Dynalink

Dynamic Linker Framework for Languages on the JVM

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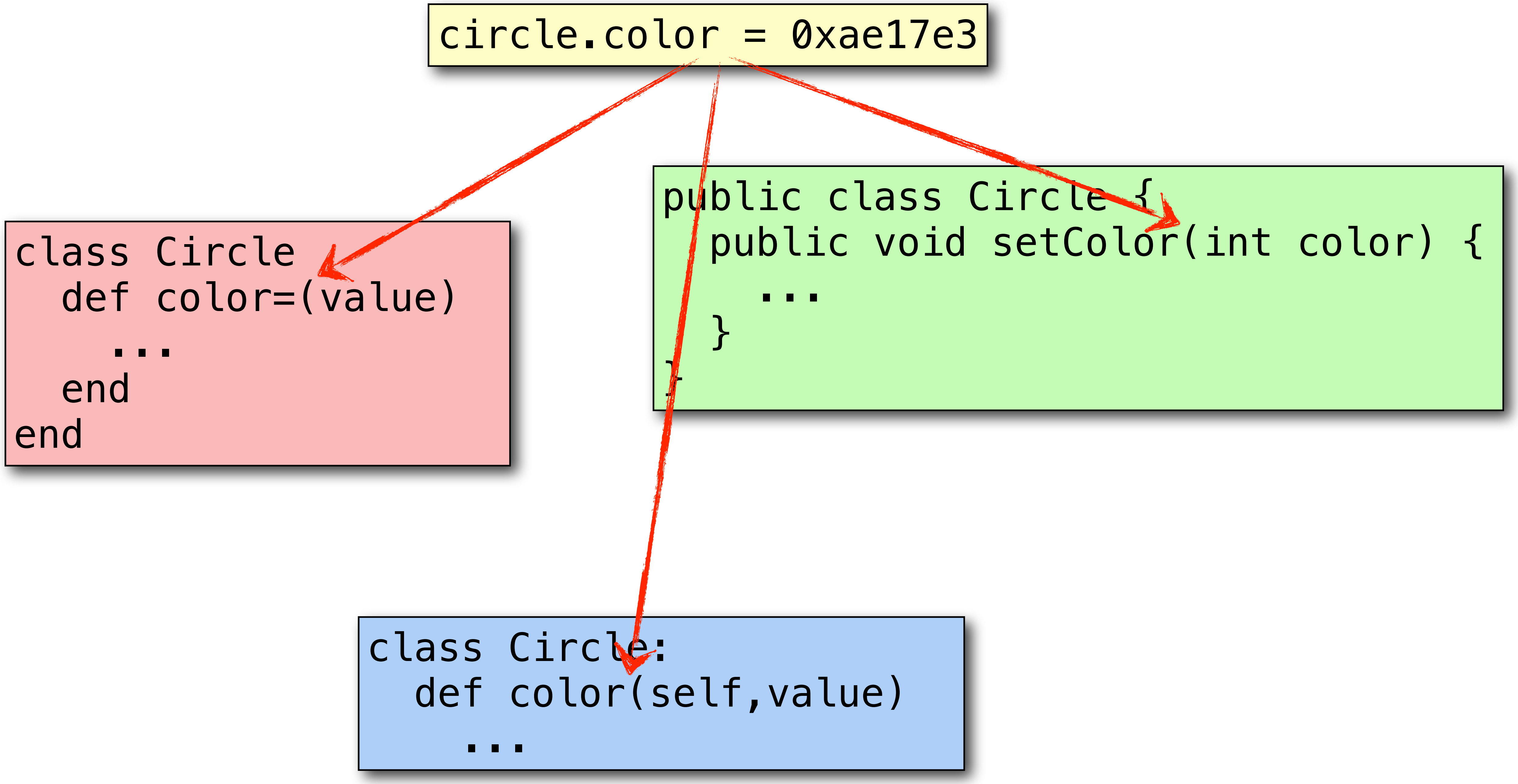
@asz

What's the problem?



```
circle.color = 0xae17e3
```

```
class Circle
  def color=(value)
    ...
  end
end
```

```
public class Circle {
  public void setColor(int color) {
    ...
  }
}
```

```
class Circle:
  def color(self,value)
    ...
```

Usual operations

- Property access
  - `obj.foo obj.foo=value`
- Method invocation
  - `obj.doIt(arg1, arg2)`
- Element access
  - `arr[i] map[key]`

Why do you care?

- The promise of Java library interop extended to JVM language interop.
- Language runtimes on JVM seldom work on their native objects only.
- At the very least, they also want to provide integration with POJOs.
- Dynalink lets you have invokedynamic call sites that automatically relink between your language native calls and POJO calls.

Is linking POJOs such a big deal?

- Actually, yes. There's lots of edge cases in:
  - overloaded methods
  - vararg methods
  - type conversions

…you can do combinations.

- Your users will bug you and/or lose confidence if you get this wrong

Ok, how do I use the POJO linker with ASM?

```
    import org.objectweb.asm.MethodHandle;
import static org.objectweb.asm.Opcodes.MH_INVOKESTATIC;
...
private static final MethodHandle BOOTSTRAP =
    new MethodHandle(MH_INVOKESTATIC,
        "org/dynalang/dynalink/support/DefaultBootstrapper","bootstrap",
        MethodType.methodType(CallSite.class, MethodHandles.Lookup.class,
            String.class, MethodType.class).toMethodDescriptorString());
private static final Object[] BOOTSTRAP_ARGS = new Object[0];
...
mv.visitIndyMethodInsn("dyn:setProp:color", "(Ljava/lang/Object;I)V",
    BOOTSTRAP, BOOTSTRAP_ARGS);
mv.visitIndyMethodInsn("dyn:getProp:shape", "(Ljava/lang/Object;)Ljava/lang/String;",
    BOOTSTRAP, BOOTSTRAP_ARGS);
```

And how do I use it with BiteScript?

