Chapter 3
Variability Patterns for Object Creation

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1) FactoryMethod
2) AbstractFactory
3) Builder

3.1 Factory Method (Polymorphic Constructor)

A Restriction of Polymorphism

- Some polymorphic languages (such as Java) do not allow for exchange of the constructor
- Problem: constructors are *concrete,* cannot be varied polymorphically

```
// Creator class abstract
public abstract class Creator {
   public void collect() {
      Set mySet = new Set(10);
      // which set should be allocated?
   }
}
```

```
// Creator class concrete
public class CreatorB extends Creator {
   public void collect() {
      Set mySet = new ListBasedSet(10);
   }
}
```

```
// Product class
public class Set extends Collection {
   public Set(int initialLength) {
      ....
   }
}
public class ListBasedSet extends Set {
   public ListBasedSet(int initialLength) {
      ....
   }
}
```

So, creator methods, which employ constructors, must be overridden carefully by hand

Factory Method (Polymorphic Constructor)

- Abstract creator classes offer abstract constructors (polymorphic constructors)
  - Concrete subclasses can specialize the constructor
  - Constructor implementation is changed with allocation of concrete Creator

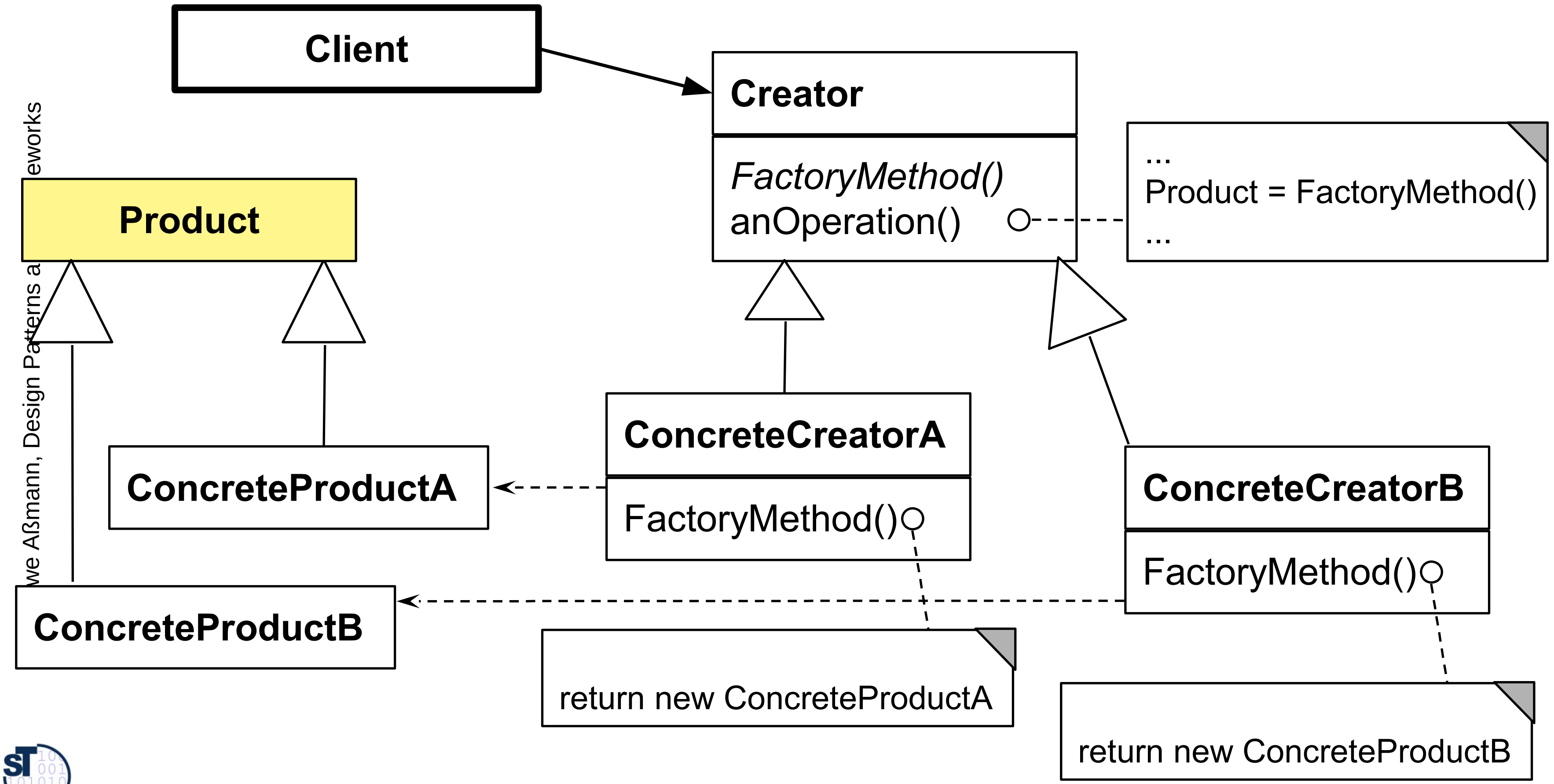
```
// Abstract creator class
public abstract class Creator  {
   // factory method
   public abstract Set createSet(int n);
}
```

```
public class Client {
... Creator cr = new ConcreteCreator(..)
  public void collect() {
    Set mySet = cr.createSet(10);
    ....
  }
}
```

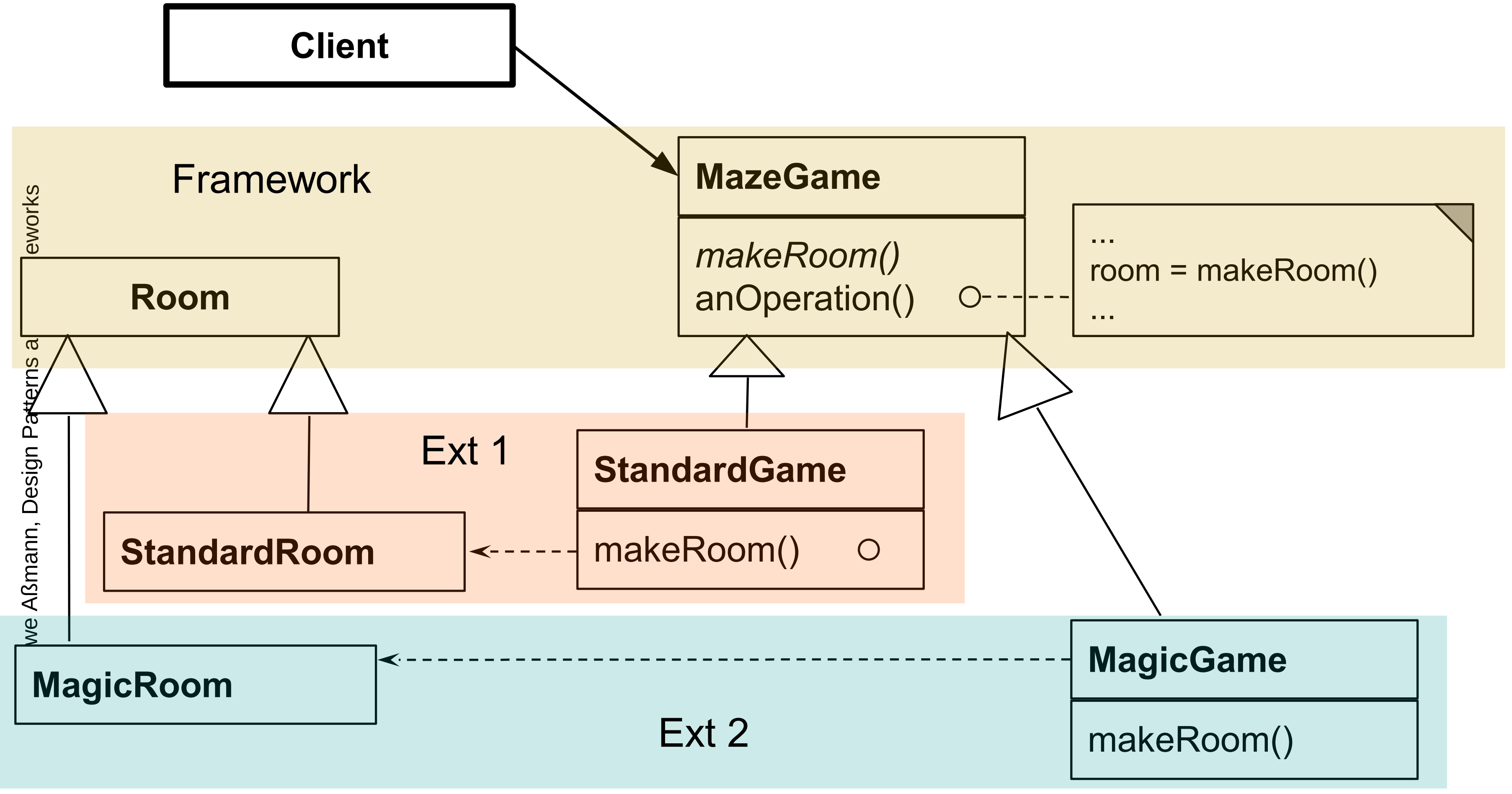
```
// Concrete creator class
public class ConcreteCreator extends Creator {
   public Set createSet(int n) {
      return new ListBasedSet(n);
  }
 ...
}
```

