

Using Lambdas to Write Mixins in Java 8

# Using Lambdas to Write Mixins in Java 8

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## Who is Heinz Kabutz?



- **Java consultant, instructor, programmer**
  - **Born in Cape Town, Economic Migrant on Crete**
  - **Created The Java Specialists' Newsletter**
    - **[www.javaspecialists.eu](http://www.javaspecialists.eu)**
  - **One of the first Java Champions**
    - **[www.javachampions.com](http://www.javachampions.com)**
  - **Unfounder of hottest Unconference JCrete ([jcrete.org](http://jcrete.org))**



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# Functional Interface

## Java 8 Lambda Syntax

- **In Java 7, we did this**

```
public void greetConcurrent() {  
    pool.submit(new Runnable() {  
        public void run() { sayHello(); }  
    });  
}
```

```
private void sayHello() { System.out.println("Kalamari!"); }
```

- **With Java 8 Lambdas, it is a lot more succinct**

```
public void greetConcurrent() {  
    pool.submit(() -> sayHello());  
}
```

## Functional Interface

- **Lambdas have to be functional interfaces**
- **Definition: *Functional Interface***
  - **Interface**
  - **Exactly one abstract method**
    - **Methods inherited from Object do not count**

## Is this a Functional Interface?

```
@FunctionalInterface  
public interface Runnable {  
    public abstract void run();  
}
```

Yes it is!

```
@FunctionalInterface  
public interface Runnable {  
    public abstract void run();  
}
```

Interface with  
exactly one  
abstract method

```
threadPool.submit(() -> sayHello());
```



## Is this a Functional Interface?

```
@FunctionalInterface  
public interface Callable<V> {  
    V call() throws Exception;  
}
```

Yes it is!

```
@FunctionalInterface  
public interface Callable<V> {  
    V call() throws Exception;  
}
```

Like Runnable -  
single abstract  
method

## Is this a Functional Interface?

```
@FunctionalInterface  
public interface ActionListener  
    extends EventListener {  
    public void actionPerformed(ActionEvent e);  
}
```

We first need to look at `EventListener`

~~*@FunctionalInterface*~~

```
public interface EventListener {  
}
```

EventListener is *not* a Functional Interface

Yes it is!

```
@FunctionalInterface  
public interface EventListener {  
}
```

```
@FunctionalInterface  
public interface ActionListener  
    extends EventListener {  
    public void actionPerformed(ActionEvent e);  
}
```

ActionListener  
Interface has  
exactly one  
abstract method

## Is this a Functional Interface?

```
@FunctionalInterface  
public interface Stringer {  
    // force class to implement toString()  
    String toString();  
}
```

No, it is not!

~~@FunctionalInterface~~

```
public interface Stringer {  
    // force class to implement toString()  
    String toString();  
}
```

Public methods  
defined inside Object  
do not count

# Object Refresher

```
public class Object {  
    public final Class<?> getClass();  
    public int hashCode();  
    public boolean equals(Object obj);  
    protected Object clone();  
    public String toString();  
    public final void notify();  
    public final void notifyAll();  
    public final void wait(long timeout);  
    public final void wait(long timeout, int nanos);  
    public final void wait();  
    protected void finalize();  
}
```

Which methods can we override? Which would be ignored in the functional interface method count?



## Final methods cannot be added to interface

```
public final Class<?> getClass();  
public final void notify();  
public final void notifyAll();  
public final void wait(long timeout);  
public final void wait(long timeout, int nanos);  
public final void wait();
```

## Public non-final methods for functional interfaces

```
public int hashCode();  
public boolean equals(Object obj);  
public String toString();
```

Protected methods count for functional interfaces

```
protected void finalize();  
protected Object clone();
```

## Is Foo1 a Functional Interfaces?

```
@FunctionalInterface  
public interface Foo1 {  
    boolean equals(Object obj);  
}
```

Nope, Foo1 is not

~~@FunctionalInterface~~

```
public interface Foo1 {  
    boolean equals(Object obj);  
}
```

equals(Object) is already an implicit member

## Is Bar1 a Functional Interfaces?

```
@FunctionalInterface  
public interface Bar1 extends Foo1 {  
    int compare(String o1, String o2);  
}
```

Indeed it is!

