GENERICS IN JAVA

Computer Science II
CS 030
Donald J. Patterson

GENERICS FROM 10,000 FEET

- Generics enable types (classes and interfaces) to be parameterized.
- The input to Generics are types
- The output of Generics are new types
- They are like parameters in methods
  - but they are about types, not data, not values
  - they are meta-data
- They let you re-use the same code with different inputs.

http://docs.oracle.com/javase/tutorial/java/generics/why.html

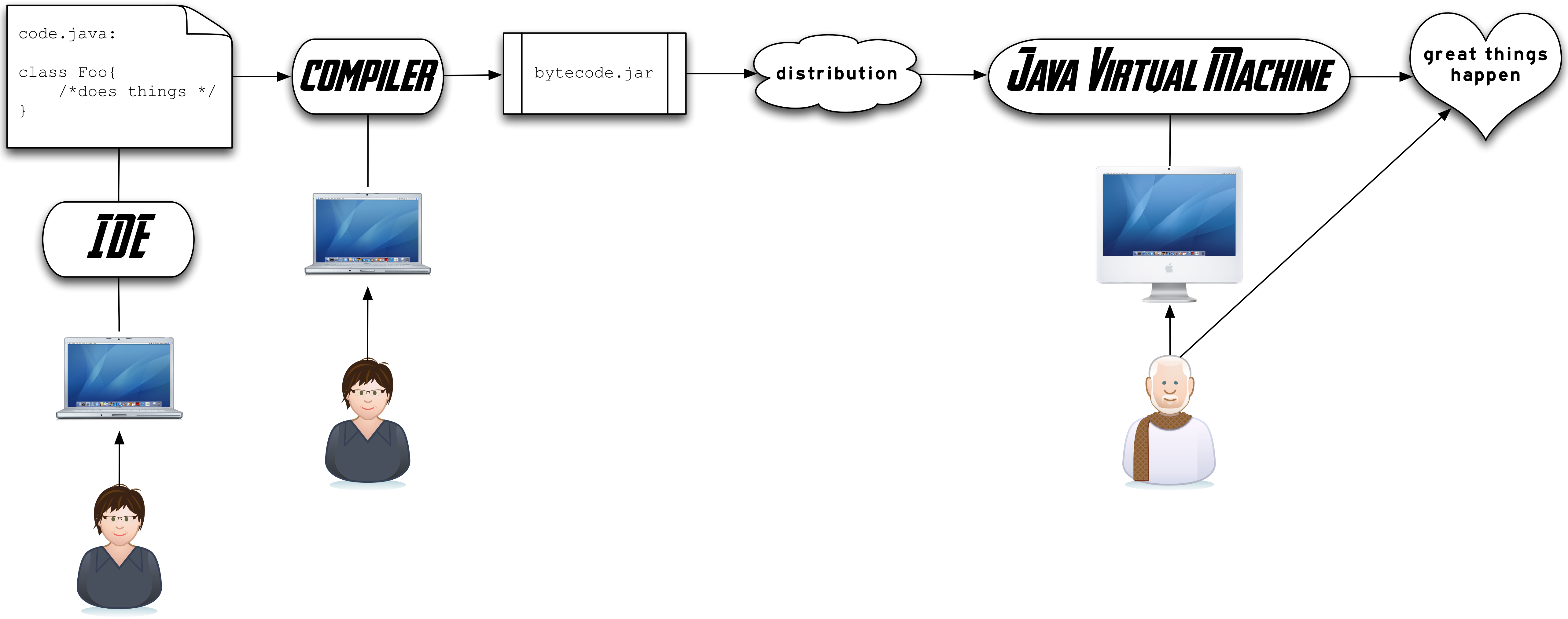
GENERICS FROM 10,000 FEET

- Benefits:
  - Write less code (code re-use)
  - They enable programmers to implement generic algorithms once (less bugs)

