Chapter 9
Inheritance

Java Software Solutions
Foundations of Program Design
9th Edition

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PEARSON

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Inheritance

- Inheritance is a fundamental object-oriented design technique used to create and organize reusable classes
- Chapter 9 focuses on:
  - deriving new classes from existing classes
  - the `protected` modifier
  - creating class hierarchies
  - abstract classes
  - indirect visibility of inherited members
  - designing for inheritance

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Outline

Creating Subclasses
Overriding Methods
Class Hierarchies
Visibility
Designing for Inheritance

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Inheritance

- *Inheritance* allows a software developer to derive a new class from an existing one
- The existing class is called the *parent class,* or *superclass*, or *base class*
- The derived class is called the *child class* or *subclass*
- As the name implies, the child inherits characteristics of the parent
- That is, the child class inherits the methods and data defined by the parent class

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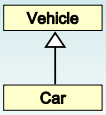
Inheritance

- Inheritance relationships are shown in a UML class diagram using a solid arrow with an unfilled triangular arrowhead pointing to the parent class



- Proper inheritance creates an *is-a* relationship, meaning the child *is a* more specific version of the parent

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Inheritance

- A programmer can tailor a derived class as needed by adding new variables or methods, or by modifying the inherited ones
- One benefit of inheritance is *software reuse*
- By using existing software components to create new ones, we capitalize on all the effort that went into the design, implementation, and testing of the existing software

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Deriving Subclasses

- In Java, we use the reserved word `extends` to establish an inheritance relationship

```
public class Car extends Vehicle
{
   // class contents
}
```

- See `Words.java`
- See `Book.java`
- See `Dictionary.java`

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```
//********************************************************************
//  Words.java       Author: Lewis/Loftus
//
//  Demonstrates the use of an inherited method.
//********************************************************************

public class Words
{
   //-----------------------------------------------------------------
   //  Instantiates a derived class and invokes its inherited and
   //  local methods.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Dictionary webster = new Dictionary();

      System.out.println("Number of pages: " + webster.getPages());

      System.out.println("Number of definitions: " +
                         webster.getDefinitions());

      System.out.println("Definitions per page: " +
                         webster.computeRatio());
   }
}
```

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Output

```
Number of pages: 1500
Number of definitions: 52500
Definitions per page: 35.0
```

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```
//********************************************************************
//  Book.java       Author: Lewis/Loftus
//
//  Represents a book. Used as the parent of a derived class to
//  demonstrate inheritance.
//********************************************************************

public class Book
{
   protected int pages = 1500;

   //-----------------------------------------------------------------
   //  Pages mutator.
   //-----------------------------------------------------------------
   public void setPages(int numPages)
   {
      pages = numPages;
   }

   //-----------------------------------------------------------------
   //  Pages accessor.
   //-----------------------------------------------------------------
   public int getPages()
   {
      return pages;
   }
}
```

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```
//********************************************************************
//  Dictionary.java       Author: Lewis/Loftus
//
//  Represents a dictionary, which is a book. Used to demonstrate
//  inheritance.
//********************************************************************

public class Dictionary extends Book
{
   private int definitions = 52500;

   //-----------------------------------------------------------------
   //  Prints a message using both local and inherited values.
   //-----------------------------------------------------------------
   public double computeRatio()
   {
      return (double) definitions/pages;
   }
```

continue

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continue

```
   //-----------------------------------------------------------------
   //  Definitions mutator.
   //-----------------------------------------------------------------
   public void setDefinitions(int numDefinitions)
   {
      definitions = numDefinitions;
   }

