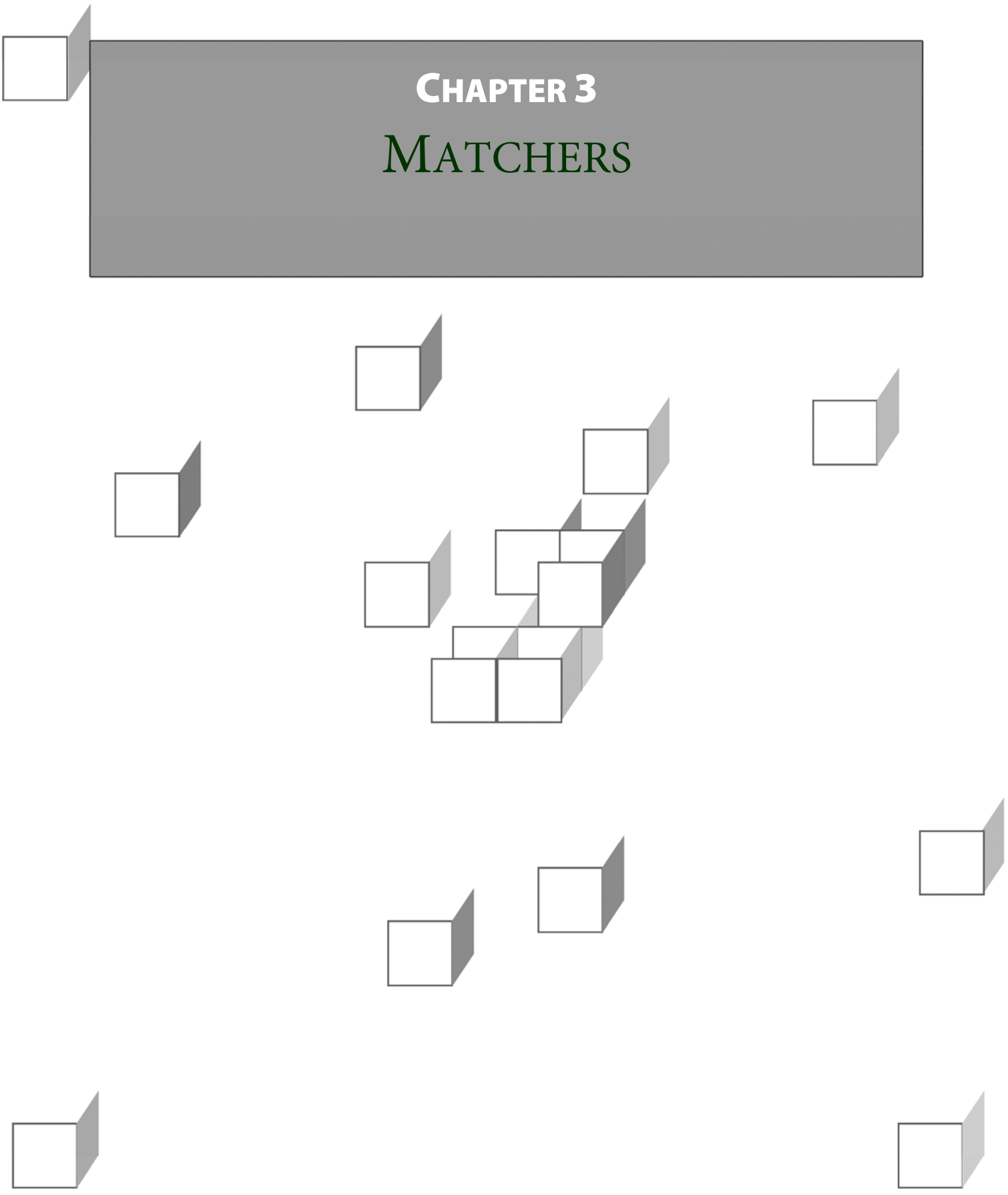
Chapter 3

Matchers



OBJECTIVES

After completing "Matchers," you will be able to:

- **Describe the advantages of encapsulating verification logic in matchers.**
- **Use built-in matchers from the Hamcrest library.**
- **Create custom matchers by**
  - Aggregating existing ones
  - Implementing **BaseMatcher<T>** or another framework class, directly
  - Building a general-purpose, "functional-friendly" matcher, and then using that with ad-hoc lambda expressions

