



# Chapter 9

## Classes and Objects: A Deeper Look ( I )

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# Outline

- ▶ A deeper look at designing classes, controlling access to class members and creating constructors
- ▶ Reexamine the use of *set* and *get* methods (setter & getter)
- ▶ **Composition**—a capability that allows a class to have references to objects of other classes as members (has-a relationship)



# Recall Our Car Example

- ▶ **Class** – a car's engineering drawings (a blueprint)
- ▶ **Method** – designed to perform tasks (e.g., making a car move)
- ▶ **Object** – the car we drive
- ▶ **Method call** – perform the task (e.g., pressing the accelerator pedal)
- ▶ **Instance variable** – to specify the attributes (e.g., the amount of gas)



# A Time Class

```
public class Time1 {  
    private int hour; // 0 - 23  
    private int minute; // 0 - 59  
    private int second; // 0 - 59  
  
    // set a new time value using universal time  
    public void setTime(int h, int m, int s) { // ...  
    }  
  
    // convert to String in universal-time format (HH:MM:SS)  
    public String toUniversalString() { // ...  
    }  
  
    // convert to String in standard-time format (H:MM:SS AM or PM)  
    public String toString() { // ...  
    }  
}
```

→ private instance variables

→ public instance methods (public services / interfaces the class provides to its clients)



# Method Details

```
public class Time1 {  
    // set a new time value using universal time  
    public void setTime(int h, int m, int s) {  
        hour = ( ( h >= 0 && h < 24 ) ? h : 0 ); // validate hour  
        minute = ( ( m >= 0 && m < 60 ) ? m : 0 ); // validate minute  
        second = ( ( s >= 0 && s < 60 ) ? s : 0 ); // validate second  
    }  
}
```



# Method Details Cont.

```
public class Time1 {  
    // convert to String in universal-time format (HH:MM:SS)  
    public String toUniversalString() {  
        return String.format("%02d:%02d:%02d", hour, minute, second);  
    }  
  
    // convert to String in standard-time format (H:MM:SS AM or PM)  
    public String toString() {  
        return String.format("%d:%02d:%02d %s",  
            ( ( hour == 0 || hour == 12 ) ? 12 : hour % 12 ),  
            minute, second, ( hour < 12 ? "AM" : "PM" ) );  
    }  
}
```



# Default Constructor

- ▶ Class `Time1` does not declare a constructor
- ▶ It will have a default constructor supplied by the compiler
- ▶ `int` instance variables implicitly receive the default value `0`
- ▶ Instance variables also can be initialized when they are declared in the class body, using the same initialization syntax as with a local variable

```
public class Time1 {  
    private int hour = 10; //default constructor will not initialize hour  
    private int minute; //default constructor will initialize minute to 0  
    private int second; //default constructor will initialize second to 0  
}
```



# Using The Time Class

```
public class Time1Test {  
    public static void main(String[] args) {  
        Time1 time = new Time1(); // invoke default constructor  
        System.out.print("The initial universal time is: ");  
        System.out.println(time.toUniversalString());  
        System.out.print("The initial standard time is: ");  
        System.out.println(time.toString());  
    }  
}
```

```
The initial universal time is: 00:00:00  
The initial standard time is: 12:00:00 AM
```





# Manipulating The Object

```
public class Time1Test {  
    public static void main(String[] args) {  
        Time1 time = new Time1();  
        time.setTime(13, 27, 6);  
        System.out.print("Universal time after setTime is: ");  
        System.out.println(time.toUniversalString());  
        System.out.print("Standard time after setTime is: ");  
        System.out.println(time.toString());  
    }  
}
```

Use object reference to invoke an instance method

Universal time after setTime is: 13:27:06  
Standard time after setTime is: 1:27:06 PM



# Manipulating The Object

```
public class Time1Test {  
    public static void main(String[] args) {  
        Time1 time = new Time1();  
  
        time.setTime(99, 99, 99);  
        System.out.println("After attempting invalid settings: ");  
        System.out.print("Universal time: ");  
        System.out.println(time.toUniversalString());  
        System.out.print("Standard time: ");  
        System.out.println(time.toString());  
    }  
}
```

```
After attempting invalid settings:  
Universal time: 00:00:00  
Standard time: 12:00:00 AM
```



# Manipulating The Object (Analysis)

- ▶ A `Time1` object always contains *consistent data*
  - The object's data values are always kept in range, even after incorrect values are passed to `setTime`.
- ▶ In our example, *zero is a consistent value* for hour, minute and second.
- ▶ hour, minute and second are all set to zero by default; thus, a `Time1` object contains consistent data from the moment it is created.