Structure for FactoryMethod

- FactoryMethod is a variant of TemplateMethod
- It hides the allocation of a product

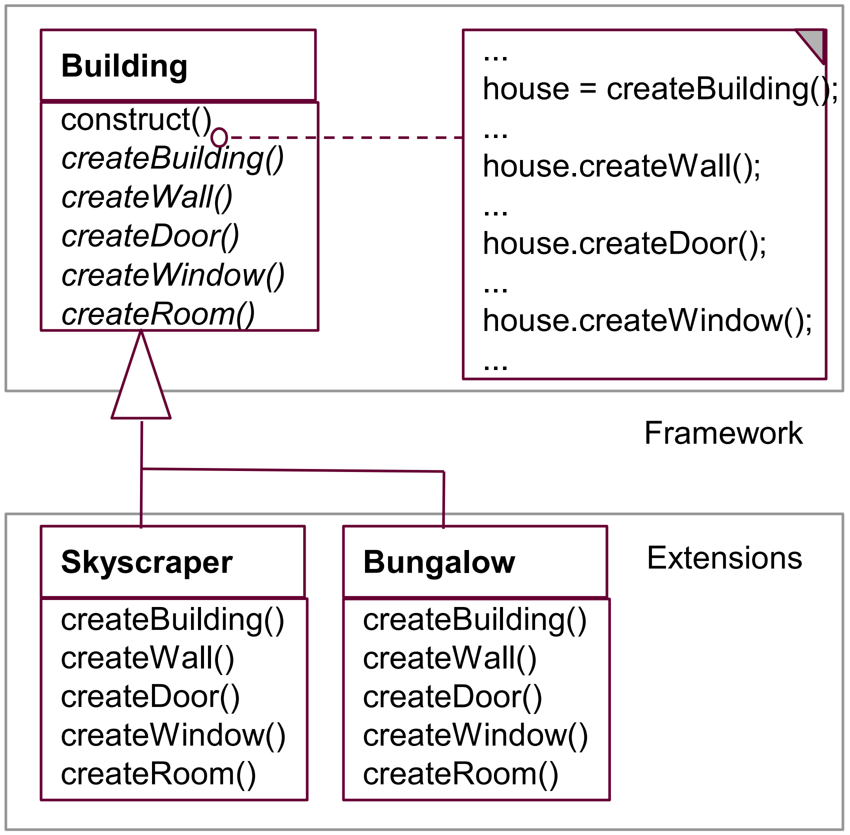


Structure for FactoryMethod



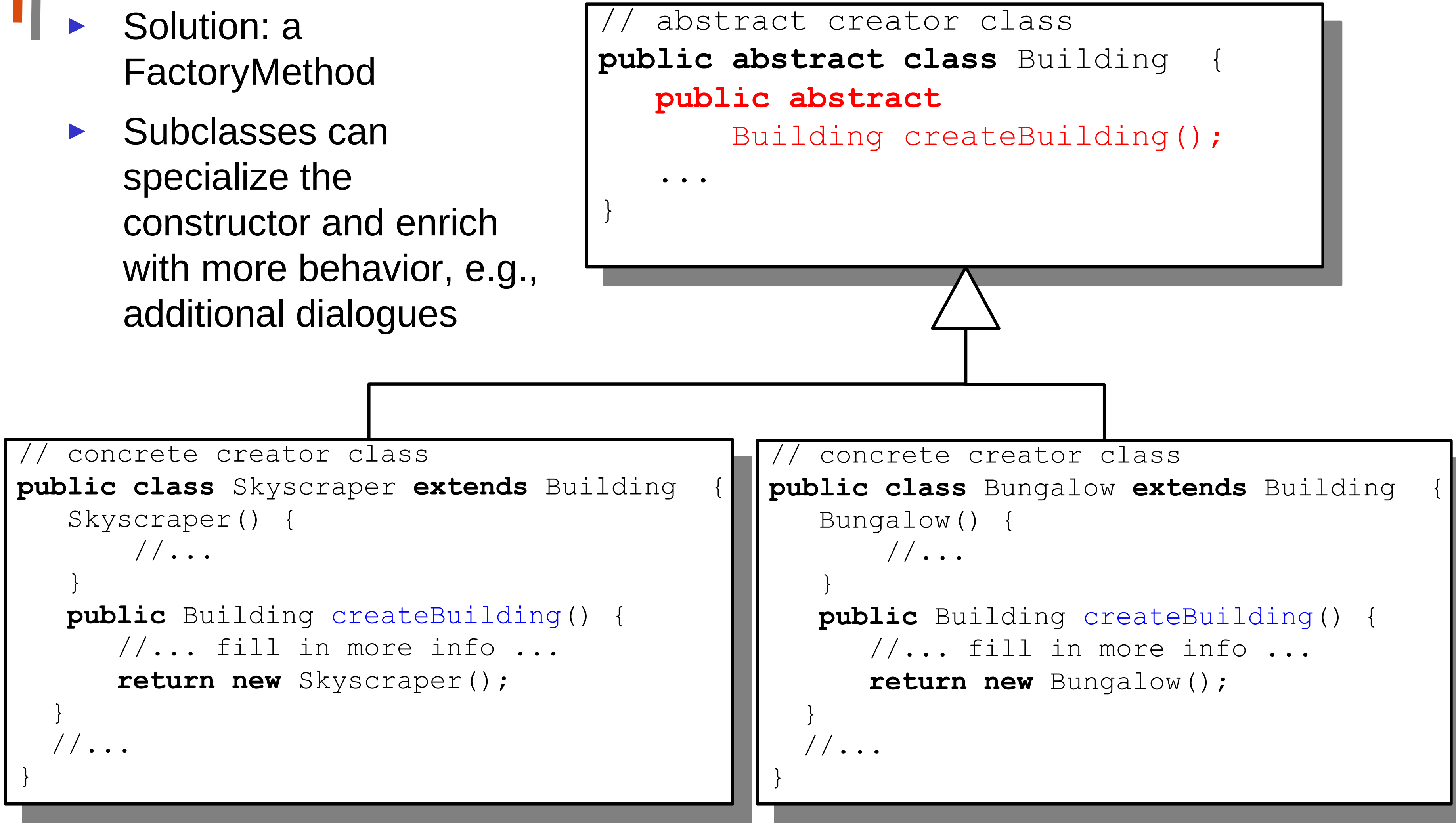
Example FactoryMethod for Buildings

- Consider a framework for planning of buildings
  - Class **Building** with template method **construct** to plan a building interactively
- Users can create new subclasses of buildings
  - All abstract methods createWall, createRoom, createDoor, createWindow must be implemented
- Problem: How can the framework treat new subclasses of Buildings? (unforeseen extension)