   //-----------------------------------------------------------------
   //  Definitions accessor.
   //-----------------------------------------------------------------
   public int getDefinitions()
   {
      return definitions;
   }
}
```

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The protected Modifier

- Visibility modifiers affect the way that class members can be used in a child class
- Variables and methods declared with private visibility cannot be referenced in a child class
- They can be referenced in the child class if they are declared with public visibility -- but public variables violate the principle of encapsulation
- There is a third visibility modifier that helps in inheritance situations: `protected`

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The protected Modifier

- The `protected` modifier allows a child class to reference a variable or method in the child class
- It provides more encapsulation than public visibility, but is not as tightly encapsulated as private visibility
- A protected variable is also visible to any class in the same package as the parent class
- See Appendix E for details of all Java modifiers
- Protected variables and methods can be shown with a # symbol preceding them in UML diagrams

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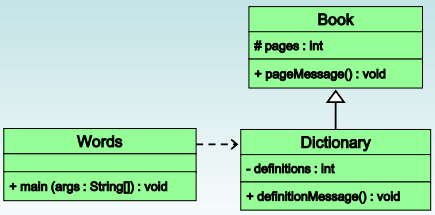
Class Diagram for Words



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The super Reference

- Constructors are not inherited, even though they have public visibility
- Yet we often want to use the parent's constructor to set up the "parent's part" of the object
- The `super` reference can be used to refer to the parent class, and often is used to invoke the parent's constructor
- A child's constructor is responsible for calling the parent's constructor

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The super Reference

- The first line of a child's constructor should use the `super` reference to call the parent's constructor
- The `super` reference can also be used to reference other variables and methods defined in the parent's class
- See `Words2.java`
- See `Book2.java`
- See `Dictionary2.java`

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```
//********************************************************************
//  Words2.java       Author: Lewis/Loftus
//
//  Demonstrates the use of the super reference.
//********************************************************************

public class Words2
{
   //-----------------------------------------------------------------
   //  Instantiates a derived class and invokes its inherited and
   //  local methods.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Dictionary2 webster = new Dictionary2(1500, 52500);

      System.out.println("Number of pages: " + webster.getPages());

      System.out.println("Number of definitions: " +
                         webster.getDefinitions());

      System.out.println("Definitions per page: " +
                         webster.computeRatio());
   }
}
```

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```
//********************************************************************
//  Words2.java
//
//  Demonstrates t
//********************************************************************
public class Words2
{
   //-----------------------------------------------------------------
   //  Instantiates a derived class and invokes its inherited and
   //  local methods.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Dictionary2 webster = new Dictionary2(1500, 52500);

      System.out.println("Number of pages: " + webster.getPages());

      System.out.println("Number of definitions: " +
                         webster.getDefinitions());

      System.out.println("Definitions per page: " +
                         webster.computeRatio());
   }
}
```

Output

```
Number of pages: 1500
Number of definitions: 52500
Definitions per page: 35.0
```

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```
//********************************************************************
//  Book2.java       Author: Lewis/Loftus
//
//  Represents a book. Used as the parent of a derived class to
//  demonstrate inheritance and the use of the super reference.
//********************************************************************

public class Book2
{
   protected int pages;

   //-----------------------------------------------------------------
   //  Constructor: Sets up the book with the specified number of
   //  pages.
   //-----------------------------------------------------------------
   public Book2(int numPages)
   {
      pages = numPages;
   }
```

continue

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continue

```
   //-----------------------------------------------------------------
   //  Pages mutator.
   //-----------------------------------------------------------------
   public void setPages(int numPages)
   {
      pages = numPages;
   }

   //-----------------------------------------------------------------
   //  Pages accessor.
   //-----------------------------------------------------------------
   public int getPages()
   {
      return pages;
   }
}
```

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```
//********************************************************************
//  Dictionary2.java       Author: Lewis/Loftus
//
//  Represents a dictionary, which is a book. Used to demonstrate
//  the use of the super reference.
//********************************************************************

public class Dictionary2 extends Book2
{
   private int definitions;