***@FunctionalInterface***

```
public interface Bar1 extends Foo1 {  
    int compare(String o1, String o2);  
}
```

Interface with  
exactly one  
abstract method

## Is this a Functional Interface?

```
@FunctionalInterface  
public interface Comparator<T> {  
    public abstract boolean equals(Object obj);  
    int compare(T o1, T o2);  
}
```



Yes, it is!

***@FunctionalInterface***

```
public interface Comparator<T> {  
    public abstract boolean equals(Object obj);  
    int compare(T o1, T o2);  
}
```

equals(Object) is already  
an implicit member

Interface with  
exactly one  
abstract method

## And what about this?

```
@FunctionalInterface  
public interface CloneableFoo {  
    int m();  
    Object clone();  
}
```

No, it is not!

~~@FunctionalInterface~~

```
public interface CloneableFoo {  
    int m();  
    Object clone();  
}
```

clone() is not  
public in Object

## Is this a Functional Interface?

***@FunctionalInterface***

```
public interface MouseListener  
    extends EventListener {  
    public void mouseClicked(MouseEvent e);  
    public void mousePressed(MouseEvent e);  
    public void mouseReleased(MouseEvent e);  
    public void mouseEntered(MouseEvent e);  
    public void mouseExited(MouseEvent e);  
}
```

No, it is not!

MouseListener has five abstract methods

~~@FunctionalInterface~~

```
public interface MouseListener
    extends EventListener {
    public void mouseClicked(MouseEvent e);
    public void mousePressed(MouseEvent e);
    public void mouseReleased(MouseEvent e);
    public void mouseEntered(MouseEvent e);
    public void mouseExited(MouseEvent e);
}
```

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# Fundamental Functional Interfaces

## Fundamental Functional Interfaces

- **Java 8 contains some standard functional interfaces**
  - **Supplier<T>**
  - **Consumer<T>**
  - **Predicate<T>**
  - **Function<T, R>**
  - **UnaryOperator<T>**
  - **BinaryOperator<T>**

## Supplier<T>

- Use whenever you want to supply an instance of a T
  - Can delay object creation, for example:

```
public void foo() {
    logger.fine("ms since 1970: " + System.currentTimeMillis());
}

public void bar() {
    logger.fine(() -> "ms since 1970: " + System.currentTimeMillis());
}
```

```
public void fine(Supplier<String> msgSupplier) {
    log(Level.FINE, msgSupplier);
}
```



## Consumer<T>

- Provide an action to be performed on an object

```
Collection<String> names =  
    Arrays.asList("Kirk", "Andrea", "Szonya", "Anna");  
names.forEach(new Consumer<String>() {  
    public void accept(String s) {  
        System.out.println(s.toUpperCase());  
    }  
});
```

```
names.forEach(s -> System.out.println(s.toUpperCase()));
```

```
names.stream().map(String::toUpperCase).forEach(System.out::println);
```

## Predicate<T>

- A boolean-valued property of an object

```
Collection<String> names =  
    Arrays.asList("Heinz", "Helene", "Maxi",  
                 "Connie", "Bangie", "Efi");  
names.removeIf(new Predicate<String>() {  
    public boolean test(String s) {  
        return s.contains("i");  
    }  
});
```

```
names.removeIf(s -> s.contains("i"));
```

## Function<T, R>

- Transforming a T to an R

```
Collection<String> names =  
    Arrays.asList("Heinz", "Helene", "Maxi",  
                 "Connie", "Bangie", "Efi");  
names.stream().map(new Function<String, Integer>() {  
    public Integer apply(String s) {  
        return s == null ? 0 : s.length();  
    }  
});
```

```
names.stream().mapToInt(s -> s == null ? 0 : s.length());
```

## UnaryOperator<T>

- Transforming a T - similar to Function<T, T>

```
List<String> names =  
    Arrays.asList("Heinz", "Helene", "Maxi",  
                 "Connie", "Bangie", "Efi");  
names.replaceAll(new UnaryOperator<String>() {  
    public String apply(String s) {  
        return s.toUpperCase();  
    }  
});
```

```
names.replaceAll(s -> s.toUpperCase());
```

```
names.replaceAll(String::toUpperCase);
```

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# Evils Of Method Overloading

## Evils of Method Overloading

- **Java has always supported method overloading**
  - **Methods can have the same name with different arguments**
  - **e.g. `System.out.println(int/long/String/Object/etc.)`**