  - Stronger type checks at compile time.
  - More errors are found at compile-time through static checking

http://docs.oracle.com/javase/tutorial/java/generics/why.html

GENERICS FROM 10,000 FEET



http://docs.oracle.com/javase/tutorial/java/generics/why.html

GENERICS FROM 10,000 FEET

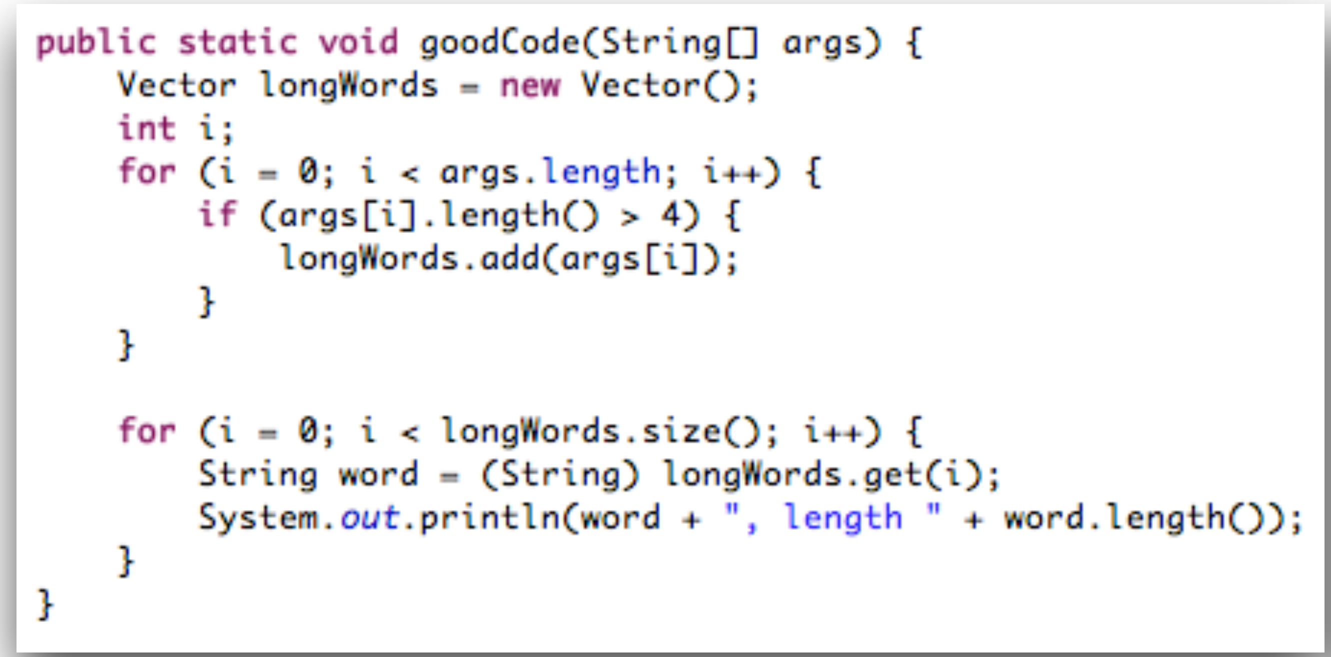
- Elimination of casts.
  - The following code snippet without generics requires casting:

```
List list = new ArrayList();
list.add("hello");
String s = (String) list.get(0);
```

  - When re-written to use generics, the code does not require casting:

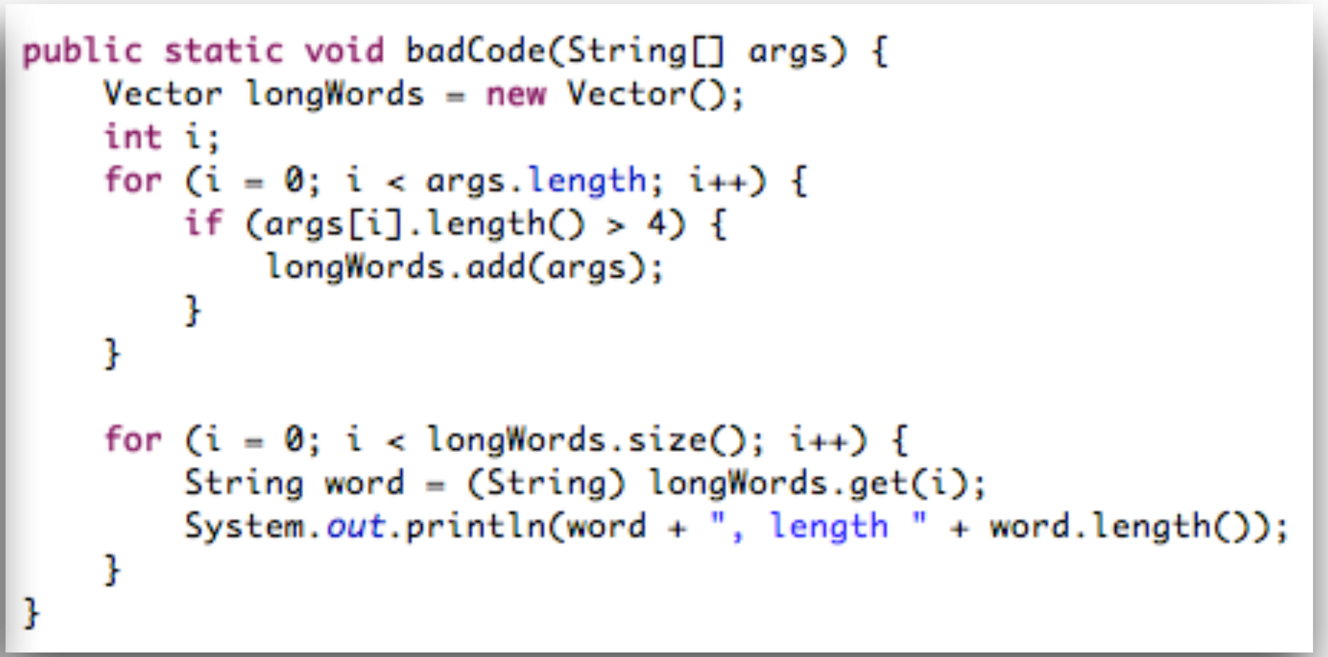
```
List<String> list = new ArrayList<String>();
list.add("hello");
String s = list.get(0);   // no cast
```