Hamcrest Matchers

- We've discussed the advantages of reusing test logic, and explored a few strategies for getting that reuse.
- Originally a third-party library, the **Hamcrest** system of **matchers** has been incorporated into JUnit in recent versions.
- A matcher encapsulates the logic involved in verifying specific post-conditions, so that it can be used in multiple test cases.
- While preserving the direct use of various assertion methods such as **assertEquals** and **assertTrue**, JUnit now offers a gateway to Hamcrest matchers, via the **assertThat** methods:

```
public static <T> void assertThat
  (T actual, Matcher<T> matcher);
public static <T> void assertThat
  (String reason, T actual, Matcher<T> matcher);
```

- The Hamcrest "core" is included in the JUnit distribution.
- Extended libraries can be included in a project as well, and we'll work with a JAR that gives us access to everything. The equivalent Maven dependency would be:

```
<dependency>
  <groupId>org.hamcrest</groupId>
  <artifactId>hamcrest-all</artifactId>
  <version>1.3</version>
</dependency>
```

Advantages of Matchers

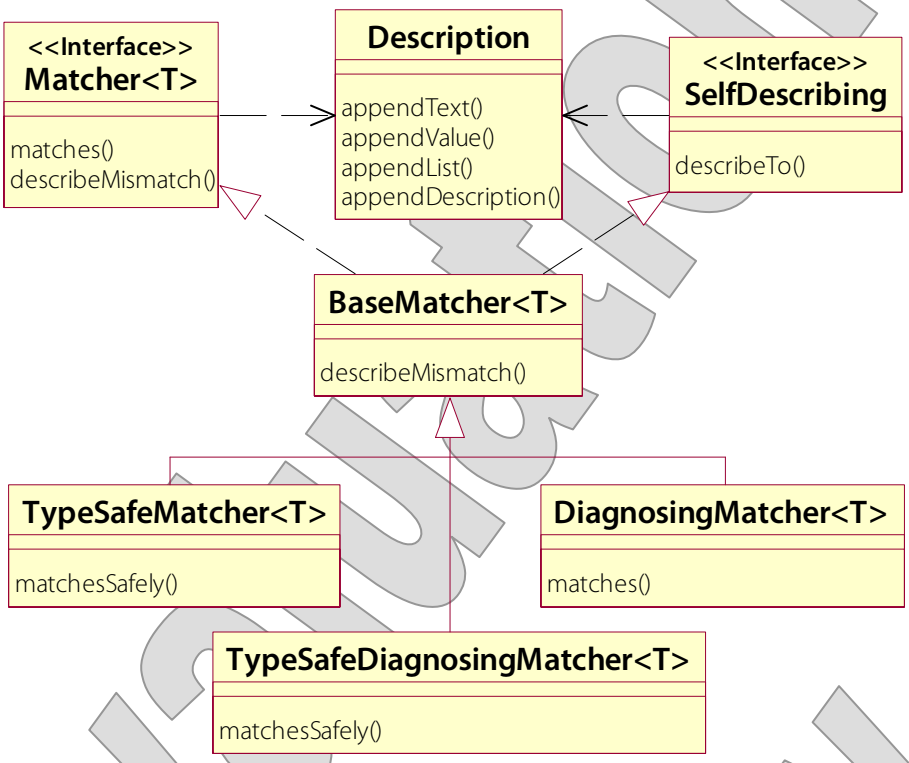
- **So the Matcher<T> becomes the most natural point of reuse for verification logic, and that's a powerful thing all by itself.**
- **There are built-in matchers, and you can create your own.**
- **Its design is also geared toward aggregation and decoration of one matcher by another.**
  - A **combining matcher** can apply boolean logic over multiple delegate matchers: all of these must be true, or at least one, etc.
  - A **collection matcher** can apply some other matcher to each of its items, and again we can insist that all match, or at least one, etc.
- **Hamcrest offers a "fluent" design that leads to more naturally readable code:**

```
assertThat (value, both (greaterThan (9))
  .and (lessThan (100));
assertThat (list, everyItem
  (hasProperty ("ID", greaterThan (0))));
```

- **A matcher encapsulates both matching logic and the description of what's expected and what may have failed to match.**
  - This is at first a little inscrutable, and can seem like more of an extra chore than an advantage.
  - But ultimately it's a win to be able to package description logic along with matching logic, especially once we start aggregating and decorating as described above.

