Java gets a closure

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Agenda

- Lambdas and closures
- Java syntax
- Functional interfaces
- Implementation notes
- Defender methods and interface evolution
- Library changes
- Lambda related language changes

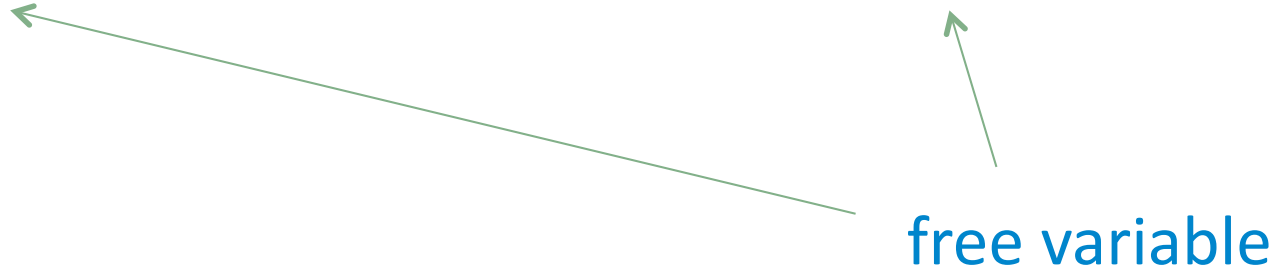
Lambda expression

- Lambda exprssion is another name for an anonymous function e.g. function not bound to an identifier.
- In Java it includes an optional list of type parameters, a list of formal parameters, and an expression or block expressed in terms of those parameters.

Example

```
char[] string = „jdd 2011”

(int count) -> {
   for(int i = 0; i< count; i++) {
         string[i] = Character.toUpperCase(string[i]);
   }
}
```



JDD

Why we hate anonymous inner classes?

- Java already has a form of closures - anonymous inner classes

```
List<Person> list = new ArrayList<>();
Collections.sort(list, new Comparator<Person>() {
  @Override
  public int compare(Person p1, Person p2) {
      return p1.getName().compareTo(p2.getName());
  }
});
```

Why we hate anonymous inner classes?

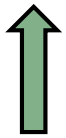
- Bulky syntax
- Inability to capture non-final local variables
- Transparency issues surrounding the meaning of return, break, continue, and 'this'
- No nonlocal control flow operators

Will we love lambda expressions?

- ~~Bulky syntax~~
- ~~Inability to capture non-final local variables~~
- Transparency issues surrounding the meaning of return, break, continue, ~~and 'this'~~
- No nonlocal control flow operators

Lambda syntax

```
List<Person> list = new ArrayList<>();
Collections.sort(list, (p1, p2) ->
  p1.getName().compareTo(p2.getName())
);
```



```
List<Person> list = new ArrayList<>();
Collections.sort(list, new Comparator<Person>() {
  @Override
  public int compare(Person p1, Person p2) {
      return p1.getName().compareTo(p2.getName());
  }
});
```

Lambda syntax

LambdaExpression:
    TypeParameters$_{opt}$ LambdaParameters '->' LambdaBody

LambdaParameters:
    Identifier
    '(' InferredFormalParameterList ')'
    '(' FormalParameterList$_{opt}$ ')'

InferredFormalParameterList:
    Identifier
    InferredFormalParameterList ',' Identifier

LambdaBody:
    Expression
    Block

Lambda syntax examples

```
() -> {}
() -> 3.14
() -> { System.out.println("lambda"); }
() -> { return 3.14; }

i -> i*2
(int i) -> i+1
(i) -> i+1

(List<Person> people) -> {
        for(Person person : people) {
                System.out.println(person.getFirstName());
        }
}
```

Invalid syntax examples

- Either types/modifiers are infered or we need to specify all of them:

```
(final x) -> {}
(int x, y) -> 3.14
```

- Lambda body is either an expression (no brackets) or a block (brakcets and return statement needed):

```
() -> { 3.14; }
```

- Only unary lambda may omit parentheses:

```
i, j -> i*j
```

What is the type of a lambda?