# Consistent Value vs. Correct Value

- ▶ A **consistent value** for `minute` must be in the range 0 to 59.
- ▶ A **correct value** for `minute` in a particular application would be the actual minute at that time of the day.
  - If the actual time is 17 minutes after the hour and you accidentally set the time to 19 minutes after, the 19 is a *consistent* value (0 to 59) but not a *correct value*.
  - If you set the time to 17 minutes after the hour, then 17 is a correct value—and a correct value is *always* a consistent value.



# Handling Inconsistent Values

- ▶ Our current `setMethod` sets the corresponding instance variables to zeros when receiving inconsistent values.

```
// set a new time value using universal time
public void setTime(int h, int m, int s) {
    hour = ( ( h >= 0 && h < 24 ) ? h : 0 ); // validate hour
    minute = ( ( m >= 0 && m < 60 ) ? m : 0 ); // validate minute
    second = ( ( s >= 0 && s < 60 ) ? s : 0 ); // validate second
}
```

While 0 is certainly a consistent value, it is unlikely to be correct. Is there an alternative approach?





# Handling Inconsistent Values

- ▶ When receiving inconsistent values, we could also simply leave the object in its current state, without changing the instance variable.
  - Time objects begin in a consistent state and setTime method **rejects** any inconsistent values.
  - Some designers feel this is better than setting instance variables to zeros.

```
// set a new time value using universal time
public void setTime(int h, int m, int s) {
    if(h >= 0 && h < 24) hour = h; // reject inconsistent values
    if(m >= 0 && m < 60) minute = m;
    if(s >= 0 && s < 60) second = s;
}
```



# Notifying The Client Code

- ▶ Approaches discussed so far do not inform the client code of inconsistent values (**no return to callers**)

// approach 1: setting to zeros

```
public void setTime(int h, int m, int s) {  
    hour = ( ( h >= 0 && h < 24 ) ? h : 0 );  
    minute = ( ( m >= 0 && m < 60 ) ? m : 0 );  
    second = ( ( s >= 0 && s < 60 ) ? s : 0 );  
}
```

// approach 2: keeping the last object state

```
public void setTime(int h, int m, int s) {  
    if(h >= 0 && h < 24) hour = h;  
    if(m >= 0 && m < 60) minute = m;  
    if(s >= 0 && s < 60) second = s;  
}
```



# Notifying The Client Code

- ▶ setTime could return a value such as `true` if all the values are consistent and `false` if any of the values are inconsistent.
  - The caller would check the return value, and if it is `false`, would attempt to set the time again.
  - **Problem:** Some Java technologies (such as JavaBeans) require that the *set* methods return `void`.

```
public boolean setTime(int h, int m, int s) {...}
```

- ▶ Exception Handling is another technique that enables methods to indicate when inconsistent values are received (**out of course scope**).





# Data Hiding (Information Hiding)

- ▶ The instance variables `hour`, `minute` and `second` are each declared **private**.
- ▶ **Principle:** *The actual data representation used within the class is of no concern to the class's clients.*

```
public class Time1 {  
    private int hour; // 0 - 23  
    private int minute; // 0 - 59  
    private int second; // 0 - 59  
}
```



# Data Hiding (Information Hiding)

- ▶ It is reasonable for `Time1` to represent the time internally as the number of seconds since midnight or the number of minutes and seconds since midnight.
- ▶ Clients could use the same public methods and get the same results without being aware of this implementation detail.

```
// set a new time value using universal time  
public void setTime(int h, int m, int s) {...}
```

```
// convert to String in universal-time format (HH:MM:SS)  
public String toUniversalString() {...}
```

```
// convert to String in standard-time format (H:MM:SS AM or PM)  
public String toString() {...}
```



# Controlling Access to Members

- ▶ Access modifiers **public** and **private** control access to a class's variables and methods.
  - Later, we will introduce another access modifier **protected**
- ▶ **public** methods present to the class's clients a view of the **services** the class provides (the class's **public** interface).
  - Clients need not be concerned with how the class accomplishes its tasks (i.e., its implementation details).
- ▶ **private** class members are not accessible outside the class.