The Matcher API

- The following diagram represents what we might call the kernel of the Hamcrest system:



- **Matcher<T>** and **SelfDescribing** are separate starting points, and though it's not immediately obvious they each contribute part of the semantics of error description.
  - **describeTo** is called as part of an **assertThat** execution, when there is a failure – specifically to describe what was **expected**.
  - **describeMismatch** is then called to explain what was wrong with the **actual** value.
  - Between them, they compose the error message, sharing a data record known as a **Description**.

The Matcher API

- **The real center of the system is BaseMatcher<T> - and in fact they go to some lengths to discourage the programmer from implementing Matcher<T> directly.**
  - Many matchers will extend this class, and then simply implement **matches** and **describeTo**.
  - It covers **describeMismatch**, with a default message, "was *value*", which you may override if you wish.
  - **TypeSafeMatcher<T>** is a further refinement that implements **matches** to check for a non-null value; check that the value is of the expected type **T**; and then call the helper method **matchesSafely**, which will be implemented more specifically by the subclass.
  - A **DiagnosingMatcher** just re-shapes the programming model so that you implement one method for both matching and description; and **TypeSafeDiagnosingMatcher<T>** does something similar while also doing null and type-safe checking.

Built-In Matchers

- **Then, not shown in the prior diagram, there are plenty of specific matchers that let you apply simple to moderately complex tests against an expected value.**
- **Though you can use these directly – instantiate a new IsCollectionWithSize matcher, and then use it – they routinely expose factory methods as well, which can be easier to use and result in more readable code.**
- **These methods are annotated as @Factory methods.**
  - This has no real impact on your code.
  - But it lets Hamcrest, as part of its built, gather these methods into a newly-generated utility class, called **Matchers**, which then serves as the one-stop shop for all of these factory methods.
- **Here is a sample of the matchers available, shown by their factory methods – many of which have multiple overloads:**

```
equalTo                          containsString
greaterThan[OrEqualTo]           startsWith
lessThan[OrEqualTo]              endsWith
isIn/isOneOf
nullValue/notNullValue           emptyArray
                                 arrayWithSize
instanceOf                       arrayContaining

allOf                            emptyCollection
anyOf                            collectionWithSize
both                             collectionContaining
either
not
```

Collection, Bean, and XPath Matchers

- **There are more involved matchers for specific types.**
  - We see the string-specific ones on the previous page.
  - For arrays and collections, we can test size and seek out items; we can also assert the success of other, delegate matchers, either requiring that every item pass a test or that at least one item exist that passes the test:

```
everyItem (notNullValue ())
hasItem (endsWith (".edu"))
```

  - We can cheek contents of maps, too:

```
hasKey ("root")
hasKey ("root")
hasValue (lessThan (0))
```

  - We can check a JavaBean's properties – individually for existence or for a specific value, or wholesale for equivalence:

```
hasProperty ("ID")
hasProperty ("ID", equalTo (6))
samePropertyValuesAs (templateObject)
```

  - XML content, represented as a DOM/JAXP **Node**, can be tested using the **XPath** addressing language:

```
hasXPath ("/Record/@Encoding")
hasXPath ("/Record/@Encoding",
  startsWith ("ISO-"))
```

Hamcrest Matchers

EXAMPLE

- In **Hamcrest_Step1**, a single JUnit test exercises a number of built-in matchers. See **test/cc/test/Hamcrest.java**.
  - We start out with some string matching:

```
@Test
public void testHamcrestMatchers()
  throws Exception
{
  String goodBoy = "Every good boy does fine.";

  assertThat (goodBoy, isA (String.class));
  assertThat (goodBoy, startsWith ("Ev"));
  assertThat (goodBoy, containsString ("boy"));
  assertThat (goodBoy, endsWith ("fine."));
```

  - We can assert multiple conditions, and join them logically:

```
assertThat (goodBoy, both (startsWith
  ("Every")).and (endsWith (".")));
assertThat (goodBoy, either (isEmptyString
  ()).or (containsString ("boy")));
```

  - In case you were wondering, yes, the inequality tests use the full power of Java's **Comparable** system; so for example you can treat chronological relationships as less-than/greater-than:

```
Date earlier = new Date (1471001168000L);
Date later = new Date (1471001169000L);
assertThat (earlier, lessThan (later));
```