Solution with FactoryMethod

- Solution: a FactoryMethod
- Subclasses can specialize the constructor and enrich with more behavior, e.g., additional dialogues



```
// abstract creator class
public abstract class Building  {
   public abstract
       Building createBuilding();
   ...
}
```

```
// concrete creator class
public class Skyscraper extends Building  {
   Skyscraper() {
       //...
   }
   public Building createBuilding() {
      //... fill in more info ...
      return new Skyscraper();
  }
  //...
}
```

```
// concrete creator class
public class Bungalow extends Building  {
   Bungalow() {
       //...
   }
   public Building createBuilding() {
      //... fill in more info ...
      return new Bungalow();
  }
  //...
}
```

Flexible Construction with Reflection

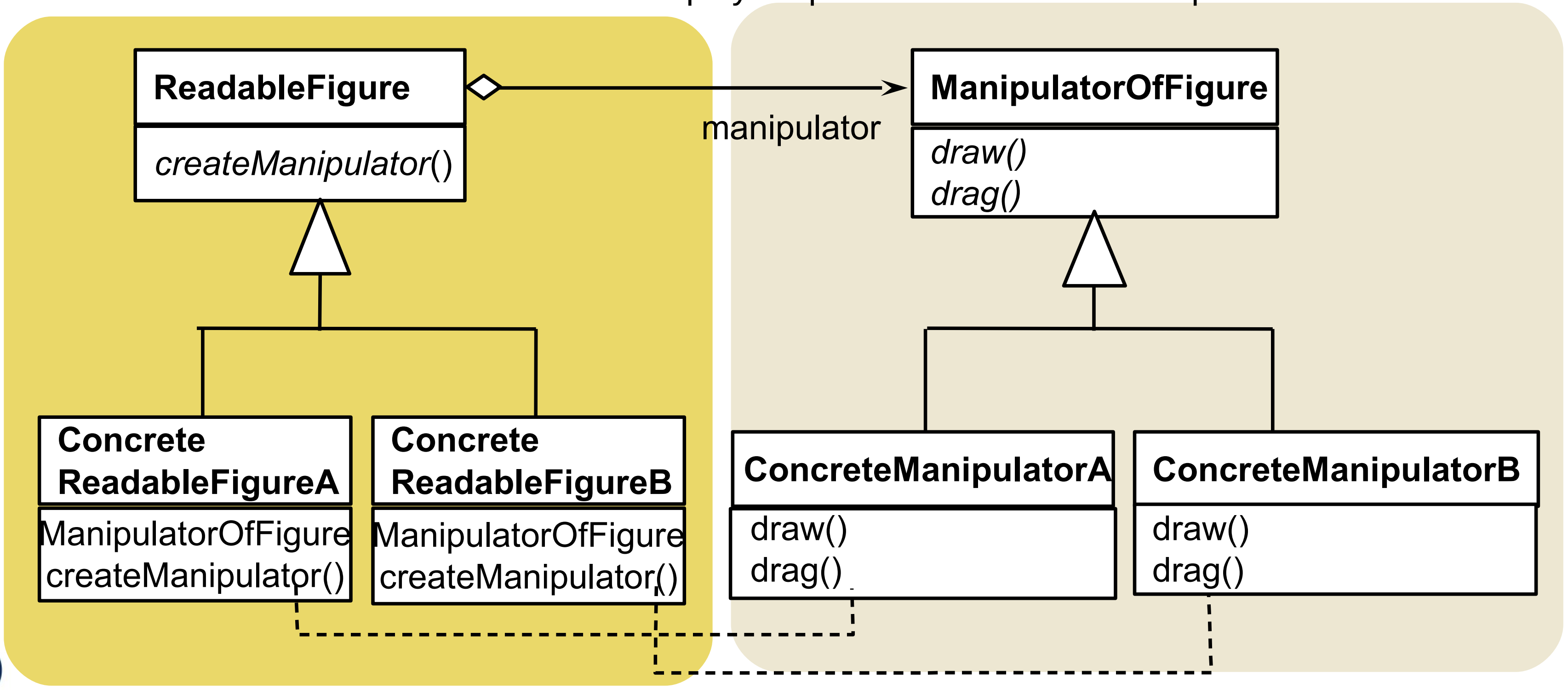
- Constructor can allocate objects of statically unknown classes
- Reflection:
  - Find the class's name and get the class object
  - Then clone the class object

    in Java: **`Class.forName`**`(String name)`
- Attention: reflection is usually slow. It has to lookup bytecode information and must load class code on-the-fly

```
... createProduct() {
    // reflective function for class name, called in subclass
    String className = getClassNameFromSomeWhere();
    // get the class object and allocate from there
    house = (Building) Class.forName(className).newInstance();
    ...
}
```

Factory Methods in Parallel Class Hierarchies

- One class hierarchy offers a factory method to create objects of a second hierarchy
- On every level, the factory method is implemented in a parallel class on exactly the same level and abstraction level
  - E.g, ReadableObject and WritableObject in ReadableFigures and FigureManipulators
- Here, the parallelism constraint is that every readable object must allocate a parallel manipulator.
  - This is a constraint on the polymorphic allocator of the manipulators



Analysis of FactoryMethod: Information Hiding of Abstract Classes

- Abstract classes know *when* an object should be allocated, but do not know which of the subclasses will be filled in at runtime
  - The knowledge which subclass should be used is encapsulated into the client subclasses
- For frameworks this means:
  - The abstract classes of the framework do not know which application class they will work on, but they know when to create an application object
  - The knowledge which application class should be used is encapsulated into the application
- Relatives of FactoryMethod
  - A FactoryMethod is a HookMethod, used by a TemplateMethod, which returns a product, i.e., FactoryMethods are called in TemplateMethods