GENERICS FROM 10,000 FEET



```java
public static void goodCode(String[] args) {
    Vector longWords = new Vector();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args[i]);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = (String) longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```

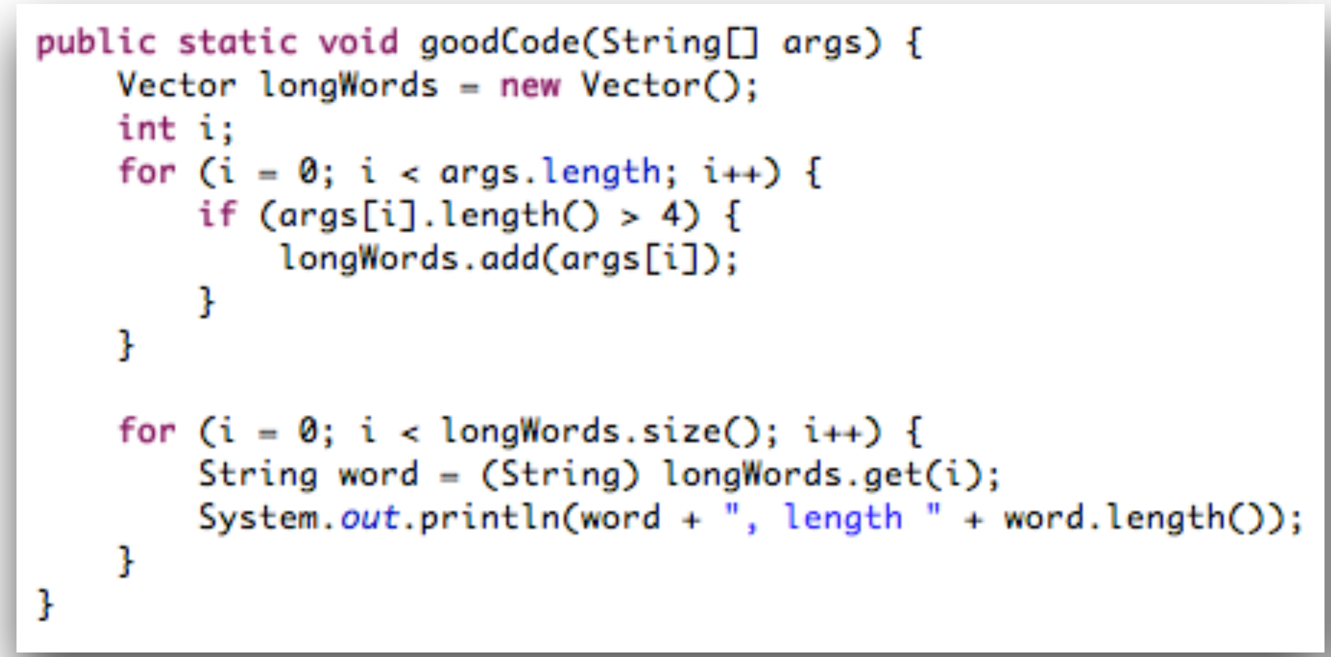


```java
public static void badCode(String[] args) {
    Vector longWords = new Vector();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = (String) longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```

- Questions:
  - What does the code on the left do?
  - What is different about the code on the right?
  - Is the code syntactically correct?