- Ther will be no function types in Java 8
- We need to define how lambdas interact with other parts of Java
- We need ways to store, pass and execute them

Functional interfaces

- Previously known as SAM interfaces
  - SAM = Single Abstract Method
- Interfaces that define one method
  - Public methods defined by Object do not count

```
interface Runnable { void run(); }

interface Callable<T> { T call(); }

interface Comparator<T> {
      int compare(T o1, T o2);

      boolean equals(Object obj);
```

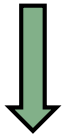
Closure conversion

- Lambda expresion is converted to an instance of a functional interface
- It can appear in assignment, invocation and casting contexts
- The type lambda is converted to is infered from the context
  - Target typing
- Parameter types of the lambda are also inferred

Type inference

```
interface Processor<T> {
      void process(Context c, T item);
}

Processor<Integer> p = (Context c, Integer i) ->
  { ... };
```



```
Processor<Integer> p = (c, i) -> { ... };
```

Local variable capture

- Lambda expressions can refer to effectively final local variables from the enclosing scope

```
int getAdultCount(List<Person> people, int threshold) {
      return Collections.filter(people, p -> p.getAge()
  > threshold).size();
}

void registerNotifier(JButton button, JLabel label) {
      button.addActionListener(e -> label.setText(""));
}
```

Local variable capture

- Cannot do this:

```
int accumulatedExperience = 0;
people.forEach(p -> accumulatedExperience += p.getEmploymentYears());
```

- Don’t even try this:

```
/* final */ int[] accumulatedExperience = { 0 };
people.forEach(p -> accumulatedExperience[0] += p.getEmploymentYears());
```

- Try this:

```
/* final */ AtomicInteger accumulatedExperience = new AtomicInteger();
people.forEach(p -> accumulatedExperience.addAndGet(p.getEmploymentYears()));
```

- Best solution:

```
people.reduce(0, (value, p) -> value +p.getEmploymentYears());
people.reduce(0, Math::add);
```

Lexical scoping

- All identifiers retain their meaning inside lambda expression
- The meaning of `this` does not change.
- Lambda formals cannot shadow variables from enclosing scope.
- There is no non-local control flow

Lexical scoping

```
interface ConfigFilter {
   String KEY = "configuration.source";
   boolean matches(Properties properties);
}

class FileConfigurator  {
   String VALUE = „file://";

   public void configure(List<Properties> list) {
        configure(list, p ->
                p.getProperty(ConfigFilter.KEY).startsWith(VALUE));
   }

   void configure(List<Properties> l, ConfigurationFilter f) { ... }
}
```

Lambda self reference

- Definite assignment rules say when a variable is definitely assigned
  - e.g. if it is a local variable it can be safely used
- Definite uassignment say when a variable is definitely unassigned
  - e.g. so that it can be assigned if it is final

- Function fib = n -> { n == 0 ? 1 : n *fib.apply(n -1) };

Method references

- Method reference is a shorthand for a lambda invoking just that method

- Static methods simply translate like lambda with same arguments and return type:

```
class Integer {
      public static String toString(int i) { ... }
}

Mapper<Integer, String> a = i ->  Integer.toString(i);
Mapper<Integer, String> b = Integer::toString;
```

Method references

- Non static method reference of type T translates like lambda with an additional argument of type T:

```
Mapper<String, Integer> a = s ->  s.length;
Mapper<String, Integer> b = String::length;
```

- Instance method reference translates like lambda with same arguments and return type (and implicit receiver):

```
Callable<Integer> c = "test"::length;
```

Constructor references

- Basically same as method references:

```
Callable<Person> p = Person::new;
```

- Generic type constructor:

```
LinkedList<Integer>::new
```

- Raw type constructor :

```
LinkedList::new
```

- Generic constructor with type argument:

```
Foo::<Integer>new
```

Exception transparency?