3.2 Factory Class (Abstract Factory)

Forces of the Factory Class Pattern

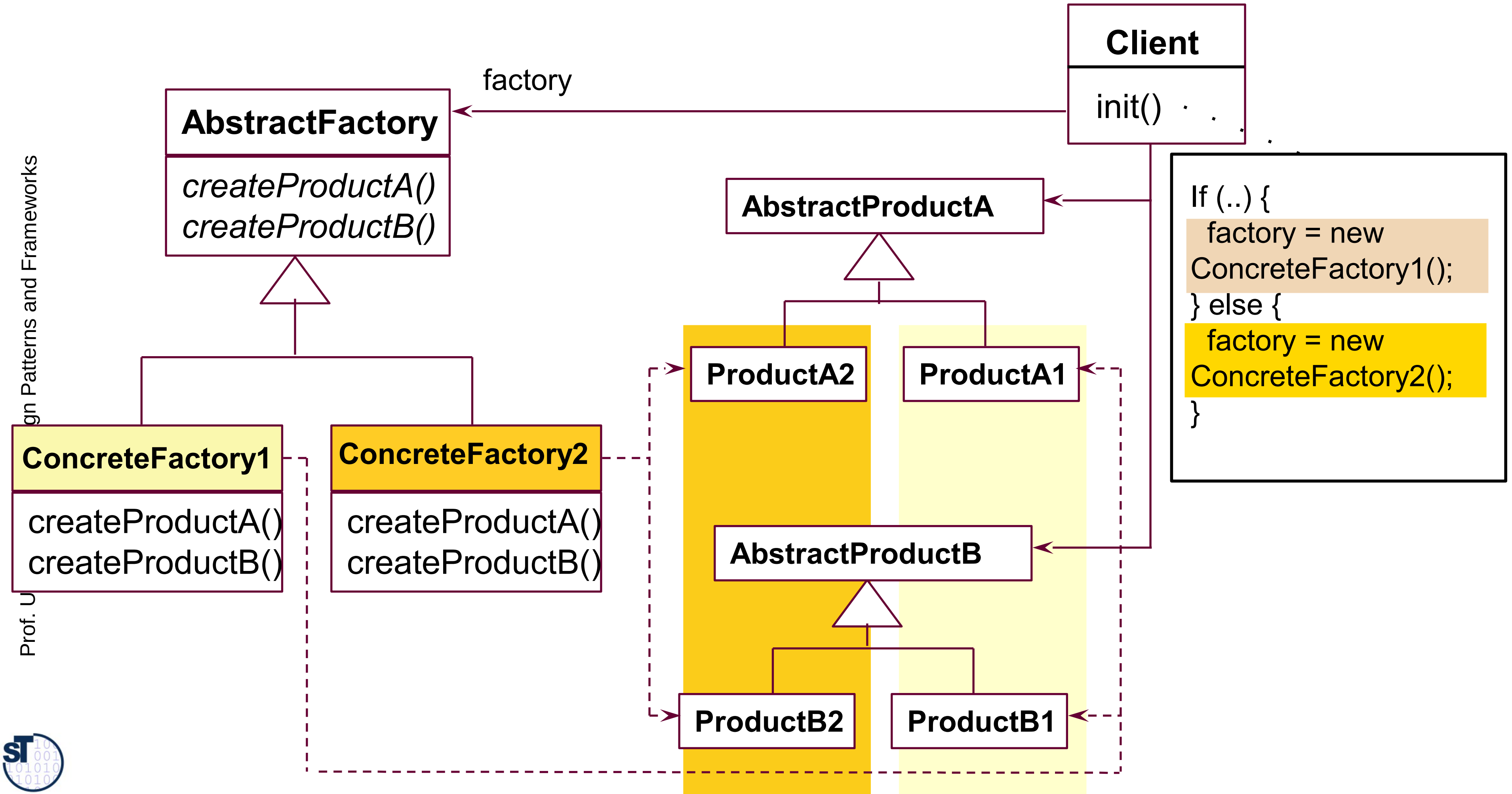
- Given a package with a family of classes (a *product family*). Examples
  - Widgets in a window system
  - Stones in a Tetris game
  - Products of a company
- How can the product family be switched in one go to a variant?
  - Swing widgets to Windows widgets?
  - 2D-stones to 3D-stones in the Tetris game?
  - Cheap variants of the products of the company to expensive variants?

Factory Class Pattern

- A **Factory (FactoryClass)** groups factory methods to a class
    - A Factory is a class that groups a *family of polymorphic constructors* of a family of classes (products)
  - The products can be classes of a layer or a package
  - The products have a strong parallelism constraint (isomorphic hierarchies)
- An **AbstractFactory** contains the interfaces of the constructors
- A **ConcreteFactory** contains the implementation of the constructors
  - The Concrete Factories can be exchanged
  - A Concrete Factory represents one concrete family of objects
- Hence, an AbstractFactory offers an interface to create families of related objects
  - That depend on each other
  - Without naming their constructors explicitly

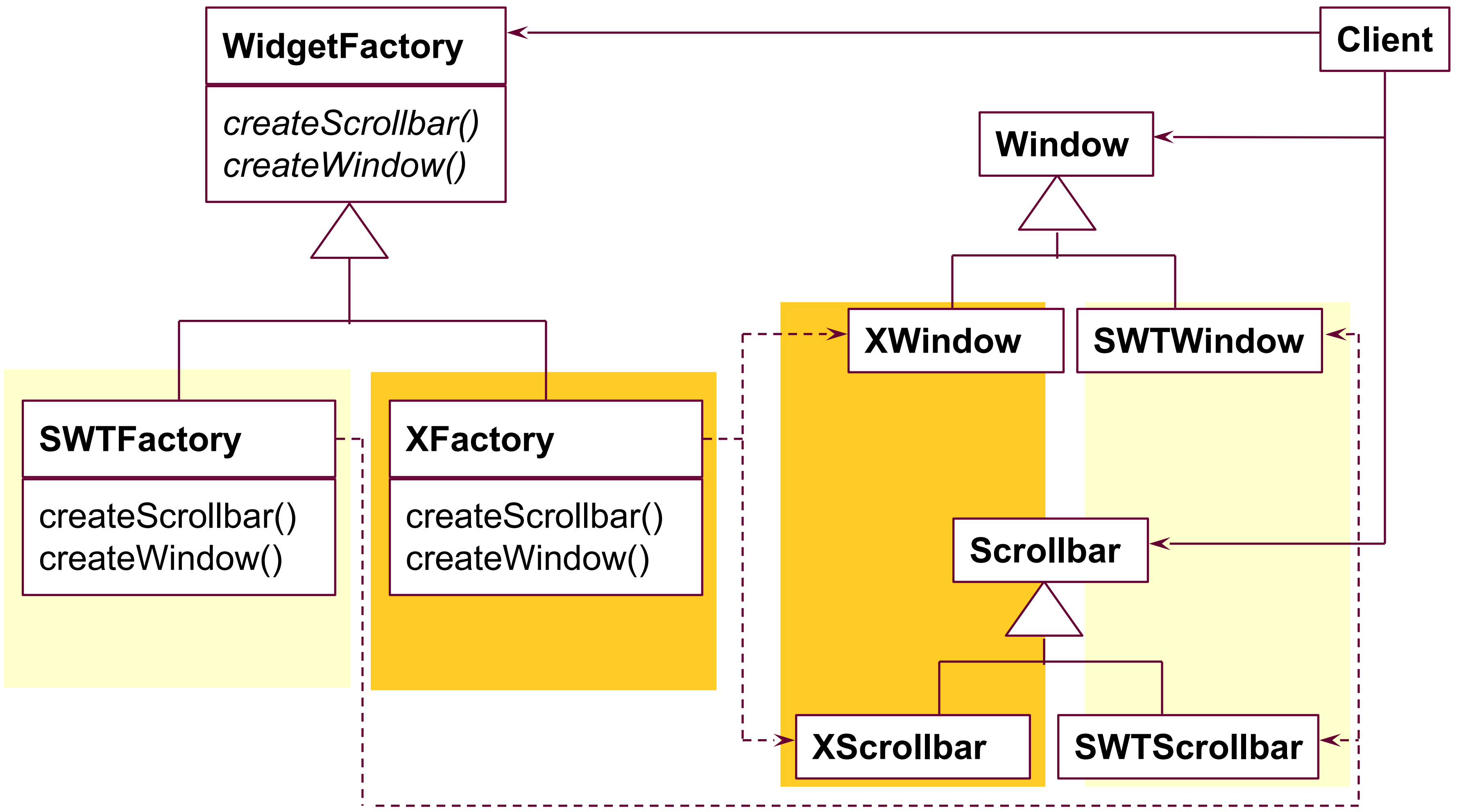
Structure for Factory Class

- By creating the concrete factory, the client determines the entire family of products (here: family 1 or 2)