   //-----------------------------------------------------------------
   //  Constructor: Sets up the dictionary with the specified number
   //  of pages and definitions.
   //-----------------------------------------------------------------
   public Dictionary2(int numPages, int numDefinitions)
   {
      super(numPages);

      definitions = numDefinitions;
   }
```

continue

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```
continue

   //-----------------------------------------------------------------
   //  Prints a message using both local and inherited values.
   //-----------------------------------------------------------------
   public double computeRatio()
   {
      return (double) definitions/pages;
   }

   //-----------------------------------------------------------------
   //  Definitions mutator.
   //-----------------------------------------------------------------
   public void setDefinitions(int numDefinitions)
   {
      definitions = numDefinitions;
   }

   //-----------------------------------------------------------------
   //  Definitions accessor.
   //-----------------------------------------------------------------
   public int getDefinitions()
   {
      return definitions;
   }
}
```

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Multiple Inheritance

- Java supports *single inheritance*, meaning that a derived class can have only one parent class
- *Multiple inheritance* allows a class to be derived from two or more classes, inheriting the members of all parents
- Collisions, such as the same variable name in two parents, have to be resolved
- Multiple inheritance is generally not needed, and Java does not support it

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Outline

- Creating Subclasses
- Overriding Methods
- Class Hierarchies
- Visibility
- Designing for Inheritance

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Overriding Methods

- A child class can *override* the definition of an inherited method in favor of its own
- The new method must have the same signature as the parent's method, but can have a different body
- The type of the object executing the method determines which version of the method is invoked
- See `Messages.java`
- See `Thought.java`
- See `Advice.java`

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```
//********************************************************************
//  Messages.java       Author: Lewis/Loftus
//
//  Demonstrates the use of an overridden method.
//********************************************************************

public class Messages
{
   //-----------------------------------------------------------------
   //  Creates two objects and invokes the message method in each.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Thought parked = new Thought();
      Advice dates = new Advice();

      parked.message();

      dates.message();  // overridden
   }
}
```

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Output

```
I feel like I'm diagonally parked in a parallel universe.

Warning: Dates in calendar are closer than they appear.

I feel like I'm diagonally parked in a parallel universe.
```

```
//********************************************************************
//  Thought.java       Author: Lewis/Loftus
//
//  Represents a stray thought. Used as the parent of a derived
//  class to demonstrate the use of an overridden method.
//********************************************************************

public class Thought
{
   //-----------------------------------------------------------------
   //  Prints a message.
   //-----------------------------------------------------------------
   public void message()
   {
      System.out.println("I feel like I'm diagonally parked in a " +
                         "parallel universe.");

      System.out.println();
   }
}
```

```
//********************************************************************
//  Advice.java       Author: Lewis/Loftus
//
//  Represents some thoughtful advice. Used to demonstrate the use
//  of an overridden method.
//********************************************************************

public class Advice extends Thought
{
   //-----------------------------------------------------------------
   //  Prints a message. This method overrides the parent's version.
   //-----------------------------------------------------------------
   public void message()
   {
      System.out.println("Warning: Dates in calendar are closer " +
                         "than they appear.");

      System.out.println();

      super.message();  // explicitly invokes the parent's version
   }
}
```

```
//********************************************************************
//  Dates.java       Author: Lewis/Loftus
//
//  Creates two objects and invokes the message method in each.
//********************************************************************

public class Dates
{
   //-----------------------------------------------------------------
   //  Creates two objects and invokes the message method in each.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Thought parked = new Thought();
      Advice dates = new Advice();

      parked.message();