- Generic exceptions are cumbersome to use
- Libraries either use interface with methods that throw Exception or throw nothing:

```
interface Runnable {
}

interface Callable<V> {
        V call() throws Exception
}

interface Callable<V, E extends Exception> {
        V call() throws E
}
```

Exception transparency?

```
interface Callable<V, throws E> {
        V call() throws E
}

class Executor {
        static <V, throws E> execute(Callable<V, E>) throws E;
}

Callable<Integer, IOException> c = ...
Executor.execute(c); // Throws IOException

Callable<Integer> d = ...
Executor.execute(d); // Throws nothing

Callable<Integer, ExecutionException, BadBreathException> e = ...
Executor.execute(e); // Throws ExecutionException, BadBreathException
```

Translation to inner classes

```
public class SimpleLambda {
        Runnable r = new Runnable() {
                public void run() { }
        };
}

public class SimpleLambda {
        Runnable r = () -> {};
}
```

- Compiling this source files will each time generate two classes:
  - `SimpleLambda.cass`
  - `SimpleLambda$1.class`
- In both situations classes are almost identical

Translation to method handles

- Try compiling with option -`XDlambdaToMethod`
- This will generate one class file.
- It will contain additional elements:
  - Static method called lambda$0 with compiled lambda body
  - Bootstrap method that will call ProxyHelper to generate interface proxy
  - Calls to Runnable.run() will be dispatched through MethodHandle
  - InvokeDynamic instruction at instantiation callsite

Extension Methods

Extension methods

- Programming style would be different if Java had closures from day one
- Different library designs, different collection classes
- Adding closures without library support would be dissapointing
- When interface is published it is effectively freezed – adding new methods will break existing implementations

Extension methods

- We would like to be able to write:

```
list.sortBy(Person::getFirstName).filter(Person::
  isEmployed).filter(p -> p.getAge()
  <30).forEach(System.out::println);

students.map(s -> s.getScore()).reduce(0.0,
  Math::max);
```

Static extension methods

- In C# they enable adding methods to existing types without recompiling or creating a new type.
- Special kind of static method, called as if it was an instance method on the extended type.
- Use site extension – user is in control
- Create illusion of adding a method
- Not reflectively discoverable
- No way to override

Extension methods

- Mechnism for interface evolution
- Library developer is in control
- Main use case: java collections
- A.k.a. public defender methods:

“if you cannot afford an implementation of this method, one will be provided for you”

Virtual extension methods

```
public interface List<E> extends Collections<E> {
public void sort(Comparator<? super E> c) default
  Collections.<E>sort;
}

public class Collections {
public static <T extends Comparable<? super T>> void
  sort(List<T> list) { ... }
}

List<Person> jddAtendee = ...
jddAtendee.sort(...);
```

