More *Effective Java*™

Joshua Bloch, Chief Java Architect, Google Inc.

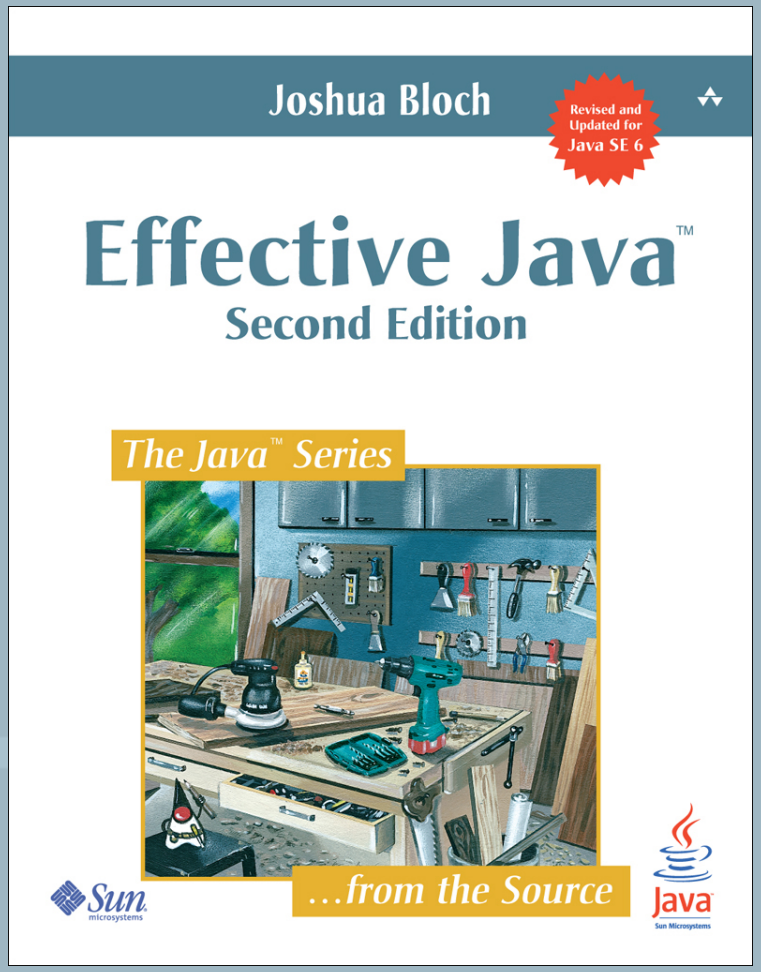
TS-6623

Java

Google™

Sun microsystems

The wait is over!



What's New?

- Chapter 5: *Generics*
- Chapter 6: *Enums and Annotations*
- One or more items on all other Java™ 5 language features
- *Threads* chapter renamed *Concurrency*
  - Rewritten for **`java.util.concurrent`**
- All existing items updated to reflect current best practices
- A few items added to reflect newly important patterns
- First edition had 57 items; second has 78

Agenda

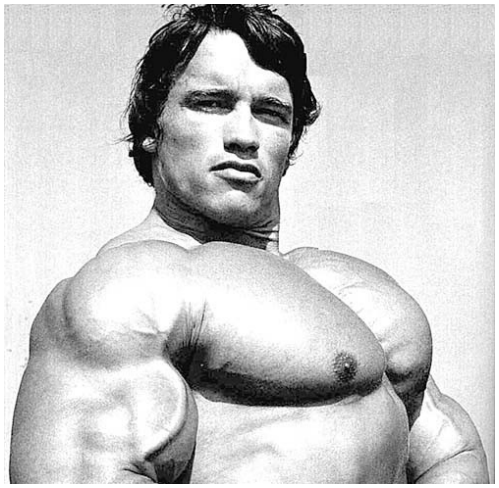
- Generics (Item 28)
- Enum types (Items 31–34, 77)
- Lazy initialization (Item 71)

Item 28: Bounded Wildcards for API Flexibility

- Generic types are *invariant*
  - That is, **`List<String>`** is not a subtype of **`List<Object>`**
  - Good for compile-time type safety, but inflexible
- *Bounded wildcard types* provide additional API flexibilty
  - **`List<String>`** is a subtype of **`List<? extends Object>`**
  - **`List<Object>`** is a subtype of **`List<? super String>`**

A Mnemonic for Wildcard Usage

- PECS—Producer **`extends`**, Consumer **`super`**
  - use **`Foo<? extends T>`** for a **`T`** producer
  - use **`Foo<? super T>`** for a **`T`** consumer
- Only applies to input parameters
  - Don't use wildcard types as return types



Guess who?