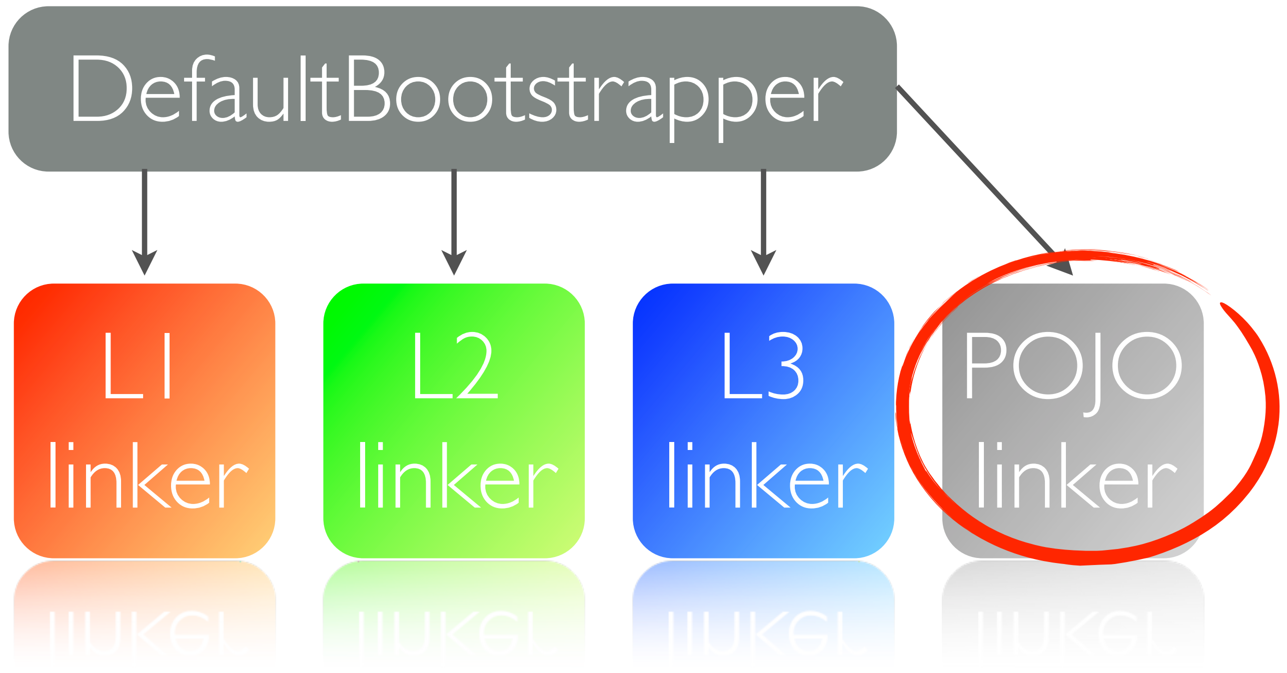
```
handle = compiler.method.mh_invokestatic(
  org.dynalang.dynalink.DefaultBootstrapper,
  "bootstrap",
  java.lang.invoke.CallSite,
  java.lang.invoke.MethodHandles::Lookup,
  java.lang.String,
  java.lang.invoke.MethodType)

compiler.method.invokedynamic(
  "dyn:setProp:color",
  [void, java.lang.Object, int],
  handle)

compiler.method.invokedynamic(
  "dyn:getProp:shape",
  [java.lang.String, java.lang.Object],
  handle)
```

And how do I link with non-POJOs?

- You just did. No extra steps are needed.
- You call site will be linked with any dynalink aware language runtime when invoked on its objects.
- 2-for-1 deal.



Dynalink city motto: Come for POJO linking, stay for the cross-language interop.

Usual operations

- Property access
  - `dyn:getProp:foo`
    `dyn:setProp:foo`
- Method invocation
  - `dyn:callPropWithThis`
- Element access
  - `dyn:getElem dyn:setElem`