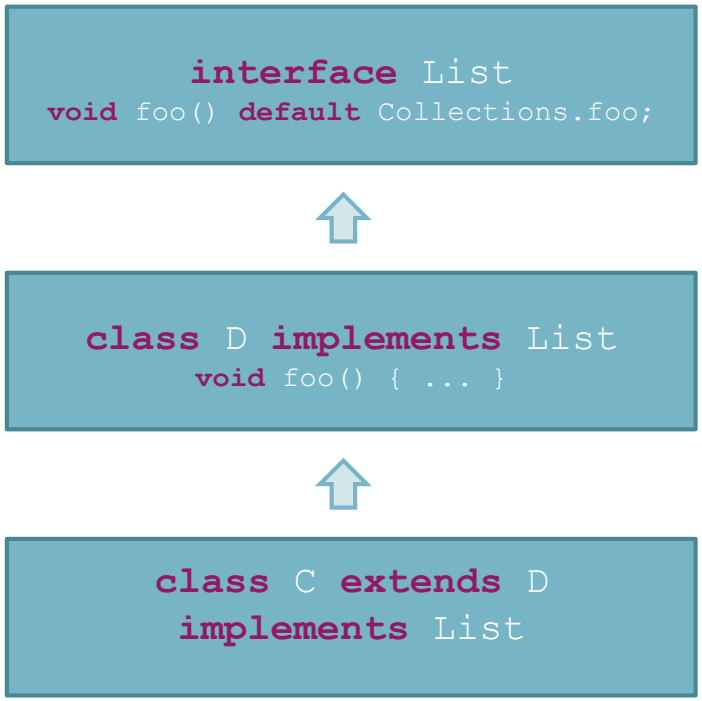
Virtual extension methods

- Compiled to regular invokeinterface call
- Caller is unaware of special call dispatch
- Target method is resolved by JVM at runtime
- Adds multiple inheritance of behavior not state!
- Changes are (mostly) soruce and binary compatible

Method resolution

- Inheritance of methods from classes and interfaces is treated separately
- First JVM performs standard method implementation search – from the receiver class upwards through inheritance hierarchy to Object

Method resolution



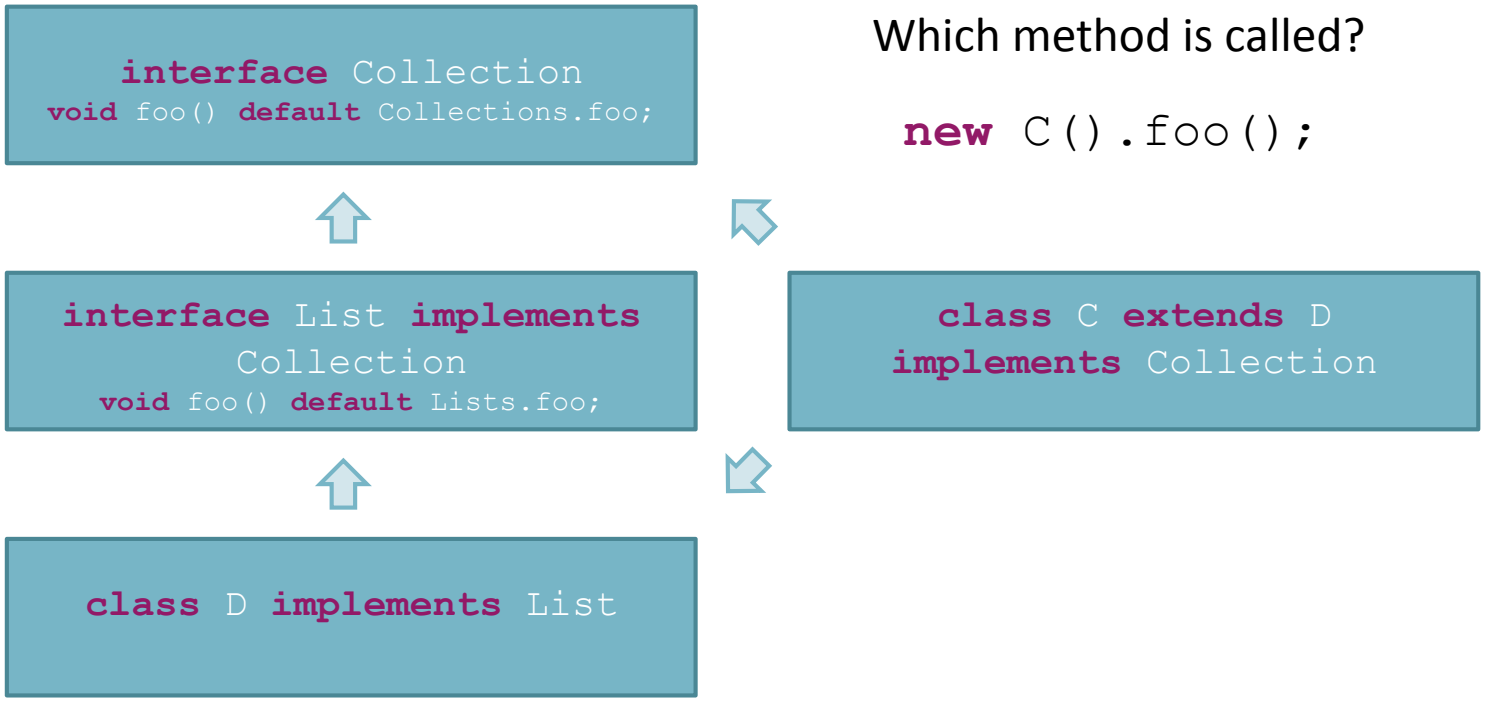
Which method is called?

```
new C().foo();
```

