Adapting Our Design Recipe to Java

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If and Other Statements

- Java is a statement based language rather than an expression language.
- `if` statements are used to express explicit conditional control in most OO languages including Java. **Note**: `if` statements are used much less frequently in well-written OO code than they are in functional or procedural code.
- An `if` statement has the following syntax:

```
if (test) statement
else statement
```

- What other forms of statements have we used implicitly up to this point?
  - Variable definition: `type var = expr;`
  - Return: `return expr;`

Statements vs Expressions

- From the perspective of FP, statement syntax is clumsy
- Bindings are created using statements that bind `final` variables.
- `if` statements can be used in essentially the same way as `if` and `cond` expressions in Racket/Scheme. Primary difference: values must be explicitly returned. If you forget to use an explicit `return`, the Java compiler may catch it (but not always!) because only expressions of `void` type area allowed as statements.
- The body of a trivial functional method definition must be wrapped in an explicit `return`.

Method Definition Revisited

```
class Entry {
  /* fields */
  String name, address, phone;

  /** return true iff name matches keyName.*/
  Entry match(String keyName) {
    if (keyName.equals(name)) return true;
    else return false;
    // method can be written more cleanly without if!
  }
}
```

Better code for `match`:

```
Entry match(String keyName) { return keyName.equals(name); }
```

Note that

```
if ... return true;
else return false;
```

is a code smell.

Aside: why not `return keyName == name;` ? In Java, strings are immutable but not necessarily interned (made unique by hashing, akin to memo-ization).

Reprise: the Design Recipe (Racket)

How should I go about writing programs?

- Analyze problem, which includes:
  - defining any data types (and templates) that are not primitive;
  - determining what top-level (visible) functions must written.
- For each top-level function *f* to be written:
  1. State contract (type signature) and purpose of *f*.
  2. Give input-output examples for *f* written as tests
  3. Select and instantiate a template for the function body. Code the function by filling in the template
  4. Run the tests and confirm that they succeed.
- Writing a function may require help functions. Add these functions to the list of functions to be written. Use local? Perhaps.

The Design Recipe for Java

How should we go about writing programs?

- Analyze problem, which includes:
  - Defining any classes ***C*** for data types that are not primitive;
  - Determining what visible methods should appear in each class.
- For each visible method ***m*** in each class ***C*** :
  1. Write the header (type signature) and contract (purpose) for ***m***.
  2. Create a test class for ***C*** (or the set of tightly coupled classes including ***C*** if it does not already exist) and write a test method for ***m*** that checks its visible behavior on representative inputs.
  3. Select and instantiate a template for the method body.
  4. Code the method by filling in the template
  5. Add tests for methods introducing in the coding process.
  6. Run the tests and confirm that they succeed.
- The code for a method ***m*** may require help methods. Add these methods to the class ***C*** containing ***m***. Use **private**? Perhaps.

Java Data Types

- Primitive types: `int long short byte double float char boolean`
- Important primitive operations discussed in monograph. Written in conventional infix/prefix notation.
- Object types
  - Organized in a strict hierarchy with `Object` at the top.
  - Every class ***C*** except **Object** has an immediate *superclass*, which is the parent of *C* in the hierarchy.
  - A descendant in the class hierarchy is called a *subclass*. ***B*** is a subclass of ***A*** iff ***A*** is a superclass of ***B***.
  - Subclassing implies subtyping and vice-versa: if ***B*** is a subclass of ***A***, then ***B*** is a subtype of ***A***. If class ***B*** is a subtype of class ***A***, then ***B*** is a subclass of ***A***.
  - An object ***o*** is an *instance* of only one class but belongs to a hierarchy of types.
  - Each subclass ***C*** *inherits* (includes) all of the members of its superclass.
  - Declared members of ***C*** augment the inherited members with *one exception*: if ***C*** declares a method ***m*** defined in the superclass, new definition *overrides* old.
  - A special kind of class called an `interface` supports restricted multiple inheritance. The restriction is more severe in versions of Java prior to Java 8. In early versions of Java, all interface methods must be abstract. In later versions of Java, methods may be concrete but fields are still excluded as interface members.