# Accessing Private Members

```
public static void main(String[] args) {  
    Time1 time = new Time1();  
    time.hour = 7; // compilation error  
    time.minute = 15; // compilation error  
    time.second = 30; // compilation error  
}
```



If this is allowed, objects can easily enter invalid states (clients can give hour a random value).



# this Reference

- ▶ The keyword `this` is a reference variable that refers to the current object in Java.
- ▶ When a non-`static` method is called on a particular object, the method's body implicitly uses keyword `this` to refer to the object's instance variables and other methods.

```
// set a new time value using universal time
public void setTime(int h, int m, int s) {
    if(h >= 0 && h < 24) hour = h; // compiler's view: this.hour
    if(m >= 0 && m < 60) minute = m; // compiler's view: this.minute
    if(s >= 0 && s < 60) second = s; // compiler's view: this.second
}
```



# this Reference

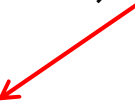
- ▶ The main use of `this` is to differentiate the formal parameters of methods and the data members of classes.
- ▶ If a method contains a local variable (including parameters) with the same name as a instance variable, the **local variable *shadows* the instance variable** in the method's scope.

```
// set a new time value using universal time
public void setTime(int hour, int minute, int second) {
    // if we use hour here, it refer to the local variable
    // not the instance variable
}
```



# this Reference

```
public class Time1 {  
    private int hour; // 0 - 23  
    private int minute; // 0 - 59  
    private int second; // 0 - 59  
  
    // set a new time value using universal time  
    public void setTime(int hour, int minute, int second) {  
        if(hour >= 0 && hour < 24) this.hour = hour;  
        if(minute >= 0 && minute < 60) this.minute = minute;  
        if(second >= 0 && second < 60) this.second = second;  
    }  
}
```



this enables us to explicitly access instance variables shadowed by local variables of the same name.

# this Reference

```
public class Time1 {  
    // convert to String in universal-time format (HH:MM:SS)  
    public String toUniversalString() {  
        return String.format("%02d:%02d:%02d", hour, minute, second);  
    }  
    public String buildString() {  
        return "Universal format: " + this.toUniversalString();  
    }  
}
```



**Q:** Do we need this reference here?

**A:** this is not required to call other methods of the same class.





# Overloaded Constructors

- ▶ **Method overloading:** methods of the same name can be declared in the same class, as long as they have different sets of parameters
  - Used to create methods that perform same tasks on **different types** or **different numbers** of arguments, e.g.,
- ▶ Similarly, **overloaded constructors** enable objects of a class to be initialized in different ways (constructors are special methods).
- ▶ Compiler differentiates overloaded methods/constructors by their *signature* (method name, the type, number, and order of parameters).
  - `max(double, double)` and `max(int, int)`



# Overloaded Constructors (Example)

```
public class Time2 {  
    private int hour;  
    private int minute;  
    private int second;  
  
    public void setTime(int h, int m, int s) {  
        setHour(h);  
        setMinute(m);  
        setSecond(s);  
    }  
  
    public void setHour(int h) {  
        hour = ( ( h >= 0 && h < 24 ) ? h : 0 );  
    }  
  
    public void setMinute(int m) {  
        minute = ( ( m >= 0 && m < 60 ) ? m : 0 );  
    }  
  
    public void setSecond(int s) {  
        second = ( ( s >= 0 && s < 60 ) ? s : 0 );  
    }  
}
```

Set methods for  
manipulating the fields



# Overloaded Constructors (Example)

```
public int getHour() {  
    return hour;  
}  
  
public int getMinute() {  
    return minute;  
}  
  
public int getSecond() {  
    return second;  
}
```

Get methods for retrieving the value of the fields

```
public String toUniversalString() {  
    return String.format("%02d:%02d:%02d",  
        getHour(), getMinute(), getSecond());  
}  
  
public String toString() {  
    return String.format("%d:%02d:%02d %s",  
        ( (getHour() == 0 || getHour() == 12) ? 12 : getHour() % 12 ),  
        getMinute(), getSecond(), (getHour() < 12 ? "AM" : "PM") );  
}  
}
```