Method resolution

- List interfaces implemented by C (directly or indirectly) which provide a default for the method in question
- Remove all items that are superinterface of any other one from this list
- Create a set of distinct defaults provided by interfaces on the list
- Resolution is succesful if this set has a single item
- Throw a linkage exception otherwise

Method resolution



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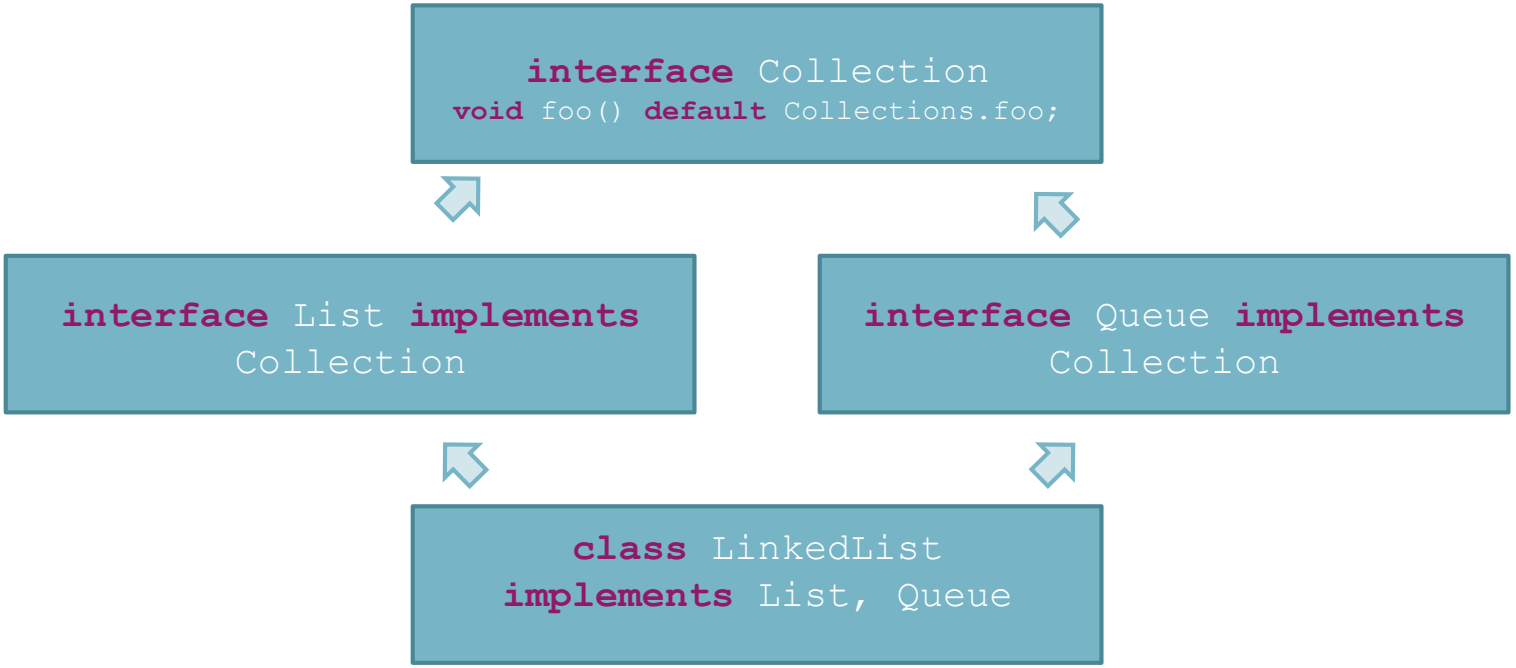
Method resolution