Hamcrest Matchers

EXAMPLE

– We exercise some of the collection matchers, checking for various properties of a list of numbers in descending order:

```
List<Integer> numbers = new ArrayList<>();
Collections.addAll (numbers, 5, 4, 3, 2, 1);

assertThat (numbers, hasSize (5));
assertThat (numbers, hasItem (is (5)));
assertThat (numbers,
  everyItem (greaterThan (0)));
assertThat (numbers,
  everyItem (lessThan (10)));
assertThat (numbers,
  containsInAnyOrder (1, 2, 3, 4, 5));
assertThat (numbers,
  anyOf (hasItem (1), hasItem (-1)));
```

– And, similarly, with a map:

```
Map<String, Double> probabilities =
  new HashMap<>();
probabilities.put ("Heads", .5001);
probabilities.put ("Tails", .4999);

assertThat (probabilities, hasKey ("Heads"));
assertThat (probabilities, hasValue (.5001));
assertThat (probabilities.get ("Heads") +
  probabilities.get ("Tails"),
    closeTo (1.00, 0.0001));
```

Hamcrest Matchers

EXAMPLE

– Notice, by the way, how little explanation the code needs? The fluent-API approach has this advantage, that the code is largely self-explanatory: "assert that every item in the collection is less than 10," and so on.

– Finally, we use the JavaBeans matcher **samePropertyValuesAs** to compare two objects:

```
MyBean expected = new MyBean ("one", 1);
MyBean actual = new MyBean ("one", 1);
assertThat (actual,
  samePropertyValuesAs (expected));

MyBean firstDelegate =
  new MyBean ("delegate", 1000);
MyBean first = new MyBean ("main", 100);
first.setDelegate (firstDelegate);

// MyBean secondDelegate = ...
MyBean second = new MyBean ("main", 100);
second.setDelegate (firstDelegate);

assertThat (first, is (second));
assertThat (first,
  samePropertyValuesAs (second));
}
```

– Note however a limitation of this matcher: it **doesn't recurse** through object references, so as to test for equivalence, but only **tests for identity** – that is, checks to see that the two references are to the same instance.

– In other words, if you were to plug in **secondDelegate** as the delegate for the **second** bean, the test would fail.

CustomMatcher

- **You can build your own matchers to encapsulate application-specific matching logic.**
- **One approach to this is simply to extend BaseMatcher<T> or TypeSafeMatcher<T>, and implement the matches[Safely] and describeTo methods.**
- **Another is to use the CustomMatcher<T> as a base class.**
  - This is optimized slightly to support the common case in which the expectation description doesn't require procedural logic, but really is just represented by a simple string.
  - A constructor accepts that string, and **describeTo** is implemented for you to append it to the error message.
  - Then, you only have to implement **matches**.
  - This is meant to support implementation via anonymous classes, as in this example from the Javadoc:

```
Matcher<String> aNonEmptyString =
  new CustomMatcher<String>("a non empty string") {
    public boolean matches(Object object) {
      return ((object instanceof String) &&
        !((String) object).isEmpty();
    }
 };
```

  - So that a test could assert as follows:

```
assertThat (myString, aNonEmptyString);
```

Aggregating Matchers

- Another approach is to use one of the combining matchers to assemble more complex matching logic.
- The result can be captured in a simple helper or utility method, and reused easily:

```
public static Matcher<MyBean> hasNameAndNumber ()
{
  return both (hasProperty ("name"))
    .and (hasProperty ("number"));
}
```

  - So, in a test method, someone could say ...

```
assertThat (myBean, hasNameAndNumber ());
```

- Again, Hamcrest is designed for progressive decoration, so your new matcher(s) can be used to create others:

```
public static Matcher<List<MyBean>>
  allHaveNameAndNumber ()
{
  return everyItem (hasNameAndNumber ());
}
```

  - And this would support ...

```
assertThat (myBeans, allHaveNameAndNumber ());
```

A Custom Matcher

EXAMPLE

- In **Hamcrest_Step2**, see **test/cc/test/PerfectSquare.java**.

```
public class PerfectSquare
  extends TypeSafeMatcher<Number>
{
  public boolean matchesSafely (Number number)
  {
    double value = number.doubleValue ();
    long root = (long) Math.sqrt (value);
    return root * root == value;
  }

  public void describeTo (Description description)
  {
    description.appendText ("perfect square");
  }

  public static PerfectSquare perfectSquare ()
  {
    return new PerfectSquare ();
  }
}
```

  - So, this matcher can test any **Number** or primitive-type number, to see if it is a perfect square.
  - We offer a factory method **perfectSquare** which can be used in favor of direct instantiation, though we allow either usage.