# Overloaded Constructors (Example)

```
public class Time2 {  
    public Time2(int h, int m, int s) {  
        setTime(h, m, s);  
    }  
    public Time2(int h, int m) {  
        this(h, m, 0);  
    }  
    public Time2(int h) {  
        this(h, 0, 0);  
    }  
    public Time2() {  
        this(0, 0, 0);  
    }  
    public Time2(Time2 time) {  
        this(time.getHour(), time.getMinute(), time.getSecond());  
    }  
}
```

Invoke setTime to validate data for object construction

Invoke three-argument constructor, hour and minute values supplied

Using this in method-call syntax invokes another constructor of the same class. This helps reuse initialization code.



# Overloaded Constructors (Example)

```
public class Time2 {  
    public Time2(int h, int m, int s) {  
        setTime(h, m, s);  
    }  
    public Time2(int h, int m) {  
        this(h, m, 0);  
    }  
    public Time2(int h) {  
        this(h, 0, 0);  
    }  
    public Time2() {  
        this(0, 0, 0);  
    }  
    public Time2(Time2 time) {  
        this(time.getHour(), time.getMinute(), time.getSecond());  
    }  
}
```

Invoke three-argument constructor,  
hour value supplied

No-argument constructor, invokes three-argument  
constructor to initialize all values to 0

Another object supplied, invoke three-argument  
constructor for initialization



# Overloaded Constructors (Example)

```
public class Time2 {  
    public Time2(int h, int m, int s) {  
        setTime(h, m, s);  
    }  
    public Time2(int h, int m) {  
        this(h, m, 0);  
    }  
    public Time2(int h) {  
        this(h, 0, 0);  
    }  
    public Time2() {  
        this(0, 0, 0);  
    }  
    public Time2(Time2 time) {  
        this(time.getHour(), time.getMinute(), time.getSecond());  
    }  
}
```

Invoke three-argument constructor,  
hour value supplied

No-argument constructor, invokes three-argument  
constructor to initialize all values to 0

We use “this” to invoke a constructor here.  
Cannot use Time2(...), which can only be used with the “new” operator



# Using Overloaded Constructors

```
public class Time2Test {  
    public static void main(String[] args) {  
        Time2 t1 = new Time2();  
        Time2 t2 = new Time2(2);  
        Time2 t3 = new Time2(21, 34);  
        Time2 t4 = new Time2(12, 25, 42);  
        Time2 t5 = new Time2(27, 74, 99);  
        Time2 t6 = new Time2(t4);  
  
        System.out.println(t1.toUniversalString());  
        System.out.println(t2.toUniversalString());  
        System.out.println(t3.toUniversalString());  
        System.out.println(t4.toUniversalString());  
        System.out.println(t5.toUniversalString());  
        System.out.println(t6.toUniversalString());  
    }  
}
```

Compiler determines which constructor to call based on the number and types of the arguments

```
00:00:00  
02:00:00  
21:34:00  
12:25:42  
00:00:00  
12:25:42
```



# More on Constructors

- ▶ Every class must have **at least one** constructor.
- ▶ If you do not provide any constructors in a class's declaration, the compiler creates a default constructor that takes no arguments when it's invoked.
- ▶ The default constructor initializes the instance variables to the **initial values specified in their declarations** or to their **default values** (zero for primitive numeric types, **false** for boolean values and **null** for references).
- ▶ **If your class declares any constructors, the compiler will not create a default constructor.**
  - In this case, you must declare a no-argument constructor if default initialization is required (i.e., you want to initialize objects with `new ClassName()`).





# Notes on *Set and Get Methods*

- ▶ Classes often provide `public` methods to allow clients to *set* (i.e., assign values to) or *get* (i.e., obtain the values of) `private` instance variables.
- ▶ *Set* methods are also called **mutator methods**, because they typically change an object's state by modifying the values of instance variables.
- ▶ *Get* methods are also called **accessor methods** or **query methods**.

```
private int hour;
```

```
public void setHour(int h) { hour = ( ( h >= 0 && h < 24 ) ? h : 0 ); }
```

```
public int getHour() { return hour; }
```

# Notes on Set and Get Methods

- ▶ The set and get methods are used in many other methods even when these methods can directly access the class's private data

```
public class Time2 {  
    private int hour;  
    private int minute;  
    private int second;  
  
    public String toUniversalString() {  
        return String.format("%02d:%02d:%02d",  
            getHour(), getMinute(), getSecond());  
    }  
  
    public String toString() {  
        return String.format("%d:%02d:%02d %s",  
            ( (getHour() == 0 || getHour() == 12) ? 12 : getHour() % 12 ),  
            getMinute(), getSecond(), (getHour() < 12 ? "AM" : "PM") );  
    }  
}
```



Why not directly accessing  
the fields?