PECS in Action (1)

- Suppose you want to add bulk methods to **`Stack<E>`**
- **`void pushAll(Collection<E> src);`**

- **`void popAll(Collection<E > dst);`**

PECS in Action (1)

- Suppose you want to add bulk methods to **`Stack<E>`**
- **`void pushAll(Collection<? extends E> src);`**
  - **`src`** is an **`E`** producer
- **`void popAll(Collection<E> dst);`**

PECS in Action (1)

- Suppose you want to add bulk methods to **`Stack<E>`**
- **`void pushAll(Collection<? extends E> src);`**
  - **`src`** is an **`E`** producer
- **`void popAll(Collection<? super E> dst);`**
  - **`dst`** is an **`E`** consumer

PECS in Action (1)

- Suppose you want to add bulk methods to **`Stack<E>`**
- **`void pushAll(Collection<? extends E> src);`**
- **`void popAll(Collection<? super E> dst);`**
- User can **`pushAll`** from a **`Collection<Long>`** or a **`Collection<Number>`** onto a **`Stack<Number>`**
- User can **`popAll`** into a **`Collection<Object>`** or a **`Collection<Number>`** from a **`Stack<Number>`**

PECS in Action (2)

- Consider this generic method:

```
public static <E> Set<E> union(Set<E> s1, Set<E> s2)
```

PECS in Action (2)

- Consider this generic method:

```
public static <E> Set<E> union(Set<? extends E> s1,
                               Set<? extends E> s2)
```

- Both **s1** and **s2** are **E** producers
- No wildcard type for return value
  - Wouldn't make the API any more flexible
  - Would force user to deal with wildcard types explicitly
  - User should not have to think about wildcards to use your API

Agenda

- Generics (Items 28)
- Enum types (Items 31–34, 77)
- Lazy initialization (Item 71)

Item 31: How would you implement this

```
public enum Ensemble {
    SOLO, DUET, TRIO, QUARTET, QUINTET,
    SEXTET, SEPTET, OCTET, NONET, DECTET;

    public int numberOfMusicians() {
        ???
    }
}
```

A common but flawed approach

```
public enum Ensemble {
    SOLO, DUET, TRIO, QUARTET, QUINTET,
    SEXTET, SEPTET, OCTET, NONET, DECTET;

    public int numberOfMusicians() {
        return ordinal() + 1;
    }
}
```

What's Wrong With This Usage?

- It's a maintenance nightmare
  - If you (or someone else) reorder constants, program breaks silently
- Can't add multiple constants with same **`int`** value
  - A *double quartet* is 8 musicians, just like an octet
- Awkward to add constants out of sequence
  - A *triple quartet* is 12 musicians, but there's no term for 11

The Solution—Store `int` in an Instance Field

```
public enum Ensemble {
    SOLO(1), DUET(2), TRIO(3), QUARTET(4), QUINTET(5),
    SEXTET(6), SEPTET(7), OCTET(8), DOUBLE_QUARTET(8),
    NONET(9), DECTET(10), TRIPLE_QUARTET(12);

    private final int numberOfMusicians;
    Ensemble(int size) {
        numberOfMusicians = size;
    }

    public int numberOfMusicians() {
        return numberOfMusicians;
    }
}
```

Item 32: Bit Fields are Obsolete

```
public class Text {
    public static final int STYLE_BOLD          = 1;
    public static final int STYLE_ITALIC        = 2;
    public static final int STYLE_UNDERLINE     = 4;
    public static final int STYLE_STRIKETHROUGH = 8;

    // Param is bitwise OR of 0 or more STYLE_ values
    public void applyStyles(int styles) { ... }
}
```

All the Problems of `int` Constants and More

- Bit fields are not typesafe
- No namespace—must prefix constant names
- Brittle—constants compiled into clients
- Printed values are cryptic
- No easy way to iterate over elements represented by bit field
- If number of constants grows beyond 32, you are toast. Beyond 64, you're burnt toast.

The Solution—`EnumSet`

A Modern Replacement for Bit Fields

```
public class Text {
    public enum Style {
        BOLD, ITALIC, UNDERLINE, STRIKETHROUGH
    }

    // Any Set could be passed in, but EnumSet is best
    public void applyStyles(Set<Style> styles) { ... }
}
```

Client Code

```
text.applyStyles(EnumSet.of(Style.BOLD, Style.ITALIC));
```

`EnumSet` Combines Safety, Power, Efficiency

- Provides type safety, richness, and interoperability of **`Set`**
- Internally, each **`EnumSet`** is represented as a bit vector
  - If underlying enum type has <= 64 elements, a single **`long`**
  - If underlying enum type has > 64 elements, a **`long[]`**
- Bulk operations implemented with bitwise arithmetic
  - Same as you'd do manually for bit fields
  - Insulates you from the ugliness of manual bit twiddling