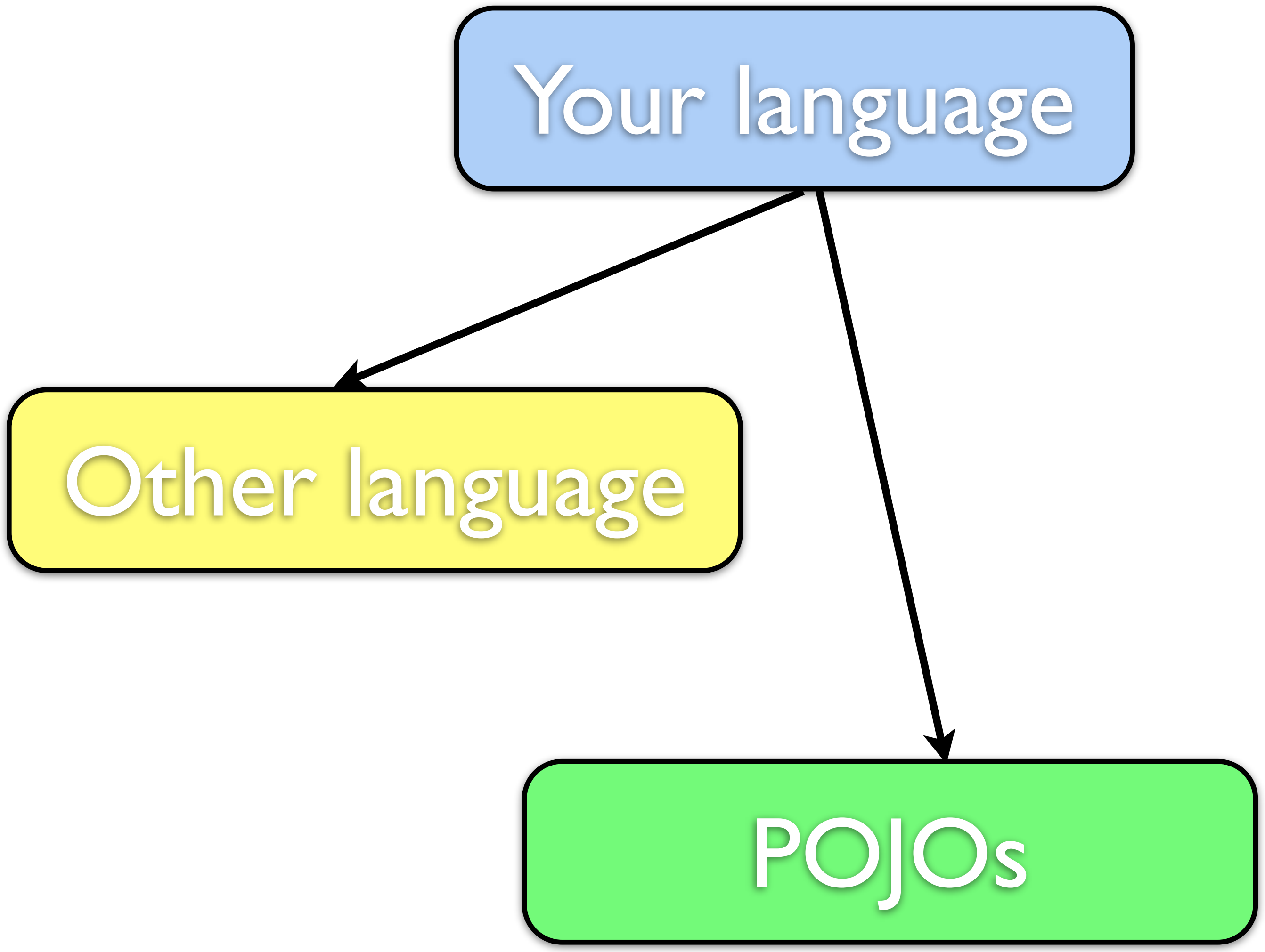
POJO linker specifics

- Element access and length works with Java arrays, j.u.List, and j.u.Map, relinks as necessary:

```
objs = [someJavaList, someJavaMap]
indices = [3, “foo”]
for(i = 0; i < 2; ++i) {
    print(objs[i][indices[i]]);
}
```

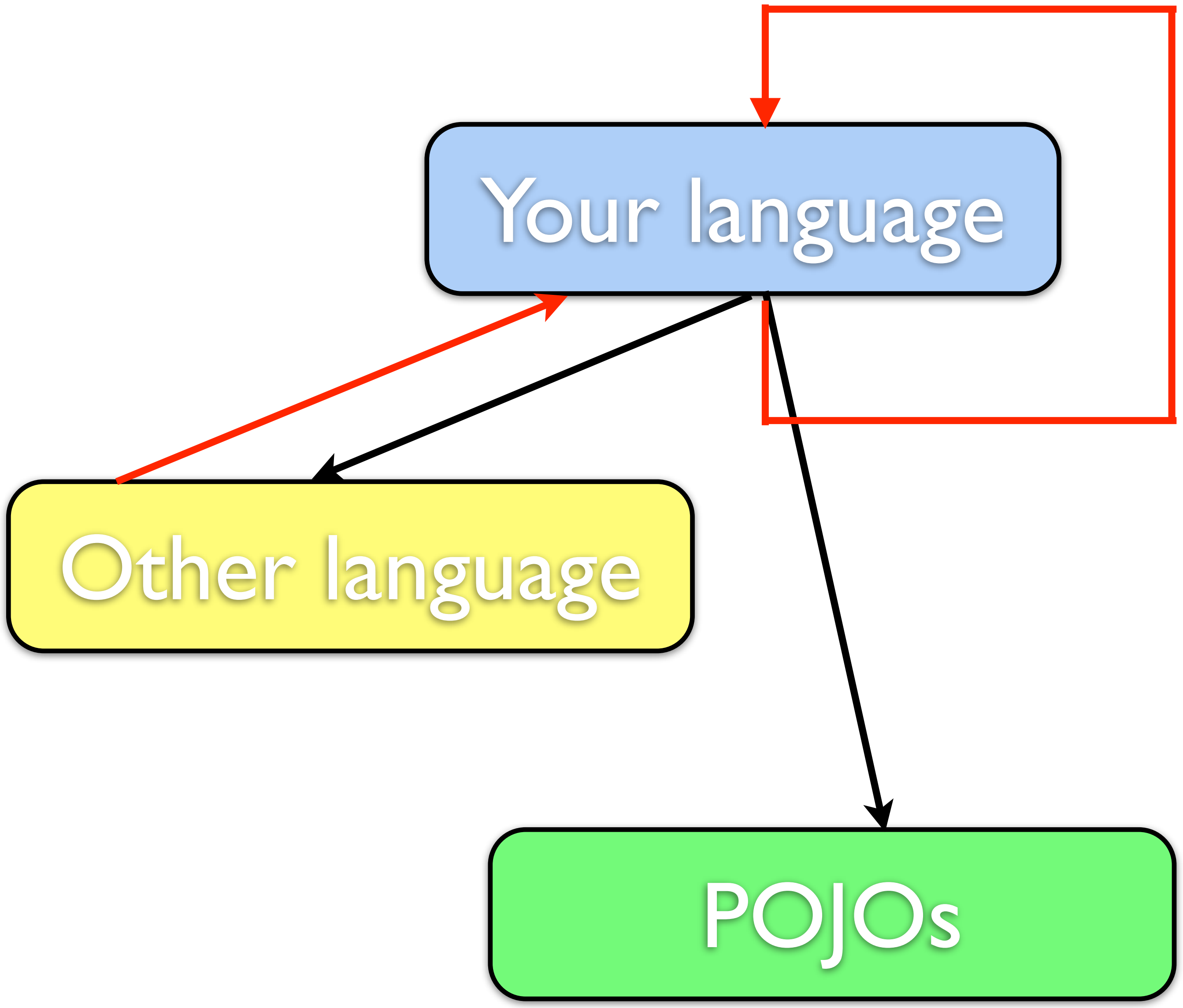
Story so far...