# Suppose we directly access fields...

- ▶ Someday, if we want to optimize the program by using only one `int` variable (**4 bytes of memory**) to store the number of seconds elapsed since midnight rather than three `int` variables (**12 bytes of memory**)

```
public class Time2 {  
    private int hour;  
    private int minute;    private int totalElapsedSeconds;  
    private int second;  
  
    public String toUniversalString() {  
        return String.format("%02d:%02d:%02d", hour, minute, second);  
    }  
  
    public String toString() {  
        return String.format("%d:%02d:%02d %s",  
            ( (hour == 0 || hour == 12) ? 12 : hour % 12 ),  
            second, second, (hour < 12 ? "AM" : "PM") );  
    }  
}
```

**We need to modify all methods:** `getHour`, `getMinute`, `getSecond`, `setHour`, `setMinute`, `setSecond`, `toUniversalString`, `toString`...



# If We Use Set and Get Methods

- ▶ We only need to modify: `getHour`, `getMinute`, `getSecond`, `setHour`, `setMinute`, `setSecond`
- ▶ No need to modify `toUniversalString`, `toString` etc. because they do not access the private data directly.

```
public class Time2 {  
    public String toUniversalString() {  
        return String.format("%02d:%02d:%02d",  
            getHour(), getMinute(), getSecond());  
    }  
    public String toString() {  
        return String.format("%d:%02d:%02d %s",  
            ( (getHour() == 0 || getHour() == 12) ? 12 : getHour() % 12 ),  
            getMinute(), getSecond(), (getHour() < 12 ? "AM" : "PM") );  
    }  
}
```



Designing the class this way reduces the likelihood of programming errors when altering the class's implementation



# Code Reuse (Avoid Duplications)

```
public class Time2 {  
    public Time2(int h, int m, int s) {  
        setTime(h, m, s);  
    }  
  
    public Time2(int h, int m) {  
        this(h, m, 0);  
    }  
  
    public Time2(int h) {  
        this(h, 0, 0);  
    }  
  
    public Time2() {  
        this(0, 0, 0);  
    }  
  
    public Time2(Time2 time) {  
        this(time.getHour(), time.getMinute(),  
            time.getSecond());  
    }  
}
```

- ▶ Similarly, each Time2 constructor could be written to include a copy of the statements from methods `setHour`, `setMinute` and `setSecond`.
  - Doing so may be slightly more efficient, because the extra constructor call and call to `setTime` are eliminated.
  - However, duplicating statements in multiple methods or constructors makes changing the class's internal data representation more difficult.
  - Having the Time2 constructors call the three-argument constructor requires any changes to the implementation of time setting to be made only once (by changing `setTime`).