A Custom Matcher

EXAMPLE

- In **test/cc/test/Hamcrest.java**, see a new last line in the **testHamcrest** method:

```
@Test
public void testHamcrestMatchers()
  throws Exception
{
  ...
  assertThat (9, perfectSquare ());
}
```

- This test succeeds, along with all of the others.
- But, try varying the actual value – change 9 to 8 for example – and see how the matcher responds:

```
java.lang.AssertionError:
  Expected: hasProperty("name")
    but: was null
  ...
```

  - The "Expected:" content is the result of our **describeTo** implementation, and the "but: was" part is the result of **BaseMatcher<T>**'s default **describeMismatch**.

Testing Query Methods

LAB 3

Suggested time: 30 minutes

In this lab you will build a JUnit test for a component that can fetch bank accounts from a persistent store. In fact the class under test is a false implementation, using hard-coded data, but it provides correct results as would a real persistence component when tested over a prepared database, and the point of this lab will be to write tests for that correct behavior. This will provide an opportunity to explore built-in Hamcrest matchers.

Detailed instructions are found at the end of the chapter.

Functional-Friendly Matchers

- **Often, there is a need to define a bit of matching logic on the fly, and as of Java 8 we have a number of new tools for injecting a bit of behavior into a bigger algorithm or process – namely, lambda expressions and method references.**
- **Currently, Hamcrest's design does not directly support this functional programming style.**
  - The **Matcher<T>** interface is not a functional interface.
  - Even if it were, it is not supposed to be implemented directly: we work by subclassing **BaseMatcher<T>** or a subclass thereof.
- **Still, it is not too hard to adapt the current design to functional programming.**
  - A **BaseMatcher<T>** or **TypeSafeMatcher<T>** subclass could accept matching and/or descriptive logic via functional interfaces.
  - **matches** is basically a **Predicate<T>**, in that it accepts an object and returns a boolean.
  - **describeTo** is a **Consumer<Description>** – though we might just simplify this and take a simple string, the way **CustomMatcher** does.
  - A class that accepts a predicate and either a description-consumer or a string could then act as a general-purpose matcher that would expect to be supplied with matching logic via an anonymous class, lambda expression, or method reference.
- **Future versions of Hamcrest may well facilitate this, as CustomMatcher already does for anonymous classes.**

Using Lambda Expressions

DEMO

- **Let's add a second custom matcher to this project that will serve as a gateway to a more free-form use of functional programming when defining specific matching criteria.**
  - Do your work in **Hamcrest_Step2**.
  - The completed demo is found in **Hamcrest_Step3**.

1. Create a new class **cc.test.FunctionalMatcher**:

```
public class FunctionalMatcher<T>
{
}
```

2. Make it extend **TypeSafeMatcher<T>**:

```
public class FunctionalMatcher<T>
  extends TypeSafeMatcher<T>
{
}
```

3. Give it fields to capture the matching logic and the description:

```
  private Predicate<T> test;
  private String text;
```

4. Define a constructor that accepts parameters for each of these, and initializes the fields:

```
  public FunctionalMatcher
    (Predicate<T> test, String text)
  {
    this.test = test;
    this.text = text;
  }
```

Using Lambda Expressions

DEMO

5. Implement **matchesSafely** by invoking the given predicate:

```
public boolean matchesSafely (T object)
{
  return test.test (object);
}
```

6. Implement **describeTo** by appending the given string:

```
public void describeTo (Description description)
{
  description.appendText (text);
}
```

7. Define a factory method:

```
public static <T> FunctionalMatcher<T> exhibits
  (Predicate<T> test, String text)
{
  return new FunctionalMatcher<T> (test, text);
}
```

Using Lambda Expressions

DEMO

8. In **test/cc/test/Hamcrest.java**, at the bottom of **testHamcrest**, apply the new matcher to a number by supplying matching criteria in a simple lambda expression:

```
assertThat (100, exhibits
  ((v) -> v > 99 && v < 1000,
    "three-digit number"));
```

9. Run the class as a JUnit test again, and see that it still passes.

10. Vary the actual value – to 10 or 1000 – and see that it (correctly) fails:

```
java.lang.AssertionError:
  Expected: three-digit number
    but: was <1000>
  ...
```

11. Try the same matcher on a different type of value, with different criteria:

```
assertThat (new Date (259200000000L), exhibits
  ((Date v) -> v.getTime () % 86400000 == 0,
    "midnight on any date"));
```

12. Try it out again, and if you like try varying the actual value to see the error message.

    – The matcher is ready for a wide range of types and matching logic, which, for relatively simple criteria, can be supplied in a simple form.