      dates.message();  // overridden
   }
}
```

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Overriding

- A method in the parent class can be invoked explicitly using the `super` reference
- If a method is declared with the `final` modifier, it cannot be overridden
- The concept of overriding can be applied to data and is called *shadowing variables*
- Shadowing variables should be avoided because it tends to cause unnecessarily confusing code

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Overloading vs. Overriding

- Overloading deals with multiple methods with the same name in the same class, but with different signatures
- Overriding deals with two methods, one in a parent class and one in a child class, that have the same signature
- Overloading lets you define a similar operation in different ways for different parameters
- Overriding lets you define a similar operation in different ways for different object types

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Quick Check

True or False?

A child class may define a method with the same name as a method in the parent.	True
A child class can override the constructor of the parent class.	False
A child class cannot override a `final` method of the parent class.	True
It is considered poor design when a child class overrides a method from the parent.	False
A child class may define a variable with the same name as a variable in the parent.	True, but shouldn't

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Outline

- **Creating Subclasses**
- **Overriding Methods**
- **Class Hierarchies**
- **Visibility**
- **Designing for Inheritance**

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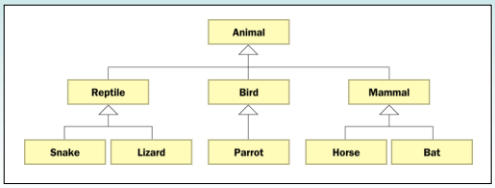
Class Hierarchies

- A child class of one parent can be the parent of another child, forming a *class hierarchy*



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Class Hierarchies

- Two children of the same parent are called *siblings*
- Common features should be put as high in the hierarchy as is reasonable
- An inherited member is passed continually down the line
- Therefore, a child class inherits from all its ancestor classes
- There is no single class hierarchy that is appropriate for all situations

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The Object Class

- A class called `Object` is defined in the `java.lang` package of the Java standard class library
- All classes are derived from the `Object` class
- If a class is not explicitly defined to be the child of an existing class, it is assumed to be the child of the `Object` class
- Therefore, the `Object` class is the ultimate root of all class hierarchies

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The Object Class

- The `Object` class contains a few useful methods, which are inherited by all classes
- For example, the `toString` method is defined in the `Object` class
- Every time we define the `toString` method, we are actually overriding an inherited definition
- The `toString` method in the `Object` class is defined to return a string that contains the name of the object's class along with a hash code

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The Object Class

- The `equals` method of the `Object` class returns true if two references are aliases
- We can override `equals` in any class to define equality in some more appropriate way
- As we've seen, the `String` class defines the `equals` method to return true if two `String` objects contain the same characters
- The designers of the `String` class have overridden the `equals` method inherited from `Object` in favor of a more useful version

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Abstract Classes

- An *abstract class* is a placeholder in a class hierarchy that represents a generic concept
- An abstract class cannot be instantiated
- We use the modifier `abstract` on the class header to declare a class as abstract:

```
public abstract class Product
{
   // class contents
}
```

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Abstract Classes

- An abstract class often contains abstract methods with no definitions (like an interface)
- Unlike an interface, the `abstract` modifier must be applied to each abstract method
- Also, an abstract class typically contains non-abstract methods with full definitions
- A class declared as abstract does not have to contain abstract methods -- simply declaring it as abstract makes it so

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Abstract Classes

- The child of an abstract class must override the abstract methods of the parent, or it too will be considered abstract
- An abstract method cannot be defined as `final` or `static`
- The use of abstract classes is an important element of software design – it allows us to establish common elements in a hierarchy that are too general to instantiate

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Interface Hierarchies

- Inheritance can be applied to interfaces
- That is, one interface can be derived from another interface
- The child interface inherits all abstract methods of the parent
- A class implementing the child interface must define all methods from both interfaces
- Class hierarchies and interface hierarchies are distinct (they do not overlap)

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Quick Check

What are some methods defined by the `Object` class?

```
String toString()
boolean equals(Object obj)
Object clone()
```

What is an abstract class?

An abstract class is a placeholder in the class hierarchy, defining a general concept and gathering elements common to all derived classes. An abstract class cannot be instantiated.

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Visibility Revisited

- It's important to understand one subtle issue related to inheritance and visibility
- All variables and methods of a parent class, even private members, are inherited by its children
- As we've mentioned, private members cannot be referenced by name in the child class
- However, private members inherited by child classes exist and can be referenced indirectly

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Visibility Revisited

- Because the parent can refer to the private member, the child can reference it indirectly using its parent's methods
- The `super` reference can be used to refer to the parent class, even if no object of the parent exists
- See `FoodAnalyzer.java`
- See `FoodItem.java`
- See `Pizza.java`

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```
//********************************************************************
//  FoodAnalyzer.java       Author: Lewis/Loftus
//
//  Demonstrates indirect access to inherited private members.
//********************************************************************

public class FoodAnalyzer
{
   //-----------------------------------------------------------------
   //  Instantiates a Pizza object and prints its calories per
   //  serving.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Pizza special = new Pizza(275);

      System.out.println("Calories per serving: " +
                         special.caloriesPerServing());
   }
}
```