# Evils of Method Overloading in Java 5

- **What's the output of `new B().foo(42)` ?**

```
public class A {  
    public void foo(Integer i) {  
        System.out.println("foo(Integer) " + i);  
    }  
}  
  
public class B extends A {  
    public void foo(long l) {  
        System.out.println("foo(long) " + l);  
    }  
}
```

## Autoboxing Cannot Change Semantics

- What's the output of `new B().foo(42)` ?

```
public class A {  
    public void foo(Integer i) {  
        System.out.println("foo(Integer) " + i);  
    }  
}  
  
public class B extends A {  
    public void foo(long l) {  
        System.out.println("foo(long) " + l);  
    }  
}
```

foo(long)



# Functional Interfaces and Overloading

- **Which functional interface is used for lambda?**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> System.out.println("Hallo München!"));
```

## Functional Interfaces and Overloading

- **Return type of void and no exceptions**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> System.out.println("Hallo München!"));
```

Runnable

# Functional Interfaces and Overloading

- **Which functional interface is used now?**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> System.out.printf("Hallo %s!\n", "München"));
```

## Functional Interfaces and Overloading

- **Return type of `System.out.printf()` is `PrintStream`**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> System.out.printf("Hallo %s!\n", "München"));
```

**`Callable<PrintStream>`**

## Functional Interfaces and Overloading

- **And with this lambda?**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> pool.awaitTermination(1, TimeUnit.DAYS));
```

## Functional Interfaces and Overloading

- **awaitTermination()** throws **InterruptedException** and returns **boolean**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> pool.awaitTermination(1, TimeUnit.DAYS));
```

**Callable<Boolean>**

## Functional Interfaces and Overloading

- **How about this one? Runnable or Callable?**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> TimeUnit.DAYS.sleep(1));
```

## Functional Interfaces and Overloading

- **sleep() throws InterruptedException, returns void**

```
ExecutorService pool = Executors.newCachedThreadPool();  
pool.submit(() -> TimeUnit.DAYS.sleep(1));
```

**Compiler error:**

**Unhandled exception:**

**java.lang.InterruptedException**



## Forcing a particular lambda type

- **If we want to use the `submit(Runnable)` method with a lambda that would typically be `Callable`**
  - **We could first write the lambda into a local variable**

```
Runnable job = () -> System.out.printf("Hallo %s!", "München");  
pool.submit(job); // uses Runnable
```

## Forcing a particular lambda type

- **We could skip the local variable**

- **Careful if we want to inline that lambda**

```
pool.submit((Runnable) () ->  
    System.out.printf("Hallo %s!", "München"));
```

- **This would not be correct - it would now be Callable**

```
pool.submit(() ->  
    System.out.printf("Hallo %s!", "München"));
```

## Forcing a particular lambda type

- **Alternatively, we can use a “Type Witness”**

```
pool.<Runnable>submit(() ->  
    System.out.printf("Hallo %s!", "München"));
```

- **This is the preferred approach!**

# Prefer Method References Over Lambdas

*This one is controversial*

# Prefer Method References over Lambdas

- **Old-school iteration**

```
Class<?> clazz = String.class;
```

```
for (Class<?> intf : clazz.getInterfaces()) {  
    System.out.println(intf.getName());  
}
```

# Prefer Method References over Lambdas

- **Newer internal iteration using stream with explicit type for lambda parameter**

```
Class<?> clazz = String.class;
```

```
Stream.of(clazz.getInterfaces())  
    .forEach((Class<?> intf) ->  
        System.out.println(intf.getName()));
```

# Prefer Method References over Lambdas

- **Newer internal iteration using stream with inferred type for lambda parameter**

```
Class<?> clazz = String.class;
```

```
Stream.of(clazz.getInterfaces())  
    .forEach(intf ->  
        System.out.println(intf.getName()));
```

# Prefer Method References over Lambdas

- **However, the `forEach` “Consumer” really does two things:**
  - **Convert class to `String` with `intf.getName()`**
  - **Print `String` to console with `System.out.println()`**



## Prefer Method References over Lambdas

- **Split into two separate actions, *map* and *forEach***
  - **But we have to think up useless names for parameters**