- You get fully JLS-compliant dynamic linkage to POJOs.
- 2-for-1 deal gives you automatic dynamic linkage to other languages.



What you still can’t do

- let other language runtimes link to code for your objects.
- Wait, you can’t link to your own objects either!



Time to write some code

- You need to actually write the code for the linker for your language!
- … to which you say, “awesome, let’s do it!”

Grab the code

- Binary JAR through Maven/Ivy/SBT:
    - groupId=org.dynalang artifactId=dynalink
- Binary JAR directly from:
    - http://repo1.maven.org/org/dynalang/dynalink/0.2/dynalink-0.2.jar
- Source:
    - https://github.com/szegedi/dynalink

Documentation, documentation, documentation

- JavaDoc:
  - http://szegedi.github.com/dynalink/javadoc/index.html
- User's guide:
  - https://github.com/szegedi/dynalink/wiki

You need to implement <u>one</u> interface with <u>one</u> method.

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(I'm making this too easy for you.)

GuardingDynamicLinker

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- Linker: it provides method handles to link call sites
- Dynamic: it links at run time. Actually, invocation time.
- Guarding: provides means to invalidate the call site and trigger relinking.

GuardingDynamicLinker

```
GuardedInvocation getGuardedInvocation(
    LinkRequest linkRequest,
    LinkerServices linkerServices
)
```

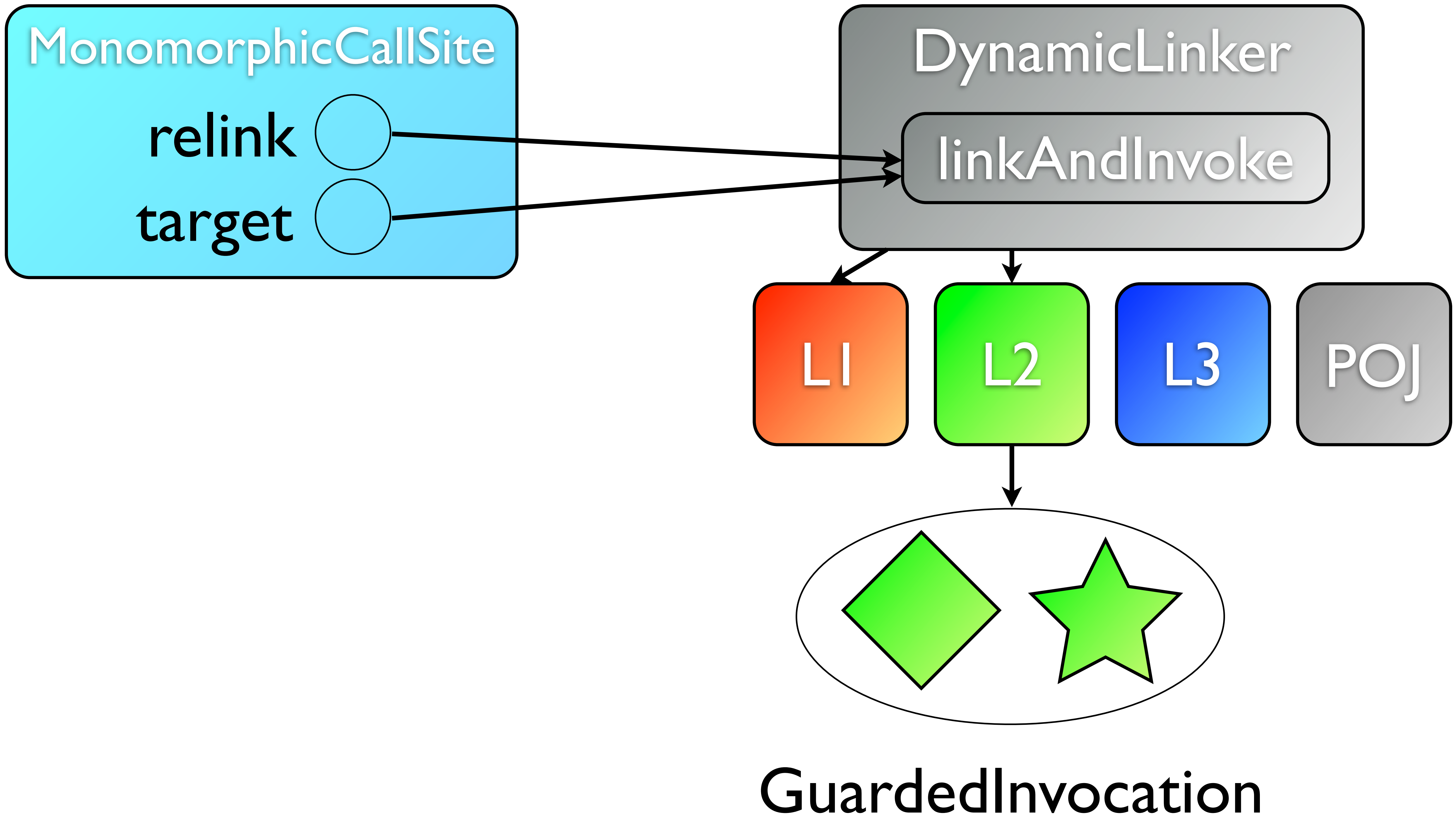
GuardingDynamicLinker

```
public class GuardedInvocation {
  private final MethodHandle invocation;
  private final MethodHandle guard;
  private final SwitchPoint  switchPoint;
  ...
}
```