Item 33: How would you implement this?

```
public enum Phase {
    SOLID, LIQUID, GAS;

    public enum Transition {
        MELT, FREEZE, BOIL, CONDENSE, SUBLIME, DEPOSIT;

        // Returns phase transition from one phase to another
        public static Transition from(Phase src, Phase dst) {
            ???
        }
    }
}
```

Another common but flawed approach

```
public enum Phase {
    SOLID, LIQUID, GAS;

    public enum Transition {
        MELT, FREEZE, BOIL, CONDENSE, SUBLIME, DEPOSIT;

        // Rows indexed by src-ordinal, cols by dst-ordinal
        private static final Transition[][] TRANSITIONS = {
            { null,    MELT,     SUBLIME },
            { FREEZE,  null,     BOIL },
            { DEPOSIT, CONDENSE, null }
        };

        // Returns phase transition from one phase to another
        public static Transition from(Phase src, Phase dst) {
            return TRANSITIONS[src.ordinal()][dst.ordinal()];
        }
    }
}
```

What's Wrong With This Usage?

- Mistakes in transition table cause runtime failures
  - If you're lucky **`ArrayIndexOutOfBoundsException`** or **`NullPointerException`**
  - If not, silent erroneous behavior
- Maintenance nightmare
  - Easy to mess up table if you add an enum value
- Size of table is quadratic in the number of phases
- If enum is large, table will not be readable

The Solution—Use a (nested) **EnumMap** (1)

The Right Way to Associate Data With Enums

```
public enum Phase {
    SOLID, LIQUID, GAS;

    public enum Transition {
        MELT(SOLID, LIQUID), FREEZE(LIQUID, SOLID),
        BOIL(LIQUID, GAS),   CONDENSE(GAS, LIQUID),
        SUBLIME(SOLID, GAS), DEPOSIT(GAS, SOLID);

        private final Phase src;
        private final Phase dst;

        Transition(Phase src, Phase dst) {
            this.src = src;
            this.dst = dst;
        }
```

The Solution—Use a (nested) **EnumMap** (2)

The Right Way to Associate Data With Enums

```
        // Initialize the phase transition map
        private static final Map<Phase, Map<Phase,Transition>> m =
            new EnumMap<Phase, Map<Phase,Transition>>(Phase.class);

        static {
            // Insert empty map for each src state
            for (Phase p : Phase.values())
                m.put(p,new EnumMap<Phase,Transition>(Phase.class));

            // Insert state transitions
            for (Transition trans : Transition.values())
                m.get(trans.src).put(trans.dst, trans);
        }

        public static Transition from(Phase src, Phase dst) {
            return m.get(src).get(dst);
        }
    }
}
```

Adding Support for the *Plasma* State

- With original approach:
  - Add the constant **`PLASMA`** to **`Phase`**
  - Add **`IONIZE, DEIONIZE`** to **`Transition`**
  - Add 1 new row and 7 new entries to the transition table
  - Don’t make any mistakes or you’ll be sorry (at runtime)
- With **`EnumMap`** approach:
  - Add the constant **`PLASMA`** to **`Phase`**
  - Add **`IONIZE(GAS, PLASMA), DEIONIZE(PLASMA, GAS)`**
  - That’s it! Program initializes table for you

What is the `ordinal` Method Good for?

- The **`Enum`** specification says this:

  Most programmers will have no use for the **`ordinal`** method. It is designed for use by general-purpose enum-based data structures such as **`EnumSet`** and **`EnumMap`**.

- Unless you are writing such a data structure, don't use it
- If you do use **`ordinal`**:
  - Assume only a dense mapping of nonnegative **`int`** values to enums
  - Don't depend on which **`int`** value is assigned to which enum

Item 77: Pop Quiz: Is This Class a Singleton?

```
public class Elvis implements Serializable {
    public static final Elvis INSTANCE = new Elvis();
    private Elvis() { }

    private final String[] favoriteSongs =
        { "Hound Dog", "Heartbreak Hotel" };

    public void printFavorites() {
        System.out.println(Arrays.toString(favoriteSongs));
    }

    private Object readResolve() {
        return INSTANCE;
    }
}
```

Answer: Unfortunately Not

The first edition oversold the power of `readResolve`

- **`Elvis`** has a nontransient field (**`favoriteSongs`**)
- Cleverly crafted attack can save reference to deserialized **`Elvis`** instance when this field is deserialized
  - See **`ElvisStealer`** for details (Item 77)
- **`readResolve`** works only if all fields are transient

The Solution—Enum Singleton Pattern

The Right Way to Implement a Serializable Singleton

```
public enum Elvis {
    INSTANCE;

    private final String[] favoriteSongs =
        { "Hound Dog", "Heartbreak Hotel" };

    public void printFavorites() {
        System.out.println(Arrays.toString(favoriteSongs));
    }
}
```