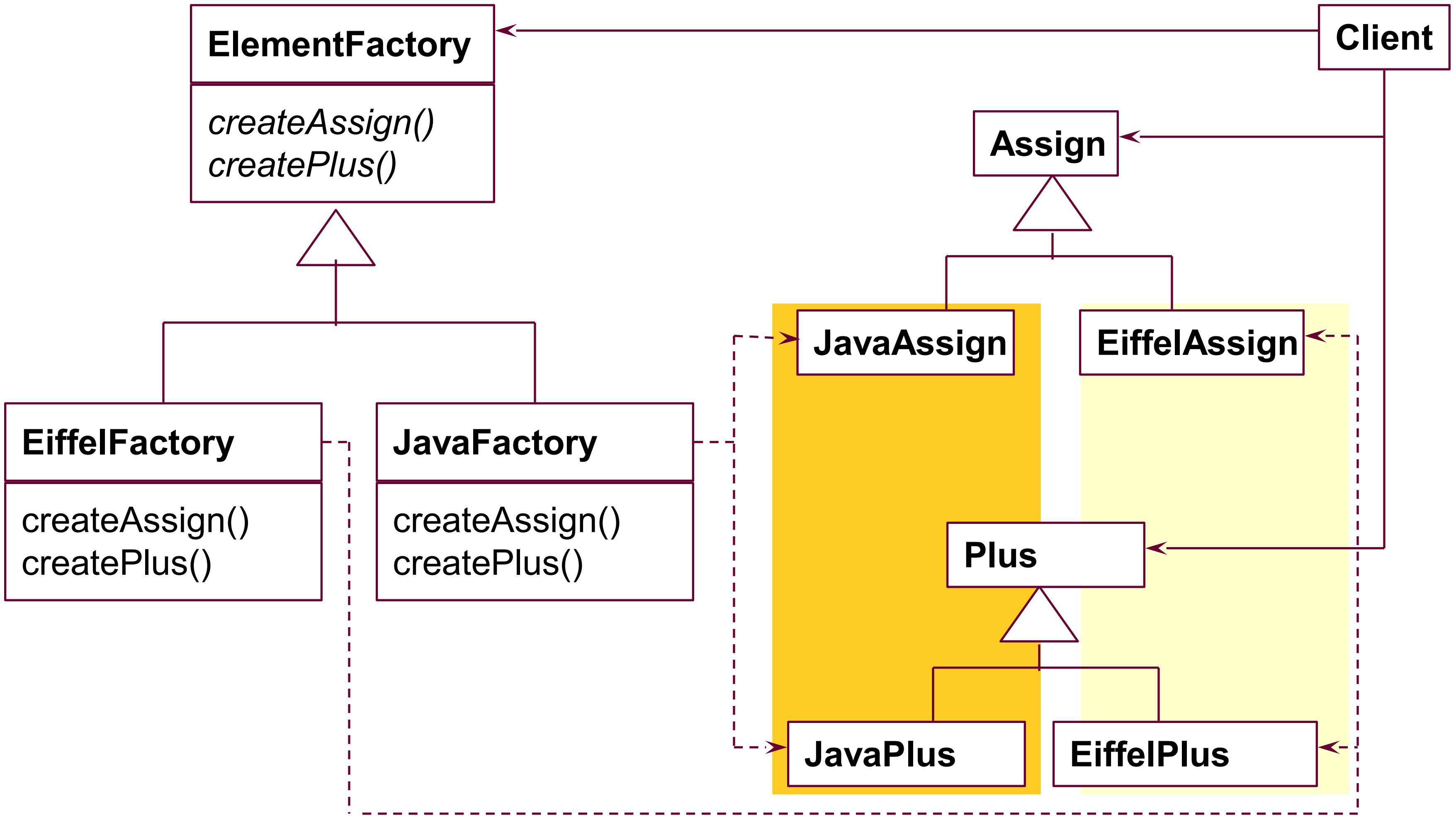


```
If (..) {
  factory = new
ConcreteFactory1();
} else {
  factory = new
ConcreteFactory2();
}
```

Example for Factory Class



Example for Factory Class in Compilers

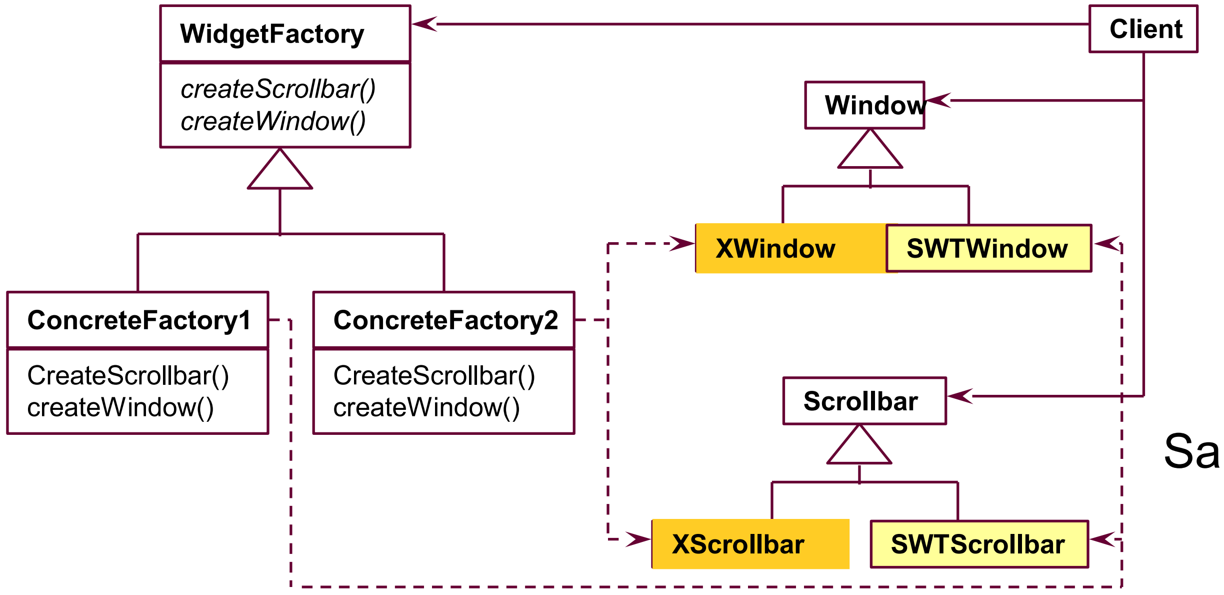


Employment of Factory Class

- For window styles
  - All widgets are used by the framework abstractly
  - The concrete style is determined by a concrete factory class
  - Swing, AWT, ...
- In office systems
  - For families of similar documents
- In business systems
  - For families of similar products
- For tools on several languages
- Factory Class is related to Tools-and-Materials (TAM), because products are materials (see later)