```
Class<?> clazz = String.class;
```

```
Stream.of(clazz.getInterfaces())  
    .map(intf -> intf.getName())  
    .forEach(name ->  
        System.out.println(name));
```

# Prefer Method References over Lambdas

- **Instead, we can use Method References**
  - Needs some “getting used to”
  - Not liked by everyone - Stephen Colebourne

```
Class<?> clazz = String.class;
```

```
Stream.of(clazz.getInterfaces())  
    .map(Class::getName)  
    .forEach(System.out::println);
```

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# Mixins Using Java 8 Lambdas

## Mixins using Java 8 Lambdas

- **State of the Lambda has this misleading example**

```
public interface ActionListener {  
    void actionPerformed(ActionEvent e);  
}  
  
button.addActionListener(new ActionListener() {  
    public void actionPerformed(ActionEvent e) {  
        ui.dazzle(e.getModifiers());  
    }  
});
```

- **With Java 8 Lambdas, this becomes**

```
button.addActionListener(e -> ui.dazzle(e.getModifiers()));
```

- **But most AWT Listeners *not* functional interfaces**

## Pre-Lambda Event Listeners

```
salaryIncreaser.addFocusListener(new FocusAdapter() {  
    public void focusGained(FocusEvent e) {  
        System.out.println("Almost there!");  
    }  
});  
salaryIncreaser.addKeyListener(new KeyAdapter() {  
    public void keyPressed(KeyEvent e) {  
        e.consume();  
        System.out.println("Not quite!");  
    }  
});  
salaryIncreaser.addMouseListener(new MouseAdapter() {  
    public void mouseEntered(MouseEvent e) {  
        shuffleSalaryButton();  
    }  
});
```

## This is What We Want

```
salaryIncreaser.addFocusGainedListener(  
    e -> System.out.println("Almost there!")  
);  
  
salaryIncreaser.addKeyPressedListener(  
    e -> {  
        e.consume();  
        System.out.println("Not quite!");  
    }  
);  
  
salaryIncreaser.addMouseEnteredListener(  
    e -> shuffleSalaryButton()  
);
```

**How do we get there?**

# Focus/Mouse/KeyListener are *not* Functional Interfaces

- They have several abstract methods

```
public interface FocusListener {  
    /**  
     * Invoked when a component gains the keyboard focus.  
     */  
    void focusGained(FocusEvent e);  
  
    /**  
     * Invoked when a component loses the keyboard focus.  
     */  
    void focusLost(FocusEvent e);  
}
```

## FocusAdapter

- In previous example, we used **MouseListener**, **FocusAdapter** and **KeyListener**

```
public abstract class FocusAdapter
    implements FocusListener {
    public void focusGained(FocusEvent e) {}
    public void focusLost(FocusEvent e) {}
}
```



## FocusEventProducerMixin

```
public interface FocusEventProducerMixin {  
    void addFocusListener(FocusListener l);  
  
    default void addFocusGainedListener(Consumer<FocusEvent> c) {  
        addFocusListener(new FocusAdapter() {  
            public void focusGained(FocusEvent e) { c.accept(e); }  
        });  
    }  
  
    default void addFocusLostListener(Consumer<FocusEvent> c) {  
        addFocusListener(new FocusAdapter() {  
            public void focusLost(FocusEvent e) { c.accept(e); }  
        });  
    }  
}
```

## What Just Happened?

- **We defined an interface with default methods**
  - Both `addFocusGainedListener()` and `addFocusLostListener()` call the abstract method `addFocusListener()` in the interface
  - It is a Functional Interface, but that does not matter in this case
- **Let's see how we can “mixin” this interface into an existing class JButton**

## JButtonLambda Mixin Magic

- **JButton contains method addFocusListener**
- **We subclass it and implement Mixin interface**
  - **We could even leave out the constructors and just have**  

```
public class JButtonLambda extends JButton  
    implements FocusEventProducerMixin { }
```
- **With our new JButtonLambda, we can now call**  

```
salaryIncreaser.addFocusGainedListener(  
    e -> System.out.println("Almost there!")  
);
```

## JButtonLambda