# More on Data Hiding and Integrity

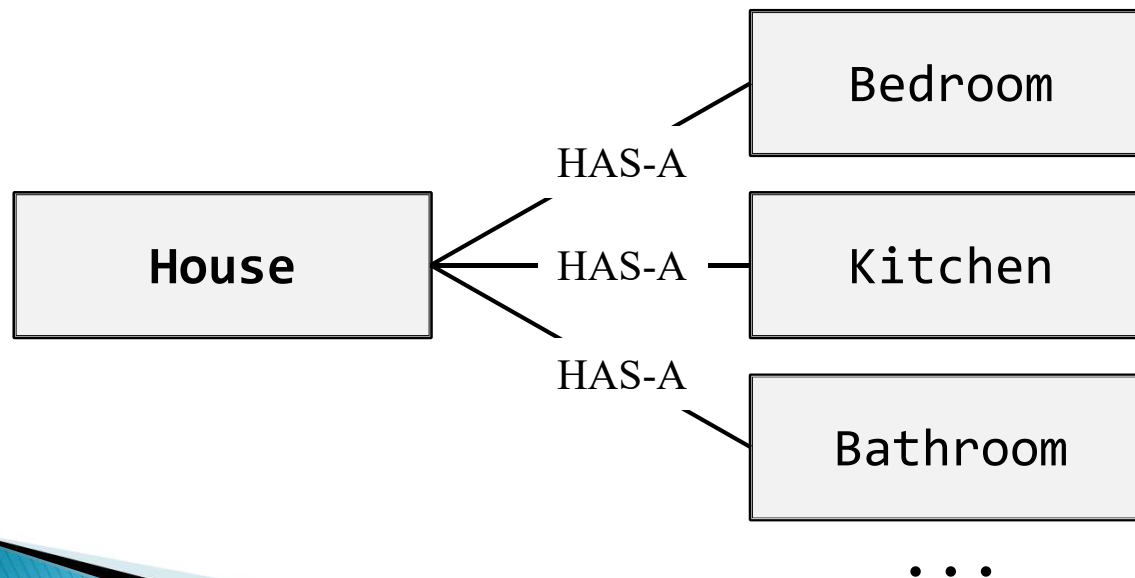
- ▶ It seems that providing *set* and *get* capabilities is essentially the same as making the instance variables `public`.
  - A `public` instance variable can be read or written by any method that has a reference to an object that contains that variable.
  - If an instance variable is declared `private`, a `public get` method certainly allows other methods to access it, but the *get* method can **control how the client can access it**.
  - A `public set` method can—and should—**carefully scrutinize attempts to modify the variable's value** to ensure that the new value is consistent for that data item.

```
public int hour; // this makes coding easier, but...  
public int minute;  
public int second;
```



# Composition

- ▶ A class can have references to objects of other classes as members.
- ▶ This is called **composition** and is sometimes referred to as a **has-a relationship**.





# Designing an Employee Class

- ▶ Suppose we are designing an Employee Management System, what information should be included in the Employee class?



First name (String type)

Last name (String type)

Date of birth (? type)

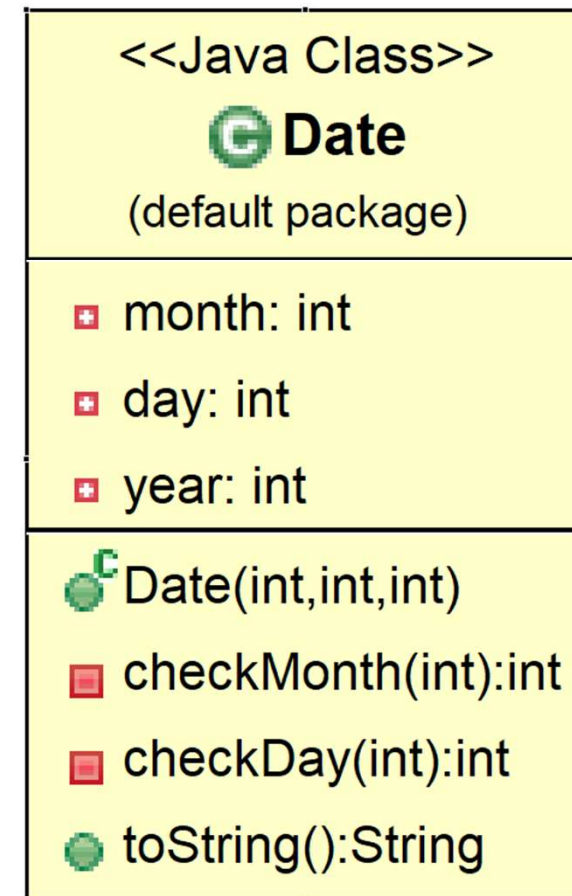
Date of hiring (? type)