Pragmatics of Factory Class

- A factory deals with 3+x inheritance hierarchies (factory, product 1, ..., product n)
- The *n* product hierarchies must be maintained *in parallel,* i.e., they form ParallelHierarchies
- The factory pattern ensures that all objects are created with the parallelism constraint

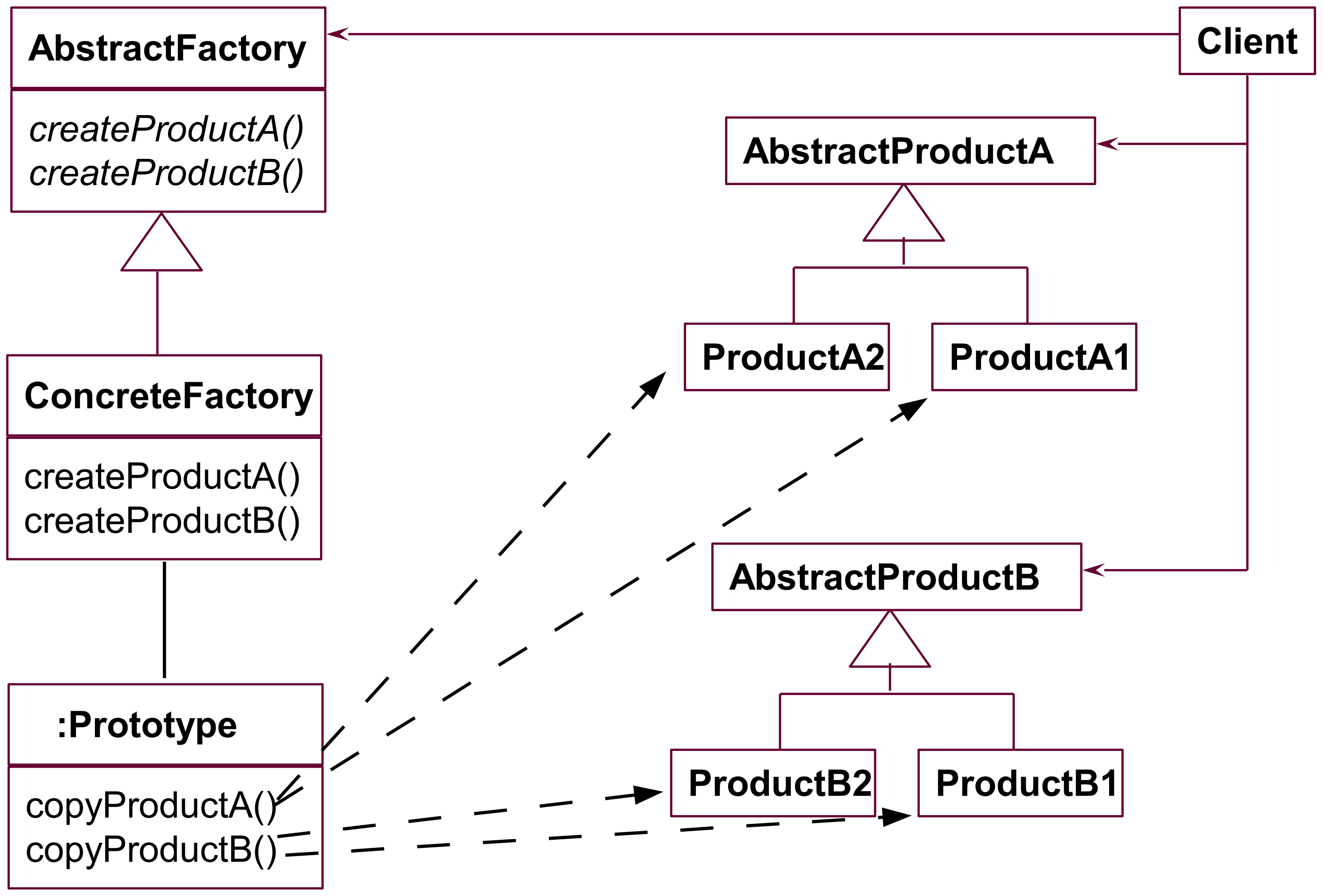


Same height of products

Variant: The Prototyping Factory

- Concrete factories need not be created; one instance is enough, if prototypes of the products exist
- To produce new products, the ConcreteFactory clones the set of available products
- The variability of products is handled by the cloning of the prototypes
- Especially useful, if products have complex default state or do not vary much

Structure for Prototyping Factory



Variant: Factory with Interpretive FactoryMethod

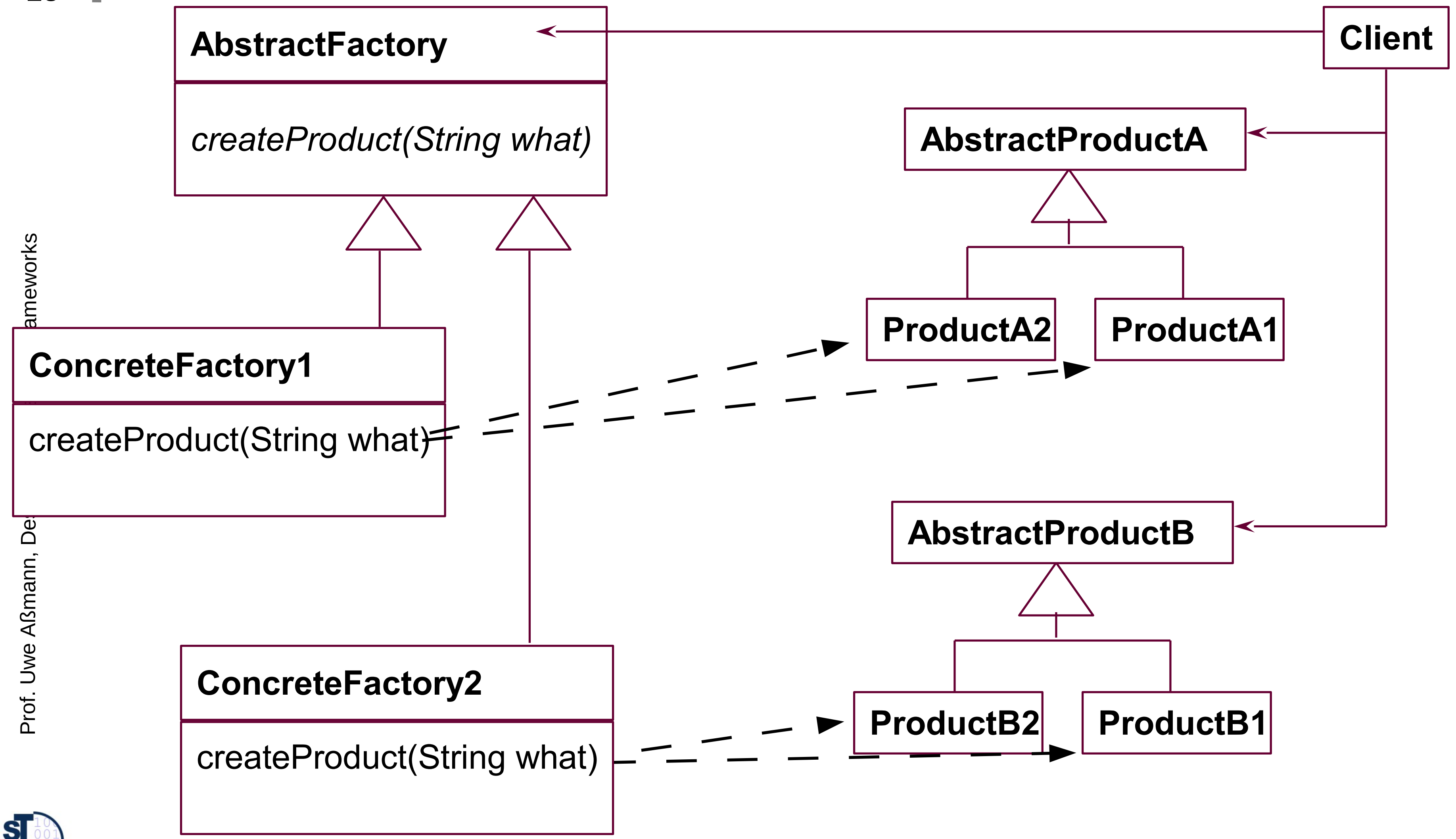
- If more factory methods should be added, this becomes tedious, since the AbstractFactory and all concrete factories must be edited
- Instead: one factory method with parameter string

```
public class abstractFactory {
    abstract Product createProduct(String what);
}



public class ConcreteFactory extends AbstractFactory {
    Product  createProduct(String what) {
        if (what.eq(“p1”)) {
            return new P1();
        else .....
    }
}
```