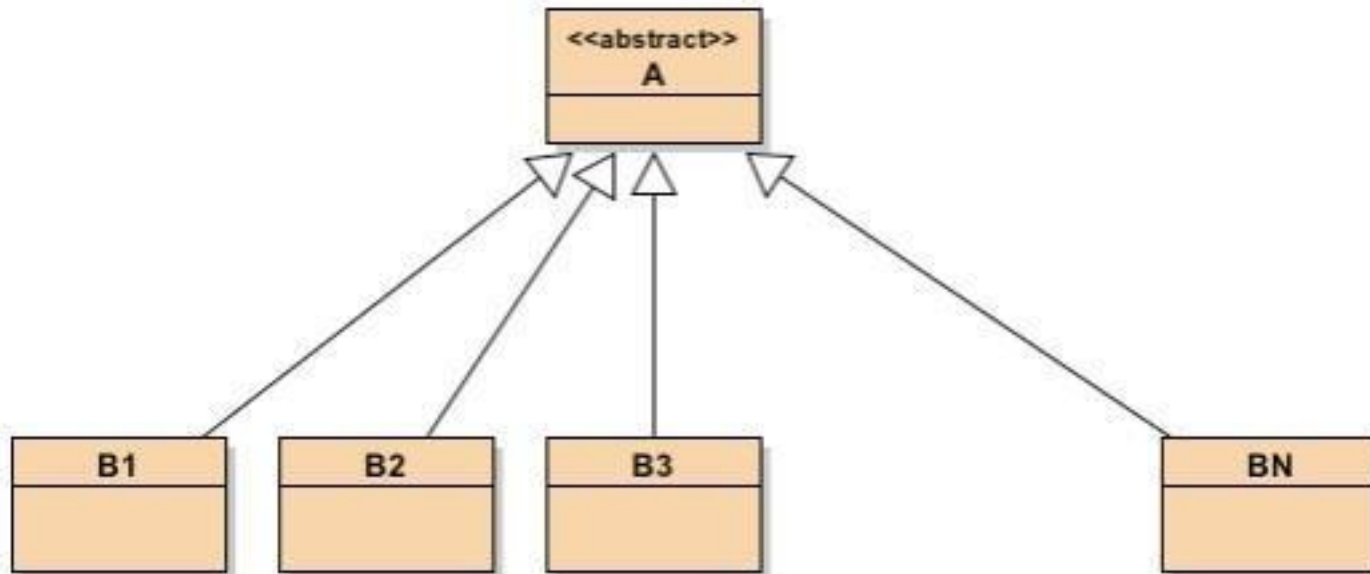
OO style

- OO languages are designed to support writing programs in which *dynamic dispatch* based on inheritance is the principal control mechanism. Dynamic dispatch refers to the fact that in a method invocation
  ```
  o.m()
  ```
  the method code executed for ***m*** depends on the *class* of ***o***. Note that the method ***m*** is conceptually part of the object ***o***. This idea is astonishingly powerful.
- The essence of OO design is representing data and computations in a form that leverages dynamic dispatch.
- Why does this idea work so well? Assuming that all of the variants of a method satisfy the **same contract** we can easily reason about the effect of any call on a method! *OO design precisely factors code with respect to common contracts*. This idea is very poorly understood by most computer scientists and software engineers.