```
public class JButtonLambda extends JButton
    implements FocusEventProducerMixin {
    public JButtonLambda() { }

    public JButtonLambda(Icon icon) { super(icon); }

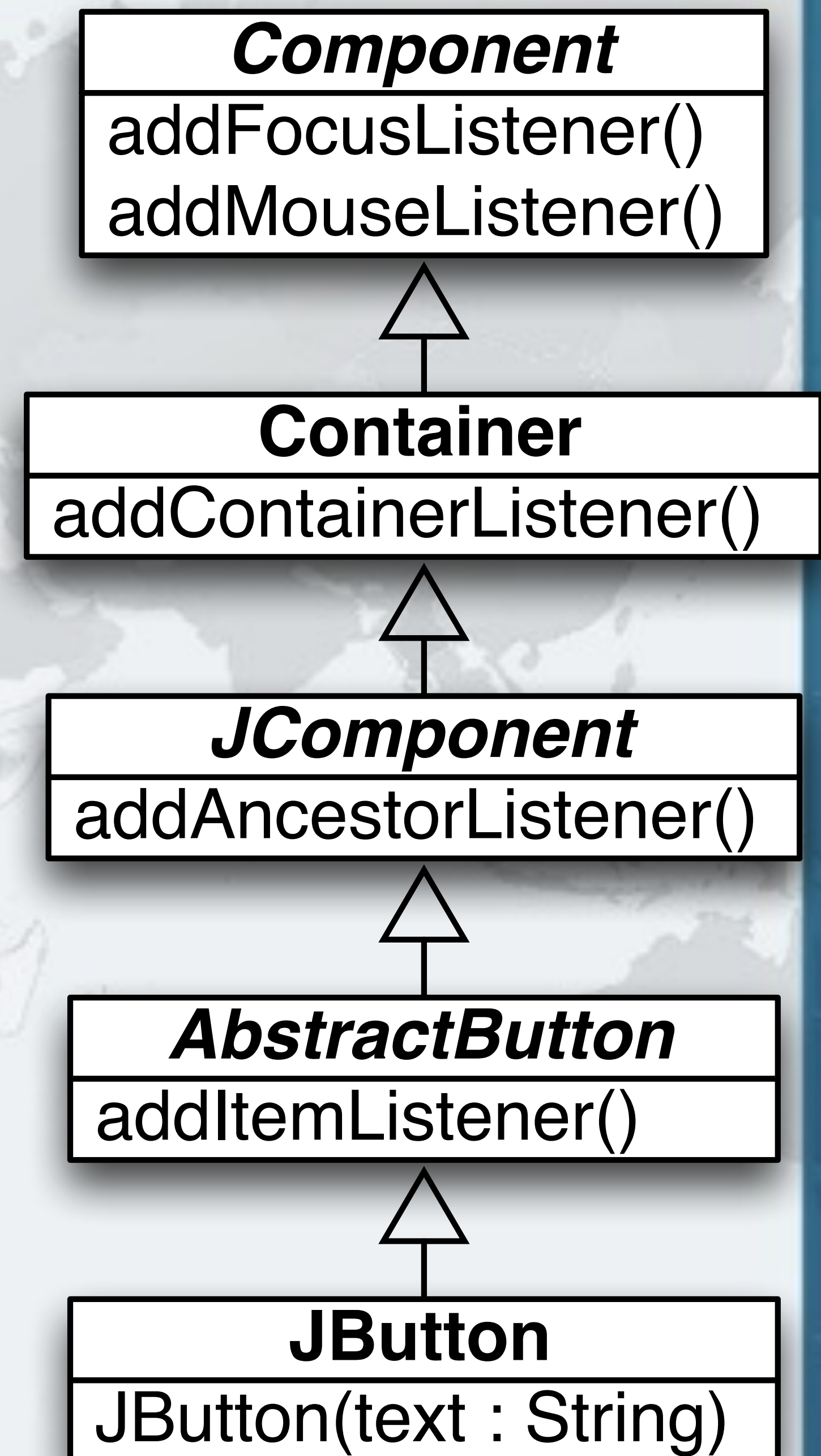
    public JButtonLambda(String text) { super(text); }

    public JButtonLambda(Action a) { super(a); }

    public JButtonLambda(String text, Icon icon) {
        super(text, icon);
    }
}
```

## Combining Different Mixins

- Each class in the hierarchy adds new `addXXXListener()` methods
  - Here are just some of them
- We can define a `JComponent` mixin that contains all the `addXXXListener` and other mixins in the classes above



## JComponent Mixin