Structure for Interpretive Factory



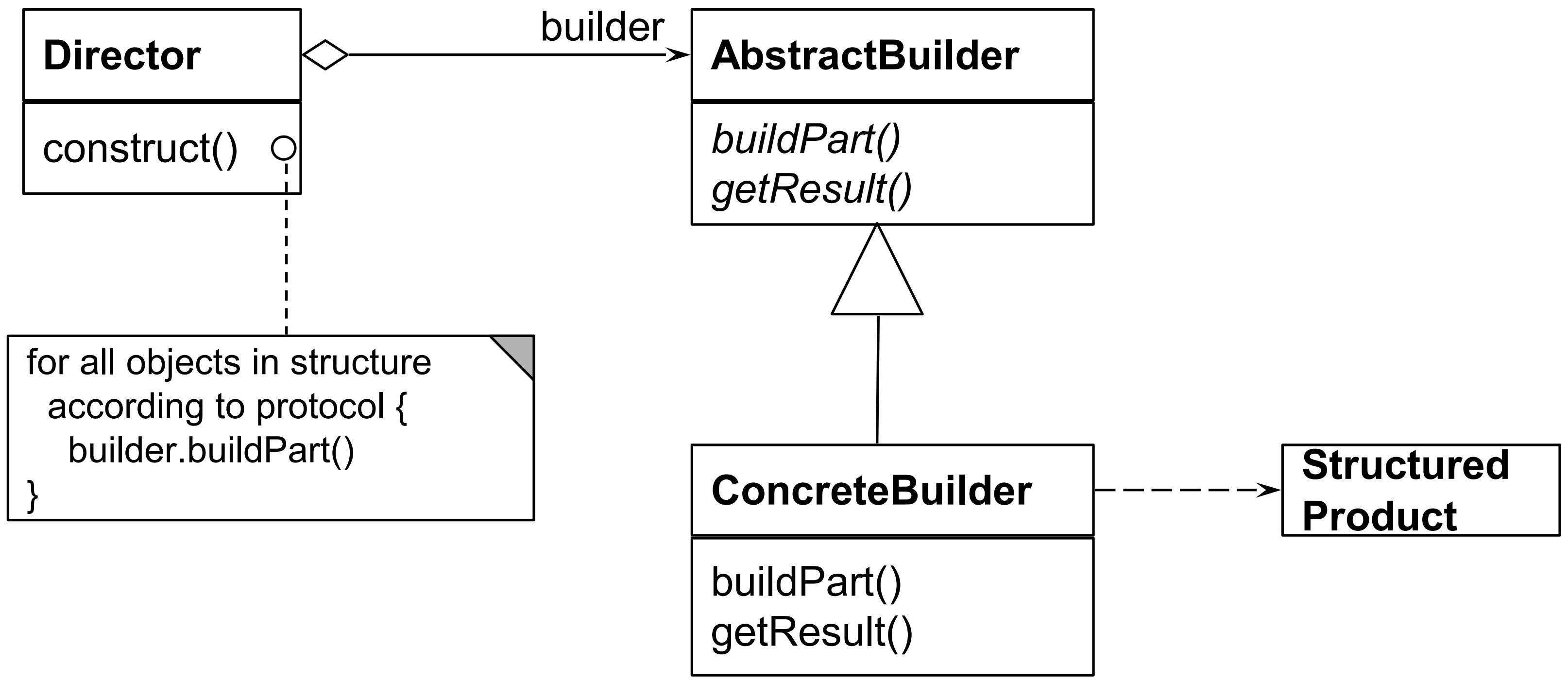
Factory Class - Employment

- Make a system independent of the way how its objects are created
- Hide constructors to make the way of creation exchangable with types
- For product families
  - In which families of objects need to be created together; but the way how is varied
- Related Patterns
  - An abstract factory is a special form of hook class, to be called by some template classes.
  - Often, a factory is a Singleton (a Singleton is a class with only one instance)
  - Concrete factories can be created by parametrizing the factory with Prototype objects

