Person this assignment is perfectly legal and performs an ***upstream cast*** from Employee to Person. This only works in an inheritance hierarchy with the pattern ***Subclass is an instance of Superclass.***

Also notice a nifty trick in the Person constructor . . . a call to the constructor

this(String, String);

this(String, String, Date, Address);

```
public Person(String fName, String lName){
    firstName   = fName;
    lastName    = lName;
}

public Person(String fName, String lName, Date dob, Address addy){
    this(fName, lName);
    this.birthDate  = new Date(dob);
    this.addy       = new Address(addy);
}

public Person(Person copy){
    this(copy.firstName, copy.lastName, copy.birthDate, copy.addy);
}
```

Instead of having the overloaded Person constructors repeat all of the explicit calls to the to set methods and field assignment, you can chain constructor calls in the same class with ***this.***

Note: Calls to "***this constructors***" ***must be the first line*** and you cannot have both ***this and super*** calls in the same constructor. In the scenario shown above the Person copy constructor routes all invocations to the overloaded constructor above it, which in turn routes to the overloaded constructor above it. This constructor contains the ***implicit super() call***. The ***super()*** call invokes the ***Object*** constructor. This invocation path is then reversed as the objects are being created.

Putting it all together

Now that we have our inheritance hierarchy, we can create an instance of Employee to demonstrate how these moving parts stack.

Make sure that you can follow the execution path of this code. I would strongly recommend tracing it explicitly with your eyes and maybe the debugger. This is a complex flow of operations.

```java
1  public class Driver {
2
       Run | Debug
3      public static void main(String[] args) {
4
5          Address address     = new Address("123 North Street", "Dryden", "NY", 13053);
6          Date dob            = new Date(1, 2, 1969);
7          Person person       = new Person("Tony", "Iommi", dob, address);
8          Employee employee   = new Employee(person, new Date(1, 13, 2020), 12345, "Intensive Care");
9
10         System.out.println(employee);
11     }
12 }
```

OUTPUT   TERMINAL   DEBUG CONSOLE   PROBLEMS   1: zsh

```
❯ javac Driver.java
❯ java Driver
Tony Iommi
1/2/1969
123 North Street Dryden NY, 13053
Hired: 1/13/2020
ID: 12345
Dept: Intensive Care
```

Line 10 is particularly interesting. What is happening here?

1. We are using ***System.out.println*** to print the Employee instance. Remember that placing an object in a String context causes the runtime environment to implicitly call that object's ***toString*** method. Here is the Employee class' toString.

```java
  @Override
  public String toString() {
      return super.toString() + "\nHired: " + hireDate + "\nID: " + id + "\nDept: " + department;
  }
```

Notice that is invokes ***super.toString()***. The Person class is the ***super class*** of Employee, so execution would immediately jump there. This toString includes calls to the String object's toString method, the Date class' toString method and the Address class' toString method.

```java
@Override
public String toString(){
    return firstName + " " + lastName + "\n" + birthDate + "\n" + addy;
}
```

We did not define the String toString, but we did define the toString for the Date class and the Address class. You have complete control over how this text is formatted. The important thing here is to understand how all of these methods are being linked together to generate the final output.

Here is an example of calling various methods that exist up and down the inheritance hierarchy.

```java
public class Driver {

    Run | Debug
    public static void main(String[] args) {

        Address address     = new Address("123 North Street", "Dryden", "NY", 13053);
        Date dob            = new Date(1, 2, 1969);
        Person person       = new Person("Tony", "Iommi", dob, address);
        Employee employee   = new Employee(person, new Date(1, 13, 2020), 12345, "Intensive Care");

        System.out.println(employee);

        // call some of the various methods that exist in the inheritance hierarchy
        String fullName     = employee.getName(); // method exists in the Person class
        Date cakeDay        = employee.getBirthDate(); // method exists in the Person class
        System.out.println(fullName + " was born on " + cakeDay);

        int month           = cakeDay.getMonth(); // method exists in the Date class
        System.out.println(fullName + " was born in " + Date.months[month -1]);

        Address add         = employee.getAddress(); // method exists in the Person class
        String state        = add.getState(); // method exists in the Address class
        System.out.println(fullName + " lives in " + state);

        String dept         = employee.getDepartment(); // method exists in the Employee class
        System.out.println(fullName + " works in the " + dept + " department");
    }
}
```

```
❯ javac Driver.java
❯ java Driver
Tony Iommi
1/2/1969
123 North Street Dryden NY, 13053
Hired: 1/13/2020
ID: 12345
Dept: Intensive Care
Tony Iommi was born on 1/2/1969
Tony Iommi was born in January
Tony Iommi lives in NY
Tony Iommi works in the Intensive Care department
```