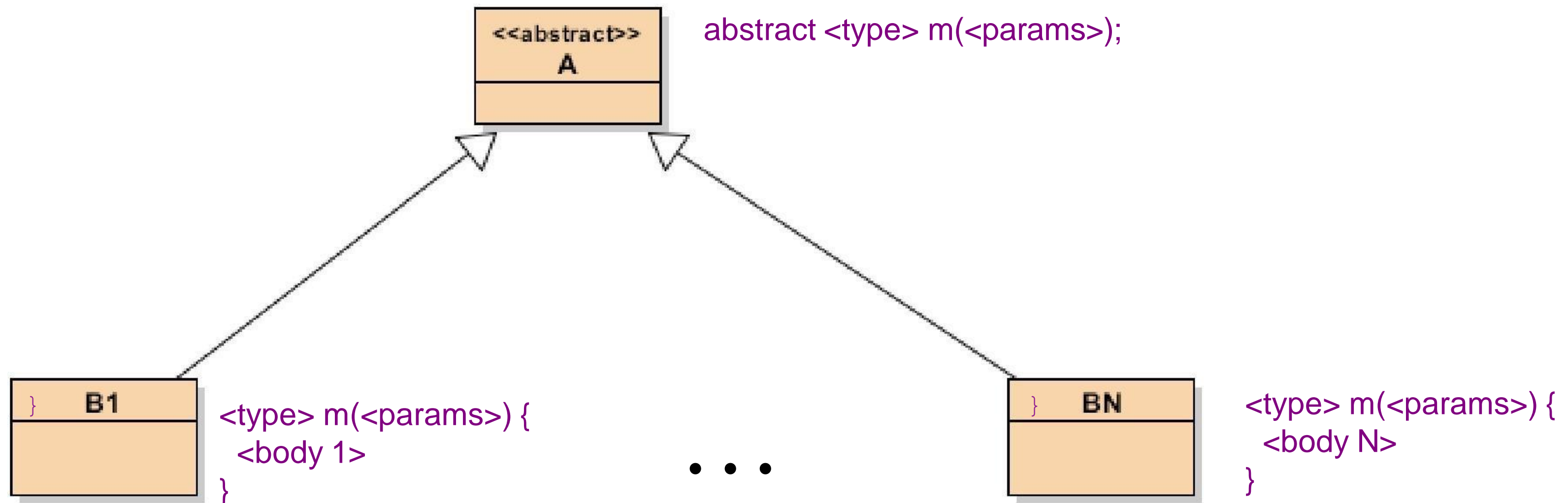
Union Pattern

- The *union pattern* is used to represent different forms of *related* data with some common behavior encapsulated in the *root* class of the union.
- The pattern consists of a root **abstract** class A together with a collection of *variant* subclasses $B_1, \ldots, B_N$ extending A. An **abstract** class cannot be instantiated using **new**. Note: if A is concrete then it is not the union of $B_1, \ldots, B_N$ because A has additional members that are instances of A
- The collection of classes A, $B_1, \ldots, B_N$ is called a union hierarchy and A is called the *root* class of the hierarchy.
- The common behavior is codified by a set of methods in A, which may be **abstract** Each such method m has an associated *contract* that that the implementation in each variant class must obey.

Class Diagram of Union Pattern



Defining a Method on a Union



City Directory Example

- Assume that we want to design the data for an online city phone book. In contrast to our **DeptDirectory** example, such a directory will contain several different kinds of listings: businesses, residences, and government agencies.
- The entry data for such a directory is represented by using the union pattern to identify the common behavior among the various kinds of listings.

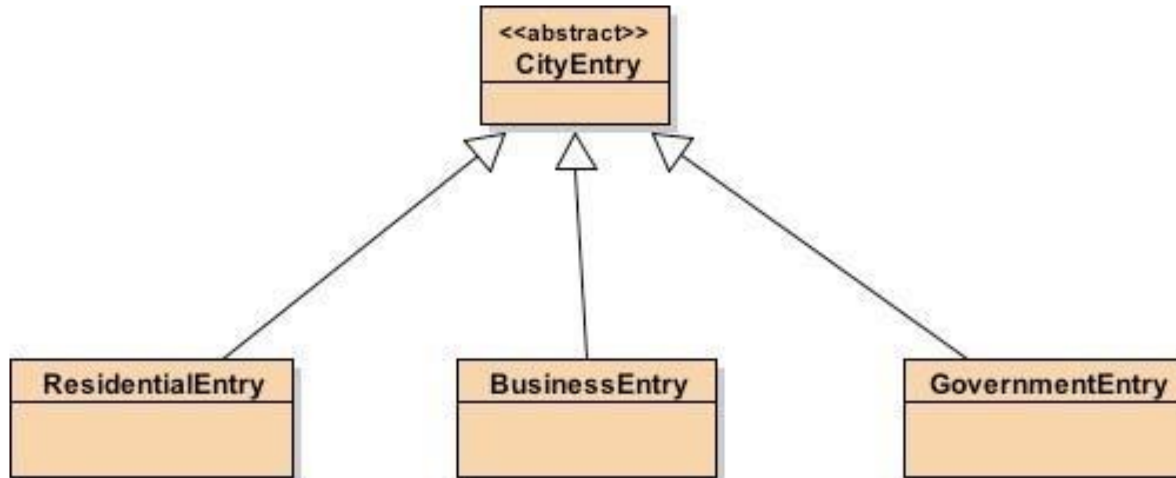
A `CityEntry` is either:

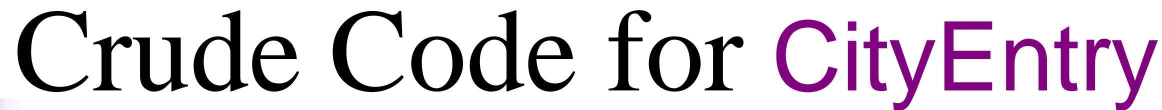
- a `ResidentialEntry(name, address, phone)`
- a `BusinessEntry(name, address, phone, city, state)`
- a `GovernmentEntry(name, address, phone, city, state, government)`

Examples:

```
ResidentialEntry("John Doe","3310 Underwood", "713-664-8809")
BusinessEntry("ToysRUs","2101 Old Spanish Trail",
  "713-664-1234","Houston", "TX")
GovernmentEntry("Federal Drug Administration", "800-666-9000",
  "Washington", "DC", "Federal")
```

Class Diagram of **CityEntry** Union





Crude Code for CityEntry

```
abstract class CityEntry { }

class BusinessEntry extends CityEntry {
  String name, address, phone, city, state;
}

class GovernmentEntry extends CityEntry {
  String name, address, phone, city, state, government;
}

class ResidentialEntry extends CityEntry {
  String name, address, phone;
}
```

- Assume that we want to define a method on a union. The method will typically require a separate implementation for each variant (subclass) of the union. But each implementation will satisfy the same (description of behavior).

- In Java, the method must not only be defined in each variant of the union, it must be declared as **abstract** in the root class of the union hierarchy. Otherwise, Java will not allow the method to be invoked on objects of the union type.

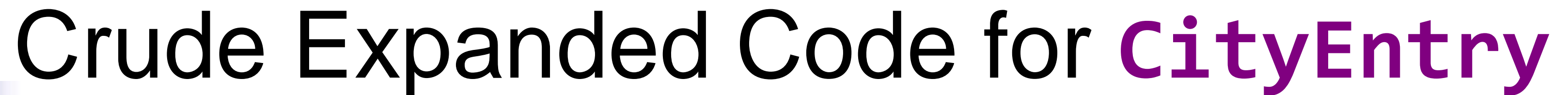
Defined Method for **CityEntry**

- Let's illustrate the definition of a plausible method for **`CityEntry`**:

```
abstract class CityEntry {

  /** Returns true if key is a prefix of name. */
  abstract boolean nameStartsWith(String key);

}
```



Crude Expanded Code for **CityEntry**

```
abstract class CityEntry {
  /** Returns true if key is a prefix of name. */
  abstract boolean nameStartsWith(String key);
}

class BusinessEntry extends CityEntry {
  String name, address, phone, city, state;
  boolean nameStartsWith(String key) { return name.startsWith(key); }
}
class GovernmentEntry extends CityEntry {
  String name, address, phone, city, state, government;
  boolean nameStartsWith(String key) { return name.startsWith(key); }
}
class ResidentialEntry extends CityEntry {
  String name, address, phone;
  boolean nameStartsWith(String key) { return name.startsWith(key); }
}
```

Member Hoisting

- In a union hierarchy, the same code may be repeated in every variant.
- A cardinal rule of software engineering is **never duplicate code**. We can eliminate code duplication in a union hierarchy by hoisting duplicated code (code that is *invariant* within the union) into the abstract class at the route of the hierarchy.

Revised Code for `CityEntry`

```
abstract class CityEntry {
 /* common fields */
 String name, address, phone;

  /** Returns true if key is a prefix of name. */
 boolean nameStartsWith(String key) { return name.startsWith(key); }
}

class BusinessEntry extends CityEntry {
  String city, state;
}
class GovernmentEntry extends CityEntry {
  String city, state, government;
}
class ResidentialEntry extends CityEntry { }
```