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Output

```
Calories per serving: 309
```

```
//********************************************************************
//  FoodAnalyzer.
//
//  Demonstrates                                    vate members.
//********************************************************************

public class FoodAnalyzer
{
   //-----------------------------------------------------------------
   //  Instantiates a Pizza object and prints its calories per
   //  serving.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      Pizza special = new Pizza(275);

      System.out.println("Calories per serving: " +
                         special.caloriesPerServing());
   }
}
```

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```
//********************************************************************
//  FoodItem.java       Author: Lewis/Loftus
//
//  Represents an item of food. Used as the parent of a derived class
//  to demonstrate indirect referencing.
//********************************************************************

public class FoodItem
{
   final private int CALORIES_PER_GRAM = 9;
   private int fatGrams;
   protected int servings;

   //-----------------------------------------------------------------
   //  Sets up this food item with the specified number of fat grams
   //  and number of servings.
   //-----------------------------------------------------------------
   public FoodItem(int numFatGrams, int numServings)
   {
      fatGrams = numFatGrams;
      servings = numServings;
   }
```

continue

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continue

```
   //-----------------------------------------------------------------
   //  Computes and returns the number of calories in this food item
   //  due to fat.
   //-----------------------------------------------------------------
   private int calories()
   {
      return fatGrams * CALORIES_PER_GRAM;
   }

   //-----------------------------------------------------------------
   //  Computes and returns the number of fat calories per serving.
   //-----------------------------------------------------------------
   public int caloriesPerServing()
   {
      return (calories() / servings);
   }
}
```

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```
//********************************************************************
//  Pizza.java       Author: Lewis/Loftus
//
//  Represents a pizza, which is a food item. Used to demonstrate
//  indirect referencing through inheritance.
//********************************************************************

public class Pizza extends FoodItem
{
   //-----------------------------------------------------------------
   //  Sets up a pizza with the specified amount of fat (assumes
   //  eight servings).
   //-----------------------------------------------------------------
   public Pizza(int fatGrams)
   {
      super(fatGrams, 8);
   }
}
```

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- **Designing for Inheritance**

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Designing for Inheritance

- As we've discussed, taking the time to create a good software design reaps long-term benefits
- Inheritance issues are an important part of an object-oriented design
- Properly designed inheritance relationships can contribute greatly to the elegance, maintainability, and reuse of the software
- Let's summarize some of the issues regarding inheritance that relate to a good software design

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Inheritance Design Issues

- Every derivation should be an is-a relationship
- Think about the potential future of a class hierarchy, and design classes to be reusable and flexible
- Find common characteristics of classes and push them as high in the class hierarchy as appropriate
- Override methods as appropriate to tailor or change the functionality of a child
- Add new variables to children, but don't redefine (shadow) inherited variables

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Inheritance Design Issues

- Allow each class to manage its own data; use the `super` reference to invoke the parent's constructor to set up its data
- Override general methods such as `toString` and `equals` with appropriate definitions
- Use abstract classes to represent general concepts that derived classes have in common
- Use visibility modifiers carefully to provide needed access without violating encapsulation

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Restricting Inheritance

- If the `final` modifier is applied to a method, that method cannot be overridden in any derived classes
- If the `final` modifier is applied to an entire class, then that class cannot be used to derive any children at all
- Therefore, an abstract class cannot be declared as final

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Summary

- Chapter 9 focused on:
  - deriving new classes from existing classes
  - the `protected` modifier
  - creating class hierarchies
  - abstract classes
  - indirect visibility of inherited members
  - designing for inheritance

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