3.3 Builder (Factory with Protocol, Structured Factory)

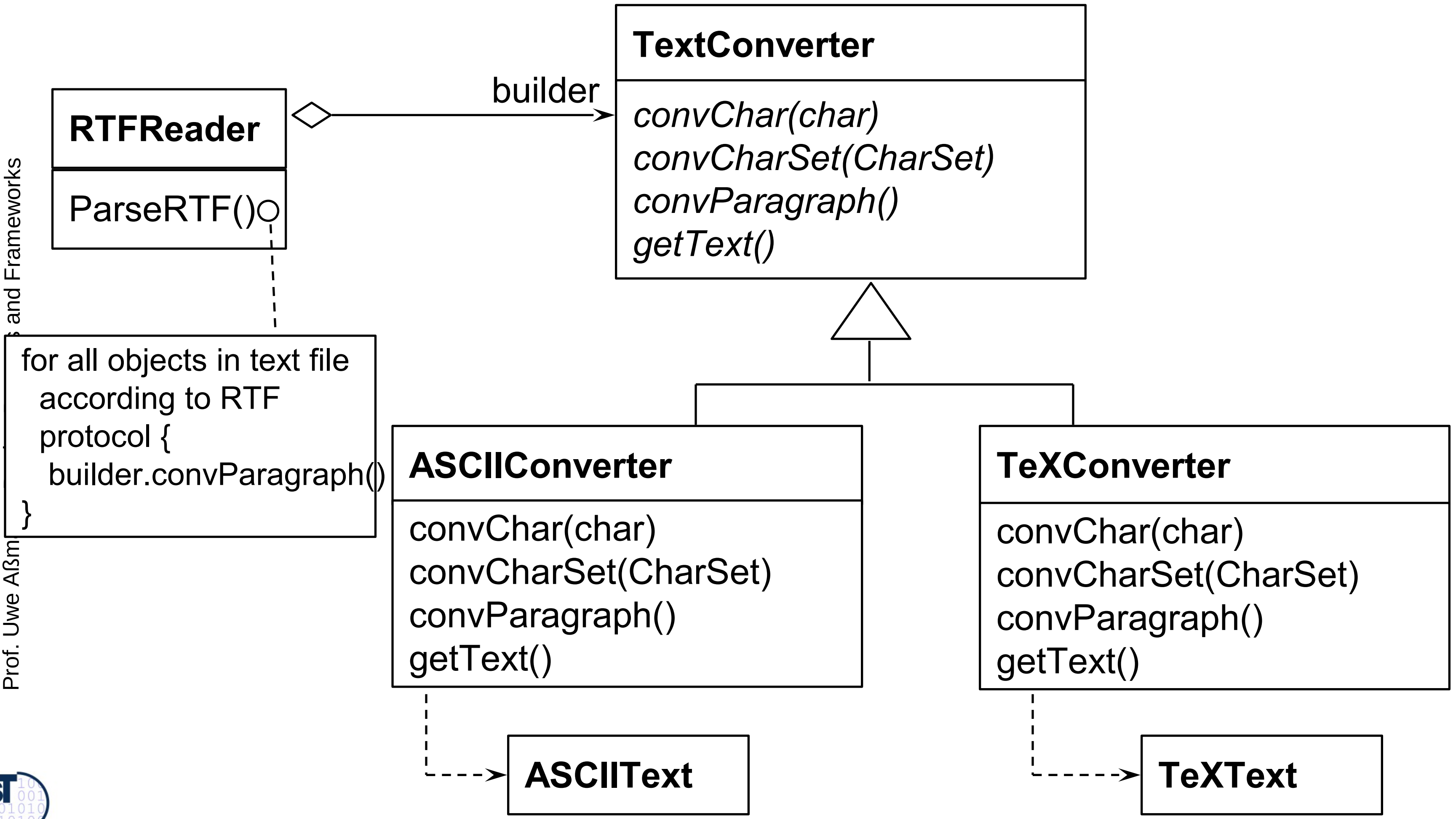
Structure for Builder

- The Builder is a Factory Class that produces a *structured* product (a whole with parts)
  - e.g., a business object or product data



Example RTF-Document Builder

- RTF grammar defines a protocol for the sequence of text converter functions

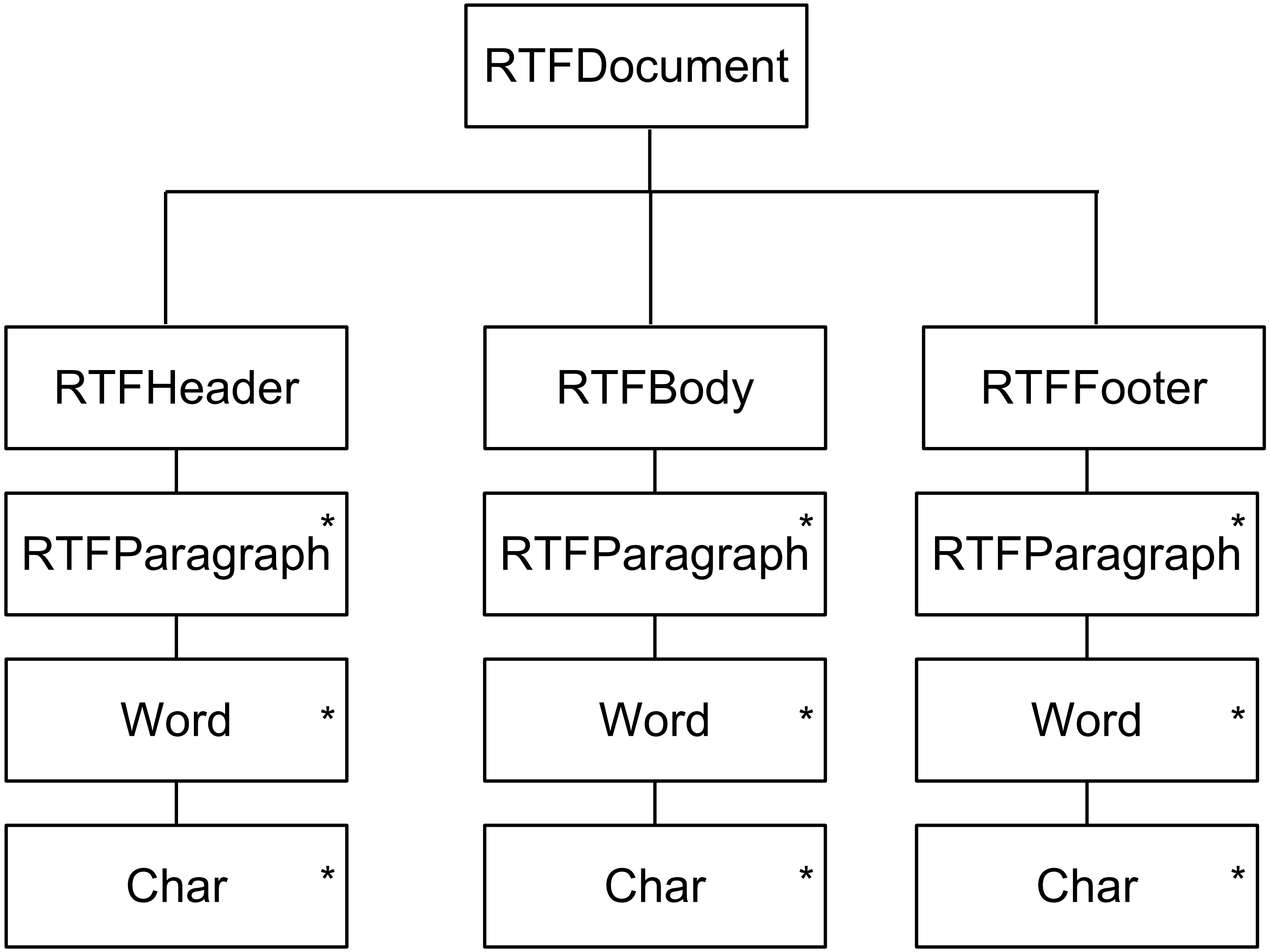


```
for all objects in text file
  according to RTF
  protocol {
   builder.convParagraph()
}
```

Builder Protocol (E.g., Specified by EBNF)

```
-- Grammar in EBNF
RTFDocument ::= RTFHeader RTFBody RTFFooter.
RTFHeader ::= RTFParagraph*.
RTFParagraph ::= Word*.
Word ::= Char*.
RTFBody ::= RTFParagraph*.
RTFFooter ::= RTFParagraph*.
```

RTF Builder Protocol



The Builder

- Maintains an internal state that memorizes the point of time in construction of the complex data structure
- Data structure defines a protocol for calls to the elementary functions
- Data structure must be defined by a
  - Grammar
  - regular expression
  - Protocol machine (statechart acceptor)
  - Other mechanisms, such as Petri nets
- The other way round: as soon as we have a data structure
  - Defined by a grammar or regular expressions
  - We can build a constructor with the Builder pattern

Builder: Information Hiding

- The builder hides
  - The protocol (the structure of the data)
  - The current status
  - The implementation of the data structure
- Similar to an Iterator, the structure is hidden

Known Uses

- Parsers in compilers are builders that contain the grammar of the concrete syntax of the programming language
- Builders for intermediate representations of all kinds of languages
  - Programming languages
  - Specification languages
  - Graphic languages such as UML
- Builders for all complex data structures
  - Databases with integrity constraints

What have we learned?

- Factory Method
  - **Problem**: constructors cannot be varied
  - **Solution**: Application of Template Method for Creation
- Factory Class
  - **Problem**: No variability of constructors in dimensional class hierarchies
  - **Solution**: Application of Template Class for Creation
- Builder
  - **Problem**: Complex products are build according to a protocol, which is to be varied, too.
  - **Solution**: Application of Template Class with stateful template method