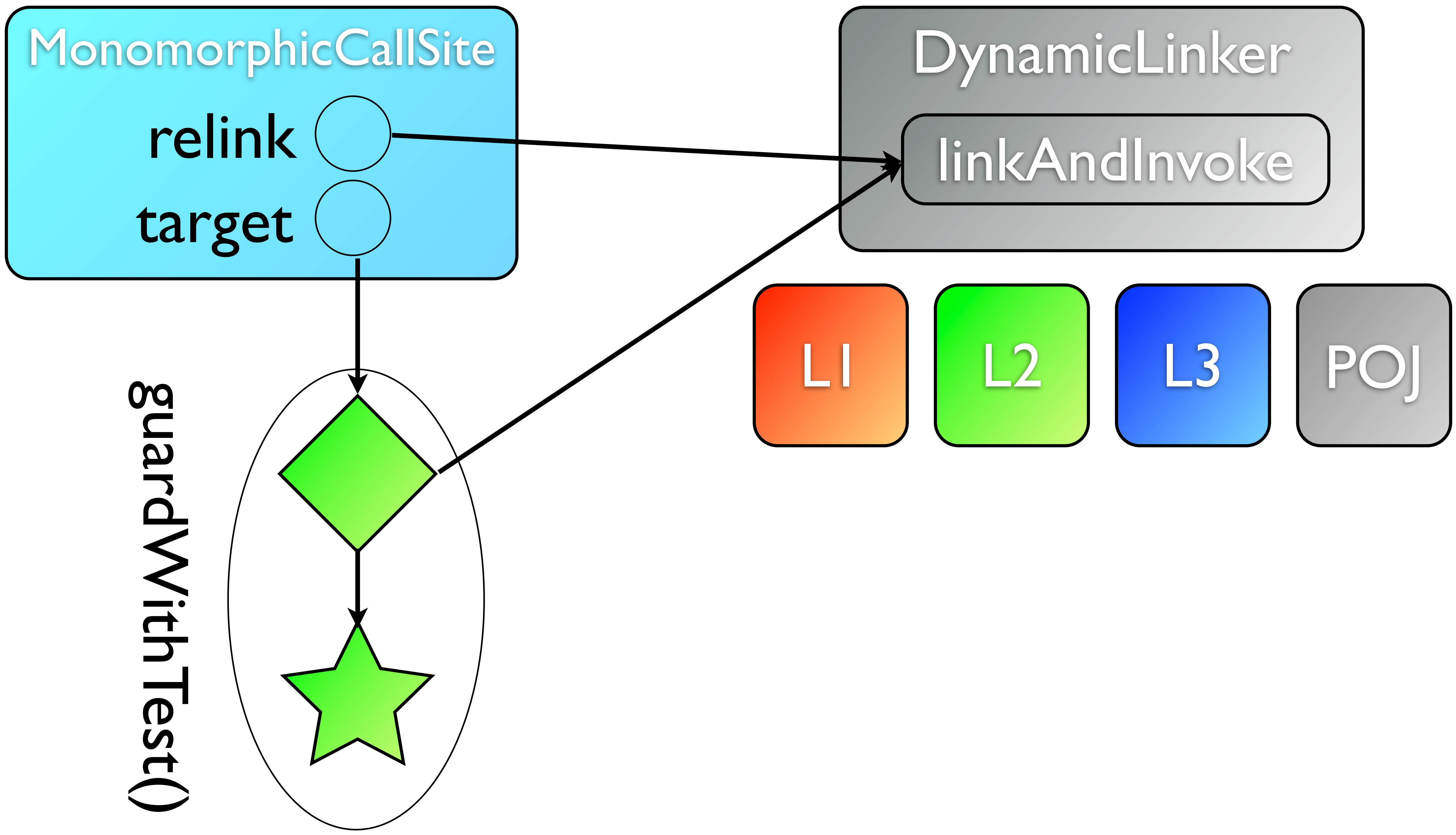
GuardingDynamicLinker

```
public interface LinkRequest {
  public CallSiteDescriptor getCallSiteDescriptor();
  public Object[] getArguments();
}
```