SUMMARY

- **Matchers can be a bit inscrutable at first, but once understood they can be a great tool for organizing your test code.**
- **You can get a good bit of mileage out of the build-in matchers, especially by using the combining matchers on the fly.**
- **You can also create custom matchers, by a few techniques.**
- **Note that there are other matcher libraries, and Hamcrest is designed to support this sort of extensibility.**
  - We'll see **Mockito** later in the course, which is primarily a dynamic-mocking library, but offers its own set of matchers as well.

Testing Query Methods

LAB 3

In this lab you will build a JUnit test for a component that can fetch bank accounts from a persistent store. In fact the class under test is a false implementation, using hard-coded data, but it provides correct results as would a real persistence component when tested over a prepared database, and the point of this lab will be to write tests for that correct behavior. This will provide an opportunity to explore built-in Hamcrest matchers.

Lab project: **Bank_Step1**

Answer project(s): **Bank_Step2**

Files: * to be created
src/cc/bank/AccountDB.java
src/cc/bank/AccountDBImpl.java
test/cc/bank/AccountDBImplTest.java

Instructions:

1. Review the **AccountDB** interface, which as you see is minimal: a method to get a single account by ID, and a search method to find account(s) by partial owner name.
2. See that there is an **AccountDBImpl** as well, with a trivial implementation.
3. Create a new class **cc.bank.AccountDBImplTest**, under the **test** folder.
4. Define a field **DB**, and initialize to a new instance of **AccountDBImpl**.
5. Define a test method **testGetAccount**. In it, declare a **final** integer **ID**, and set it to 123456789.
6. Call **DB.getAccount**, passing your **ID**, and capture a reference **bean** to the **Account** object that's given back.
7. **assertThat bean hasProperty** named "firstName", with a value that **is** "Michael". You'll need to static-import **org.junit.Assert.assertThat** and **org.hamcrest.Matchers.hasProperty** – or use the wildcard ***** instead of the method names, to support other matchers later on.
8. Run your test and see that it succeeds. You can re-test as you go along from here.
9. Add more **assertThat**s for other properties of the **Account** class: "lastName" of "Bean", "username" of "mbean", "ID" of **ID**.
10. For the "balance" property, which is a floating-point number, use a different matcher: instead of **is** some value, assert that it's **closeTo** 1000, with a tolerance of .0001.

Testing Query Methods LAB 3

11. Now we'll go after the search method, in a couple of ways. Define a new test method **testGetAccountsByName1**. In this one, we'll test the actual attributes of the returned accounts that they do indeed contain the search string – without insisting that they be specific accounts.
12. For this we will need some customized matching logic. Define a new **TypeSafeMatcher<Account>** class – you can do this with a nested class, a local class, or an anonymous class, whatever you prefer. (Answer code uses an anonymous class.)
13. Implement **matchesSafely** by deriving a variable **fullName** that is the concatenation of first name, a space, and last name from the given **Account**. Then report a good match only if that string **contains** the search string "Will".
14. Implement **describeTo** to append a string describing the matcher's expectations – in the answer code this is "an Account with a full name that contains 'Will'".
15. Now, in your new test method, **assertThat** the results of a call to **DB.getAccountsByName**, passing "Will", is a collection whose **everyItem** passes your custom matcher.
16. Run your test and it should succeed.
17. Create another method **testGetAccountsByName2**. This time we'll rely on the prepared data in the target class (or would rely on, say, a test database or mocked data in memory), and just test for specific results.
18. In this method, **assertThat** the results of the call to **DB.getAccountsByName** is a collection that **containsInAnyOrder** a list of objects, each of which **hasProperty** "ID" with a specific value. The IDs you want are 12345687 and 123456788.

    The syntax of this one may take a moment to sort out: most of it is similar to earlier work in this lab, but note that **containsInAnyOrder** accepts a list of **Matcher** parameters, and for each one you call **hasProperty** with the name "ID" and one of the expected values.