GENERICS FROM 10,000 FEET



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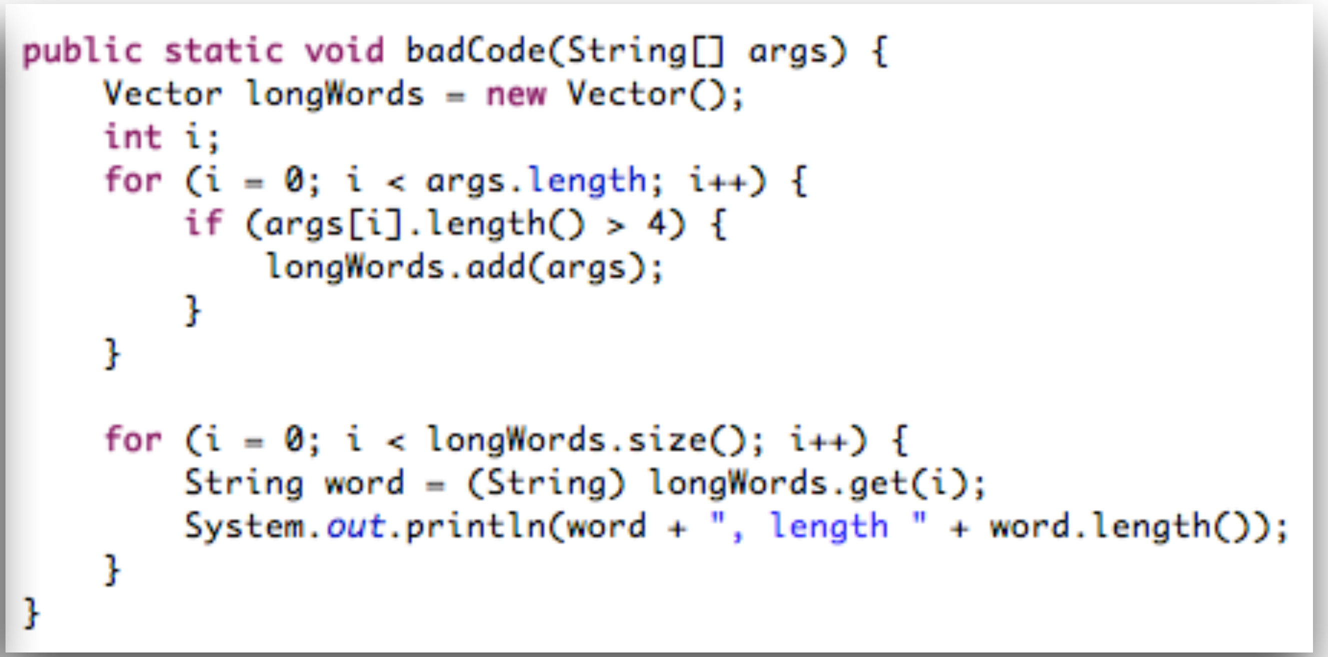
    Vector longWords = new Vector();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args[i]);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = (String) longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```