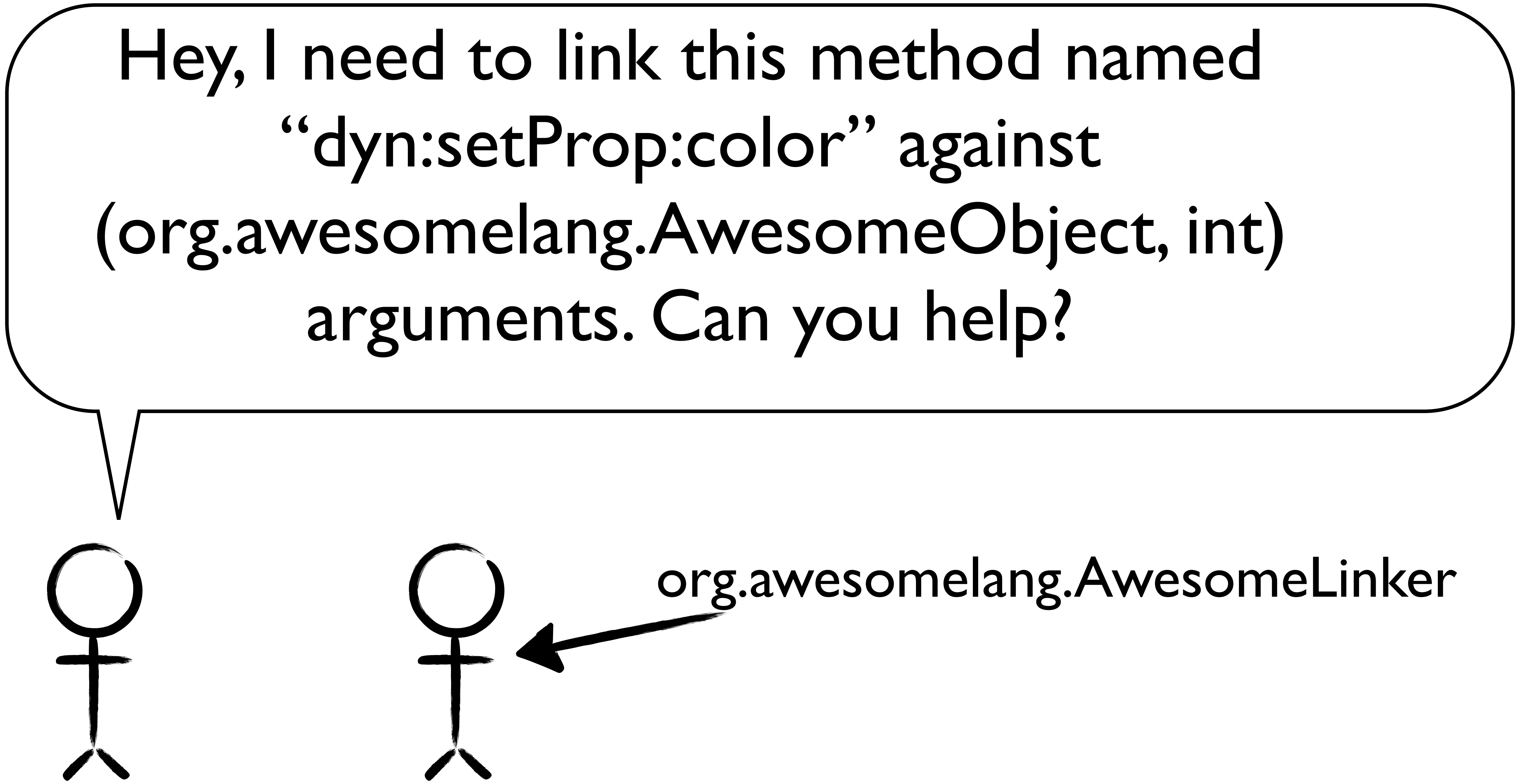
Linking a call site



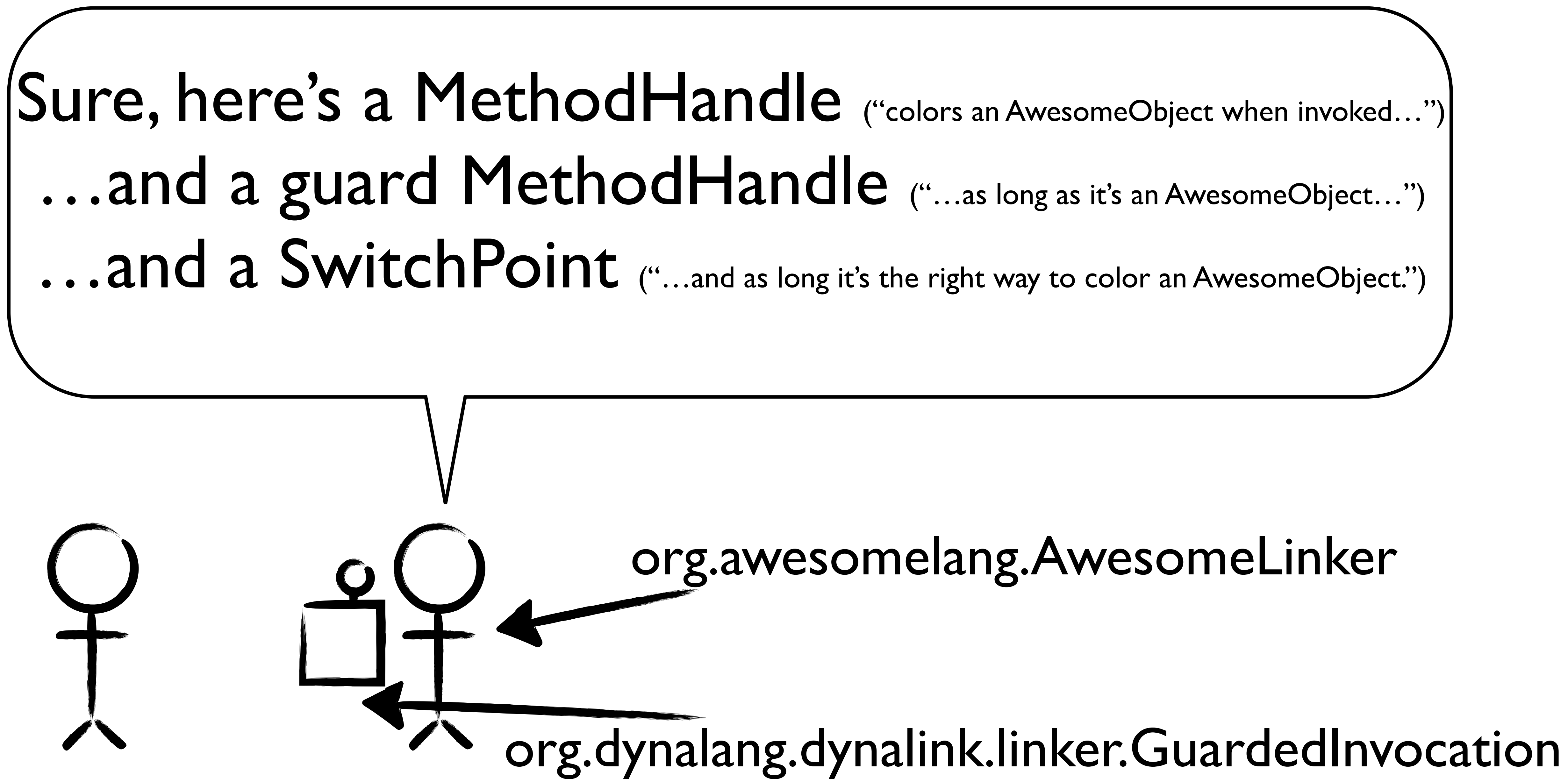
Linking a call site



Linkers, how do they work?


Hey, I need to link this method named "dyn:setProp:color" against (org.awesomelang.AwesomeObject, int) arguments. Can you help?
org.awesomelang.AwesomeLinker

Linkers, how do they work?


Sure, here’s a MethodHandle (“colors an AwesomeObject when invoked…”)
…and a guard MethodHandle (“…as long as it’s an AwesomeObject…”)