- When using this method resolution rules diamonds are not a problem (there is no state inheritance!)

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Manual method disambiguation

- Compile time disambiguation of conflicting defaults is done using new syntax: `A.super.method()`

```
interface A {
  void foo() default As.foo;
}

interface B {
  void foo() default Bs.foo;
}

class C implements A, B {
  public void foo() { A.super.foo(); }
}
```

Collection enhancements

Collection enhancements

```
public interface Predicate<T> {
      boolean eval(T t);
}

public interface Block<T> {
      void apply(T t);
}

public interface Mapper<T, U> {
     U map(T t);
}
```

Iterable

```
public interface Iterable<T>{
  Iterable<T> filter(Predicate<? super T> predicate)
      default Iterables.filter;

  Iterable<T> forEach(Block<? super T> block)
      default Iterables.forEach;

  <U> Iterable<U> map(Mapper<? super T, ? extends U>
  mapper) default Iterables.map;

  T reduce(T base, Operator<T> reducer)
      default Iterables.reduce;
}
```

Collection

```
public interface Collection<E> extends Iterable<E> {

    boolean retainAll(Predicate<? super E> filter)
      default CollectionHelpers.retainAll;

    boolean removeAll(Predicate<? super E> filter)
      default CollectionHelpers.removeAll;

    void addAll(Iterable<? extends E> source)
      default CollectionHelpers.addAll;
}
```

Iterator

```
public interface Iterator<E> {
  boolean hasNext();
  E next();
  void remove() default Iterators.removeUnsupported;
}

public final class Iterators {
  public static <T> void removeUnsupported(Iterator<T> t) {
        throw new UnsupportedOperationException("remove");
    }
}
```

Enumeration

```
interface Enumeration<E> extends Iterator<E> {
  boolean hasMoreElements();

  E nextElement();

  // { return hasMoreElements(); }
  boolean hasNext() default Enumerations.hasNext;

  // { return nextElement(); }
  E next() default Enumerations.next;
}
```

Collections enhancements

```
Collections.sort(list, (p1, p2) ->
  p1.getName().compareTo(p2.getName())
);
```

```
interface Extractor<T,U> { public U extract(T t); }

public void<T, U extends Comparable<? super U>>
  sortBy(Collection<T> coll, Extractor<T, U> ext);
```

```
Collections.sortBy(people, Person::getName);
```

```
people.sortBy(Person::getName);
```

Development status

- Started in december 2009
- Compiler implemented as part of an OpenJDK
- Early Draft Review recently published
  - http://www.jcp.org/en/jsr/summary?id=335
- No VM support for extension methods yet

Resources

- Compiler prototype binaries available at:
  - http://jdk8.java.net/lambda/
- State of the lambda document:
  - http://cr.openjdk.java.net/~briangoetz/lambda/lambda-state-3.html
- Extension methods draft:
  - http://cr.openjdk.java.net/~briangoetz/lambda/Defender%20Methods%20v3.pdf
- Extension methods weaving agent availbale at:
  - hg.openjdk.java.net/lambda/defender-prototype/

Resources

- Brian Goetz's Oracle Blog
  - http://blogs.oracle.com/briangoetz
- Neal Gafter's blog (interesting for historical purposes)
  - http://gafter.blogspot.com
- lambda-dev discussion list
  - http://mail.openjdk.java.net/pipermail/lambda-dev