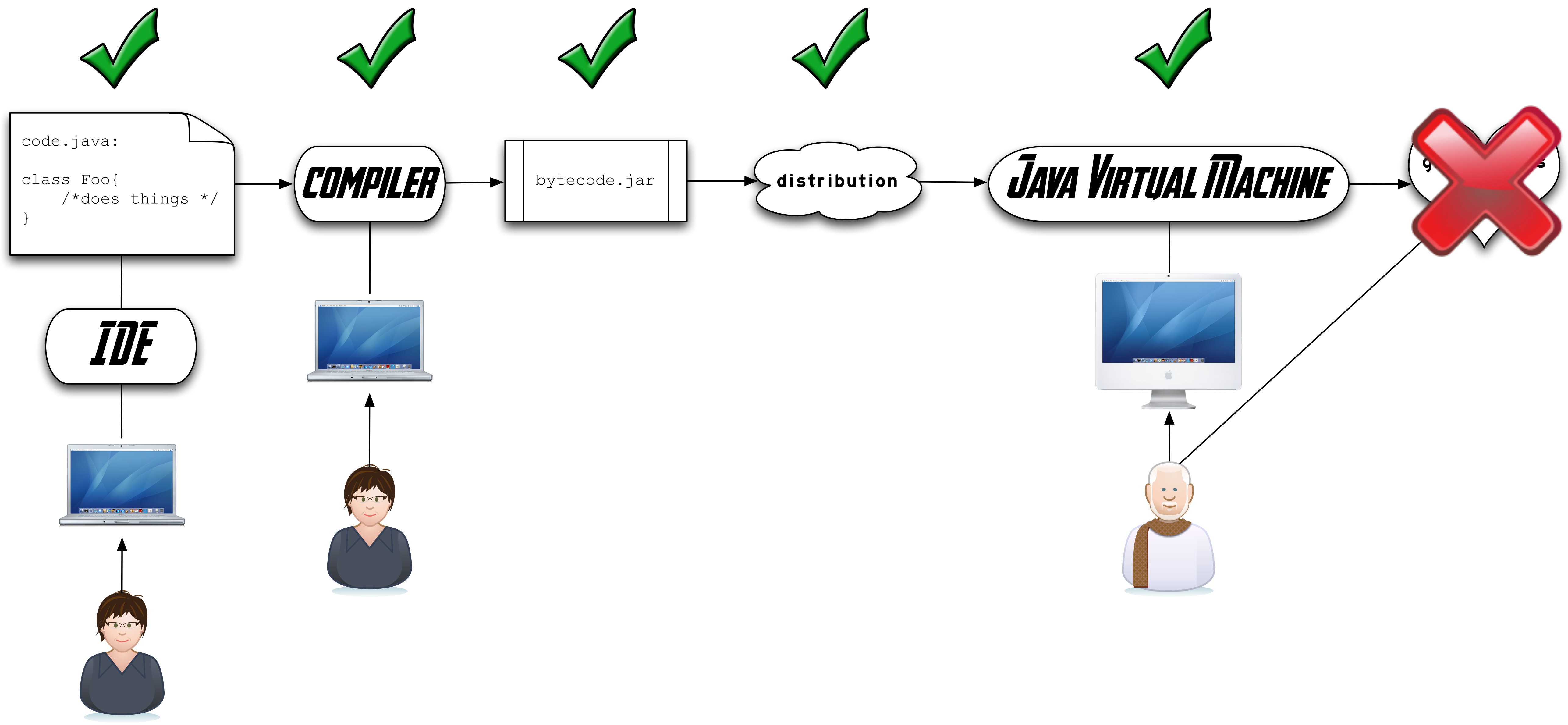


```java
public static void badCode(String[] args) {
    Vector longWords = new Vector();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = (String) longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```

- Questions:
  - What does the code on the left do?
  - What is different about the code on the right?
  - Is the code syntactically correct?
- Let’s try it

GENERICS FROM 10,000 FEET

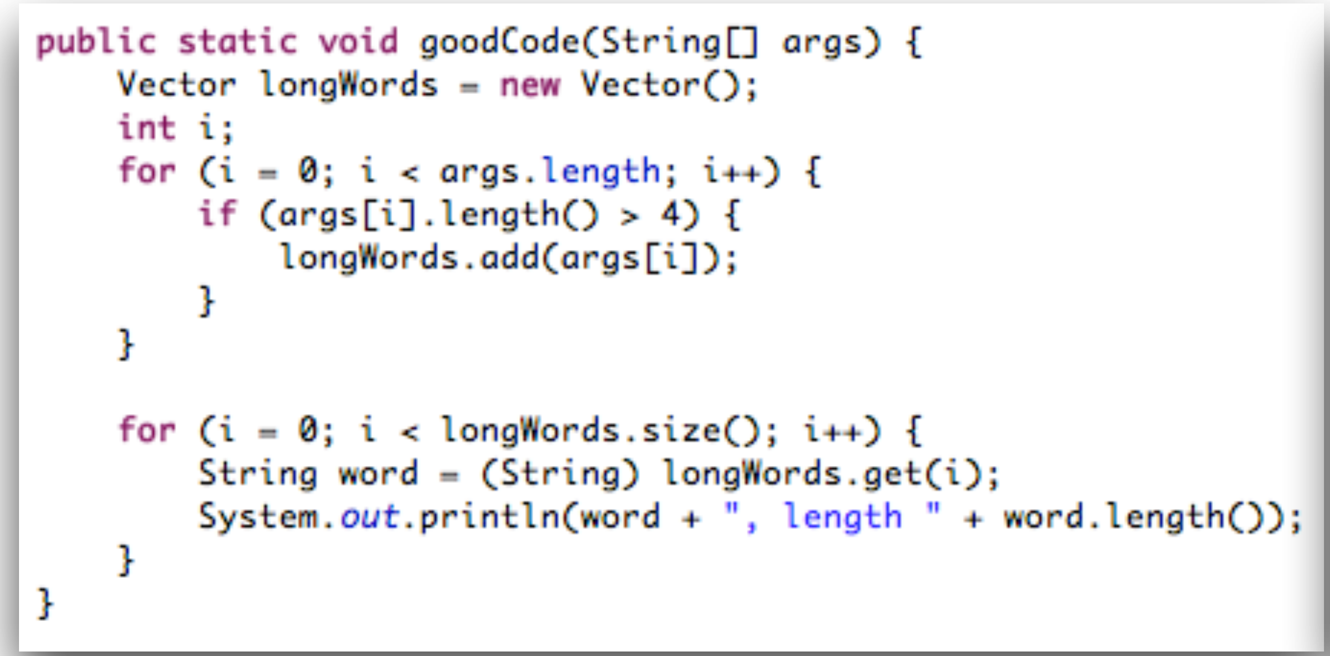