…and a SwitchPoint (“…and as long it’s the right way to color an AwesomeObject.”)
org.awesomelang.AwesomeLinker
org.dynalang.dynalink.linker.GuardedInvocation

Linker/CallSite concern separation

- Linker finds the method and specifies guard and/or switchpoint
- RelinkableCallSite implementation decides how to compose them
  - MonomorphicCallSite included

Linker implementation constraints

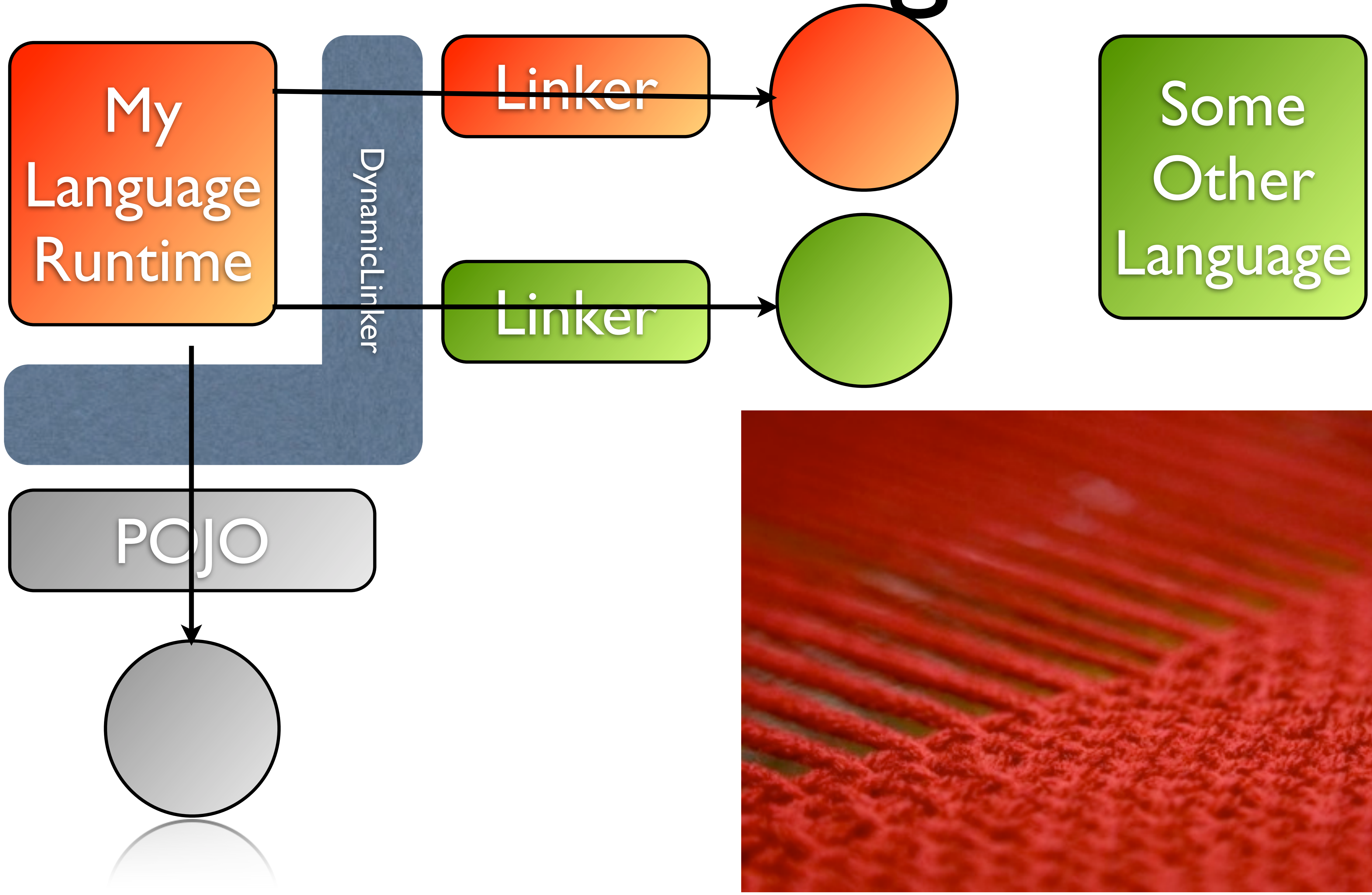
- There are really none…
- You can have switchpoint-invalidated metaclasses in the background if you want