```
public interface JComponentEventProducerMixin extends
    AncestorEventProducerMixin,
    ComponentEventProducerMixin,
    ContainerEventProducerMixin,
    FocusEventProducerMixin,
    HierarchyEventProducerMixin,
    InputMethodEventProducerMixin,
    KeyEventProducerMixin,
    MouseEventProducerMixin,
    MouseMotionEventProducerMixin {
void addHierarchyListener(HierarchyListener l);
void addMouseListener(MouseWheelListener l);
void addPropertyChangeListener(PropertyChangeListener l);
void addVetoableChangeListener(VetoableChangeListener l);
}
```

## AbstractButton Mixin

```
public interface AbstractButtonEventProducerMixin {  
    void addActionListener(ActionListener l);  
    void addItemListener(ItemListener l);  
    void addChangeListener(ChangeListener l);  
}
```

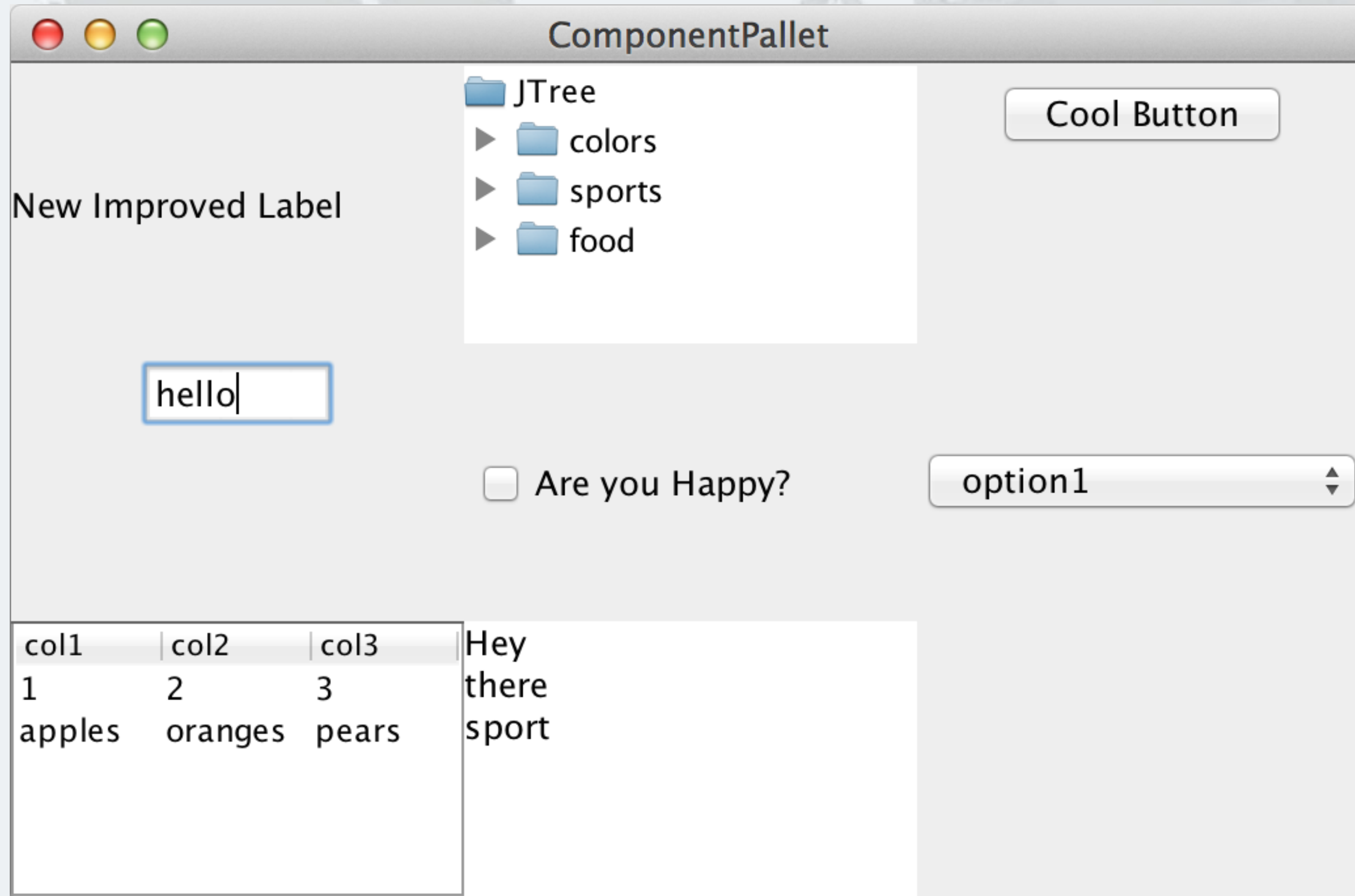
**We need this so that we have a common super-interface that we can cast all types of abstract buttons to.**

## JButton using JComponent Mixins