... potentially lots of other information



# Let's Define a Date Class

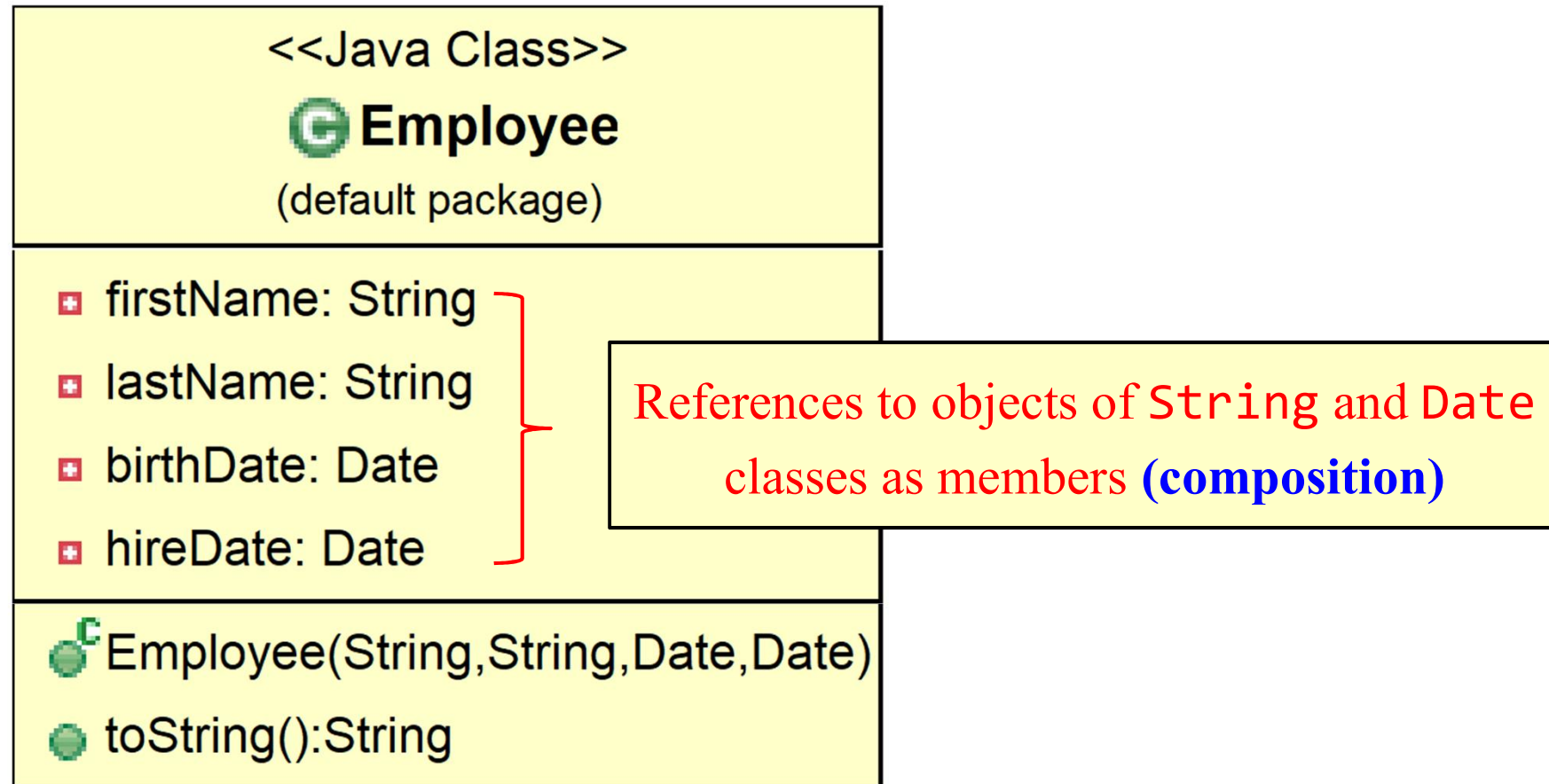
- ▶ What kind of information (stored in instance variables) should be included?
- ▶ What kind of operations (methods) should be included?



This UML class diagram is automatically generated by Eclipse with a plugin named ObjectAid



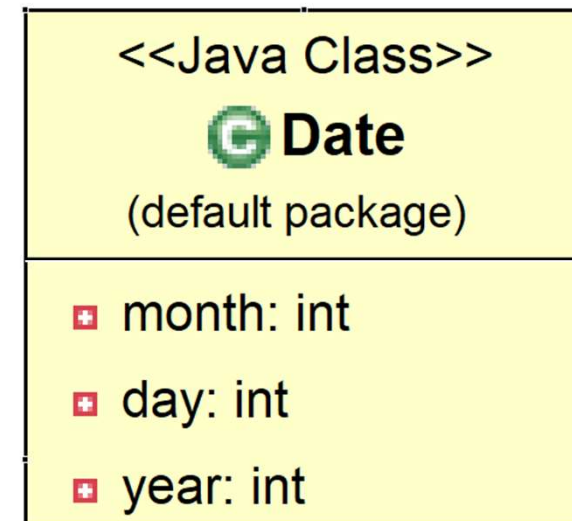
# Define the Employee class





# Let's Look at the Real Code

```
public class Date {  
    private int month;  
    private int day;  
    private int year;  
}
```





We make the instance variables private for data hiding.