Item 34: Coping With a Limitation of Enums

- Enums provide linguistic support for typesafe enum pattern
- All the advantages *, and more
  - Support for **`EnumSet`** and **`EnumMap`**
  - Reliable support for serialization
  - Support for **`switch`** statement
- * But one thing is missing—you can't extend an enum type
  - In most cases, you shouldn't
  - One compelling use case—operation codes

The Solution—Couple Enum With Interface (1)

Emulated Extensible Enum

```
public interface Operation {
    double apply(double x, double y);
}

public enum BasicOperation implements Operation {
  PLUS   { double apply(double x, double y){ return x + y; } },
  MINUS  { double apply(double x, double y){ return x - y; } },
  TIMES  { double apply(double x, double y){ return x * y; } },
  DIVIDE { double apply(double x, double y){ return x / y; } };
}
```

Use `Operation` to represent an operation in APIs

Use `Collection<? extends Operation>` for multiple ops

The Solution—Couple Enum With Interface (2)

Emulated Extendable Enum

```
public enum ExtendedOperation implements Operation {
    EXP {
        public double apply(double x, double y) {
            return Math.pow(x, y);
        }
    },
    REMAINDER {
        public double apply(double x, double y) {
            return x % y;
        };
    }
}
```

Enum Summary

- Don’t use **`ordinal`** to store **`int`** data; use **`int`** field
- Don’t use bit fields; use **`EnumSet`**
- Don’t use **`ordinal`** to index arrays; use **`EnumMap`**
- Don’t use **`readResolve`** for serializable singleton; use enum
- Emulate extensible enums with interfaces

Agenda

- Generics (Items 28)
- Enum types (Items 31–34, 77)
- Lazy initialization (Item 71)

Item 71: lazy initialization

- Delaying the initialization of a field until its value is needed
- When should you use it?
  - To fix an initialization circularity
  - To solve a performance problem
- Otherwise, prefer normal initialization

```
private final FieldType field = computeFieldValue();
```

- What is the best technique for lazy initialization?
  - It depends

To Break an Initialization Circularity, Use a Synchronized Accessor

```
private FieldType field;

synchronized FieldType getField() {
    if (field == null)
        field = computeFieldValue();
    return field;
}
```

For High-Performance on a Static Field, use the Lazy Initialization Holder Class Idiom

```
private static class FieldHolder {
    static final FieldType field = computeFieldValue();
}

static FieldType getField() {
    return FieldHolder.field;
}
```

For High-Performance on an Instance Field, use the Double-Check Idiom

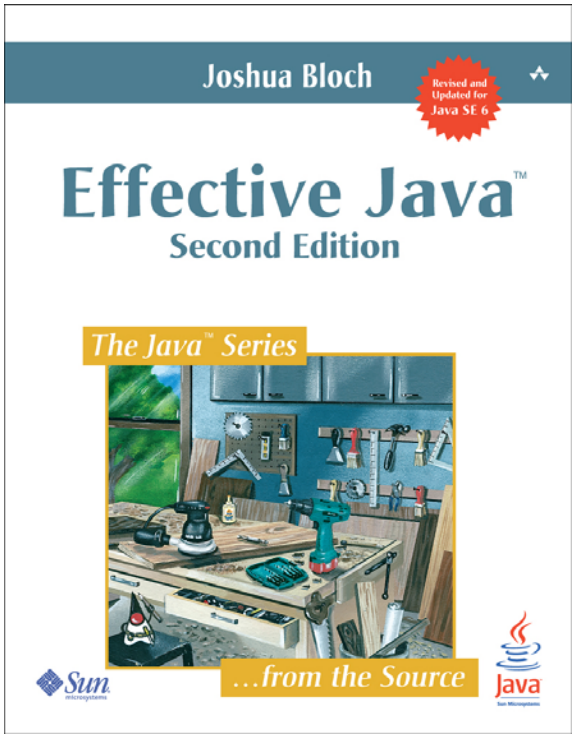
```
private volatile FieldType field;

FieldType getField() {
    FieldType result = field;
    if (result == null) {        // 1st check (no lock)
        synchronized(this) {
            result = field;
            if (result == null) // 2nd check (w/ lock)
                field = result = computeFieldValue();
        }
    }
    return result;
}
```

Lazy Initialization Summary

- Your default instinct should be normal (not lazy) initialization
- To break an initialization circularity: synchronized accessor
- For performance on a static field: holder class idiom
- For performance on an instance field: double-check idiom

Shameless Commerce Division

- For (much) more information:



- I'll be signing copies at the bookstore at Noon today

THANK YOU