```
public class JButtonLambda extends JButton  
    implements JComponentEventProducerMixin,  
                AbstractButtonEventProducerMixin {  
    public JButtonLambda() {  
    }  
    // and other constructors  
}
```



## ComponentPallet Demo



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# Facade Pattern For Listeners

## Facade Pattern for Listeners

- **Another approach is facades for each listener**

```
public interface FocusListeners {  
    static FocusListener forFocusGainedListener(  
        Consumer<FocusEvent> c) {  
        return new FocusAdapter() {  
            public void focusGained(FocusEvent e) {c.accept(e);}  
        };  
    }  
    static FocusListener forFocusLostListener(  
        Consumer<FocusEvent> c) {  
        return new FocusAdapter() {  
            public void focusLost(FocusEvent e) { c.accept(e); }  
        };  
    }  
}
```

## Facade Pattern for Listeners

```
salaryIncreaser.addFocusListener(  
    FocusListeners.forFocusGainedListener(  
        e -> System.out.println("Almost there!"))));
```

```
salaryIncreaser.addKeyListener(  
    KeyListeners.forKeyPressedListener(  
        e -> {  
            e.consume();  
            System.out.println("Not quite!");  
        }));
```

```
salaryIncreaser.addMouseListener(  
    MouseListeners.forMouseEntered(  
        e -> shuffleSalaryButton()));
```

Using Lambdas to Write Mixins in Java 8

# Method Call Stacks

**Bonus material (if we have time)**

## Method Call Stacks

- **Anonymous inner classes use synthetic static methods to access private members**

```
private void showStack() {  
    Thread.dumpStack();  
}
```

```
private void anonymousClassCallStack() {  
    Runnable runnable = new Runnable() {  
        public void run() {  
            showStack();  
        }  
    };  
    runnable.run();  
}
```

## Method Call Stacks

- **Output of run**

```
java.lang.Exception: Stack trace
  at java.lang.Thread.dumpStack(Thread.java:1329)
  at MethodCallStack.showStack(MethodCallStack.java:3)
  at MethodCallStack.access$000(MethodCallStack.java:1)
  at MethodCallStack$1.run(MethodCallStack.java:9)
  at MethodCallStack.anonymousClassCallStack(MethodCallStack.java:12)
```

- **Synthetic method in MethodCallStack.class**

```
static void MethodCallStack.access$000(MethodCallStack)
```

## Method Call Stacks

- **Lambdas have more direct access to outer class**

```
public void lambdaCallStack() {  
    Runnable runnable = () -> showStack();  
    runnable.run();  
}
```

```
java.lang.Exception: Stack trace  
    at java.lang.Thread.dumpStack(Thread.java:1329)  
    at MethodCallStack.showStack(MethodCallStack.java:3)  
    at MethodCallStack.lambda$lambdaCallStack$0(MethodCallStack.java:16)  
    at MethodCallStack$$Lambda$1/455659002.run(Unknown Source)  
    at MethodCallStack.lambdaCallStack(MethodCallStack.java:17)
```

- **Synthetic  $\lambda$  method in MethodCallStack.class**

```
private void MethodCallStack.lambda$lambdaCallStack$0()
```



# Conclusion

## Mixins in GitHub

- **Code with more details available here**
  - **<https://github.com/kabutz/javaspecialists-awt-event-mixins>**
  - **(<http://tinyurl.com/jmixins>)**



# Lambdas, Static and Default Methods

- **Java 8 released in March 2014**
- **Practical use of language is producing idioms**
- **Mixin idea can be applied in other contexts too**
  - e.g. Adding functionality to Enums
- **A lot of my customers are moving to Java 8**
  - Some concurrency constructs like ReentrantLock have fewer bugs in Java 8

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