# Let's Look at the Real Code

```
public Date(int theMonth, int theDay, int theYear) {  
    month = checkMonth(theMonth);  
    year = theYear;  
    day = checkDay(theDay);  
    System.out.printf("Date object constructor for date %s\n", this);  
}
```

 Date(int,int,int)  
 checkMonth(int):int

Constructor performs data validation

```
private int checkMonth(int testMonth) {  
    if(testMonth > 0 && testMonth <=12) return testMonth;  
    else {  
        System.out.printf("Invalid month (%d), set to 1", testMonth);  
        return 1;  
    }  
}
```

Data validation



# Let's Look at the Real Code

```
private int checkDay(int testDay) { // data validation
    int[] daysPerMonth =
        { 0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31 };
    if(testDay > 0 && testDay <= daysPerMonth[month]) return testDay;
    if(month == 2 && testDay == 29 && (year % 400 == 0 ||
        (year % 4 == 0 && year % 100 != 0)))
        return testDay;
    System.out.printf("Invalid day (%d), set to 1", testDay);
    return 1;
}

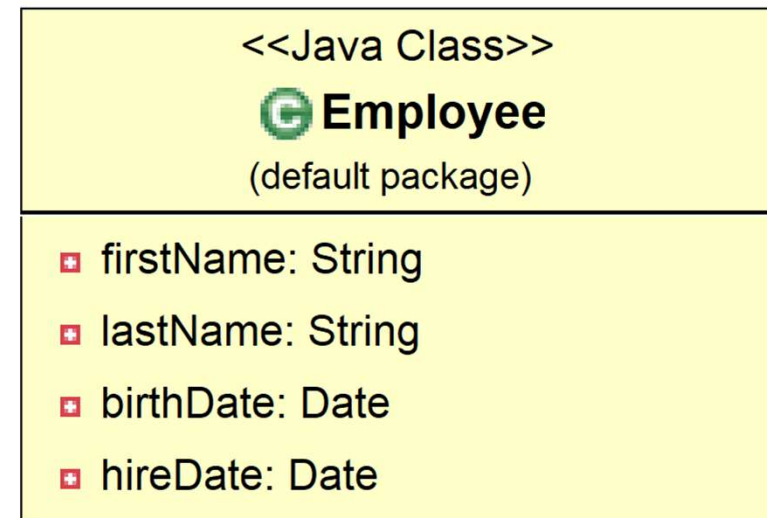
public String toString() { // transform object to String representation
    return String.format("%d/%d/%d", month, day, year);
}
```

■ checkDay(int):int  
● toString():String



# Let's Look at the Real Code

```
public class Employee {  
    private String firstName;  
    private String lastName;  
    private Date birthDate;  
    private Date hireDate;  
}
```



Again, we make the instance variables private for data hiding.



# Let's Look at the Real Code

```
public Employee(String first, String last, Date dateOfBirth,  
                Date dateOfHire) { // constructor  
    firstName = first;  
    lastName = last;  
    birthDate = dateOfBirth;  
    hireDate = dateOfHire;  
}
```

Employee(String,String,Date,Date)  
toString():String

```
public String toString() { // to String representation  
    return String.format("%s, %s Hired: %s Birthday: %s",  
        lastName, firstName, hireDate, birthDate);  
}
```



# Let's Run the Code

```
public class EmployeeTest {  
    public static void main(String[] args) {  
        Date birth = new Date(7, 24, 1949);  
        Date hire = new Date(3, 12, 1988);  
        Employee employee = new Employee("Bob", "Blue", birth, hire);  
        System.out.println(employee);  
    }  
}
```

Date object constructor for date 7/24/1949

Date object constructor for date 3/12/1988

Blue, Bob Hired: 3/12/1988 Birthday: 7/24/1949