Let them find you

- Now you have your linker, you still need to make sure other language runtimes can find it in the classpath.
- Name your linker class in

```
META-INF/services/
 org.dynalang.dynalink.linker.GuardingDynamicLinker
```

Unified API for object handling



Some more advanced concepts

Give yourself priority

- Your code manipulates native objects most of the time.
- Therefore, you want your language linker to enjoy priority for linking your own call sites.
- There's a way to do that.

Customized Linker Factory

```
import org.dynalang.dynalink.*;

public class AwesomeBootstrapper {
  private static final DynamicLinker dynamicLinker;
  static {
    final DynamicLinkerFactory factory = new DynamicLinkerFactory();
    final GuardingDynamicLinker awesomeLanguageLinker = new AwesomeLanguageLinker();
    factory.setPrioritizedLinker(awesomeLanguageLinker);
    dynamicLinker = factory.createLinker();
  }

  public static CallSite bootstrap(MethodHandles.Lookup caller, String name, MethodType type) {
    final MonomorphicCallSite callSite = new MonomorphicCallSite(caller, name, type);
    dynamicLinker.link(callSite);
    return callSite;
  }
```

The modified ASM example

```
    import org.objectweb.asm.MethodHandle;
import static org.objectweb.asm.Opcodes.MH_INVOKESTATIC;
...
private static final MethodHandle BOOTSTRAP =
    new MethodHandle(MH_INVOKESTATIC,
        "org/awesomelang/AwesomeBootstrapper","bootstrap",
        MethodType.methodType(CallSite.class, MethodHandles.Lookup.class,
            String.class, MethodType.class).toMethodDescriptorString());
private static final Object[] BOOTSTRAP_ARGS = new Object[0];
...
mv.visitIndyMethodInsn("dyn:setProp:color",
    "(Ljava/lang/Object;I)V",
    BOOTSTRAP, BOOTSTRAP_ARGS);
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    BOOTSTRAP, BOOTSTRAP_ARGS);
```

Type-based linker

- Your linker can declare it's the authority for linking certain types.
- DynamicLinkerFactory can create optimized type-based composite linkers

Type-based linker

```
public class AwesomeLinker implements TypeBasedGuardingDynamicLinker {
    public boolean canLinkType(Class<?> type) {
        return AwesomeObject.class.isAssignableFrom(type);
    }

    public GuardedInvocation getGuardedInvocation(LinkRequest linkRequest,
        LinkerService linkerServices)
    {
        // Can assume there's at least one arg, and it's of the required type
        AwesomeObject target = (AwesomeObject)linkRequest.getArguments()[0];
        ...
    }
}
```

Implicit type conversions

- Does your language allows an implicit Object-to-boolean conversion?
  - Yeah, it isn’t necessarily a good idea.
  - But if it does, there’s an interface for that!

Implicit type conversions

```
public class AwesomeLinker
implements TypeBasedGuardingDynamicLinker, GuardingTypeConverterFactory {
    private static final MethodHandle CONVERT_AWESOME_TO_BOOLEAN = ...;
    private static final GuardedInvocation GUARDED_CONVERT_AWESOME_TO_BOOLEAN =
        new GuardedInvocation(
            CONVERT_AWESOME_TO_BOOLEAN,
            Guards.isInstance(AwesomeObject.class, CONVERT_AWESOME_TO_BOOLEAN.type());

    public GuardedInvocation convertToType(Class<?> sourceType, Class<?> targetType) {
        if(AwesomeObject.class.isAssignableFrom(sourceType) && Boolean.class == targetType) {
            return GUARDED_CONVERT_AWESOME_TO_BOOLEAN;
        }
        return null;
    }

    ...
}
```

Private linking

- Rhino: need customized linking for Double, Boolean, String for call sites in its own code.
- This semantics however shouldn't be exposed to other language runtimes.

Private linking

```
import org.dynalang.dynalink.*;

public class RhinoBootstrapper {
  private static final DynamicLinker dynamicLinker;
  static {
    final DynamicLinkerFactory factory = new DynamicLinkerFactory();
    final GuardingDynamicLinker rhinoPrimitiveLinker = new RhinoPrimitiveLinker();
    final GuardingDynamicLinker rhinoLinker = new RhinoLinker();
    factory.setPrioritizedLinkers(rhinoPrimitiveLinker, rhinoLinker);
    dynamicLinker = factory.createLinker();
  }

  public static CallSite bootstrap(MethodHandles.Lookup caller, String name, MethodType type) {
     ...
  }
```

Runtime context args

- Many language runtimes pass context/ thread specific information on stack
- Support for automatic stripping of these across language boundaries
- Runtimes should make sure these are still accessible in thread-locals.

Things still to do

- POJO linker should:
  - Use Lookup at call site to allow linking non-public members
  - Expose constructors somehow
  - link to field getter/setter for accessible fields
  - standardized iterator and block support

Dynalink

https://github.com/szegedi/dynalink

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