```
code.java:

class Foo{
    /*does things */
}
```

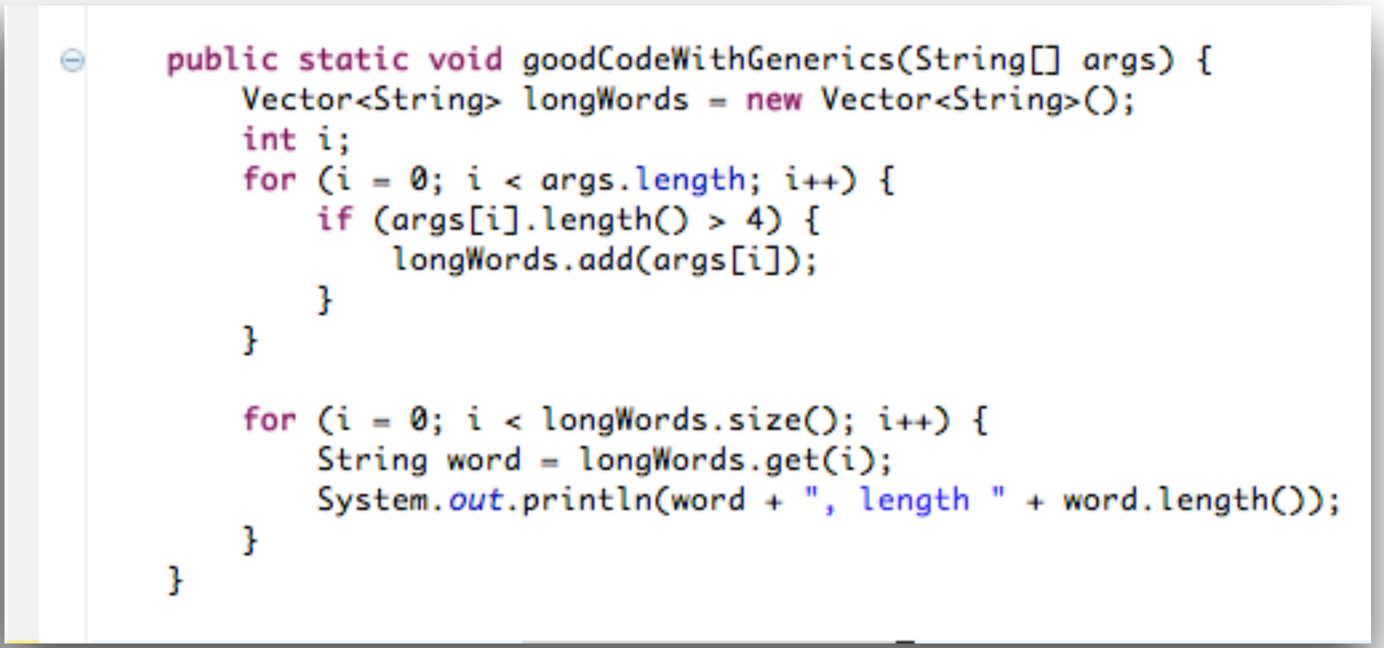
http://docs.oracle.com/javase/tutorial/java/generics/why.html

GENERICS FROM 10,000 FEET



```java
public static void goodCode(String[] args) {
    Vector longWords = new Vector();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args[i]);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = (String) longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```

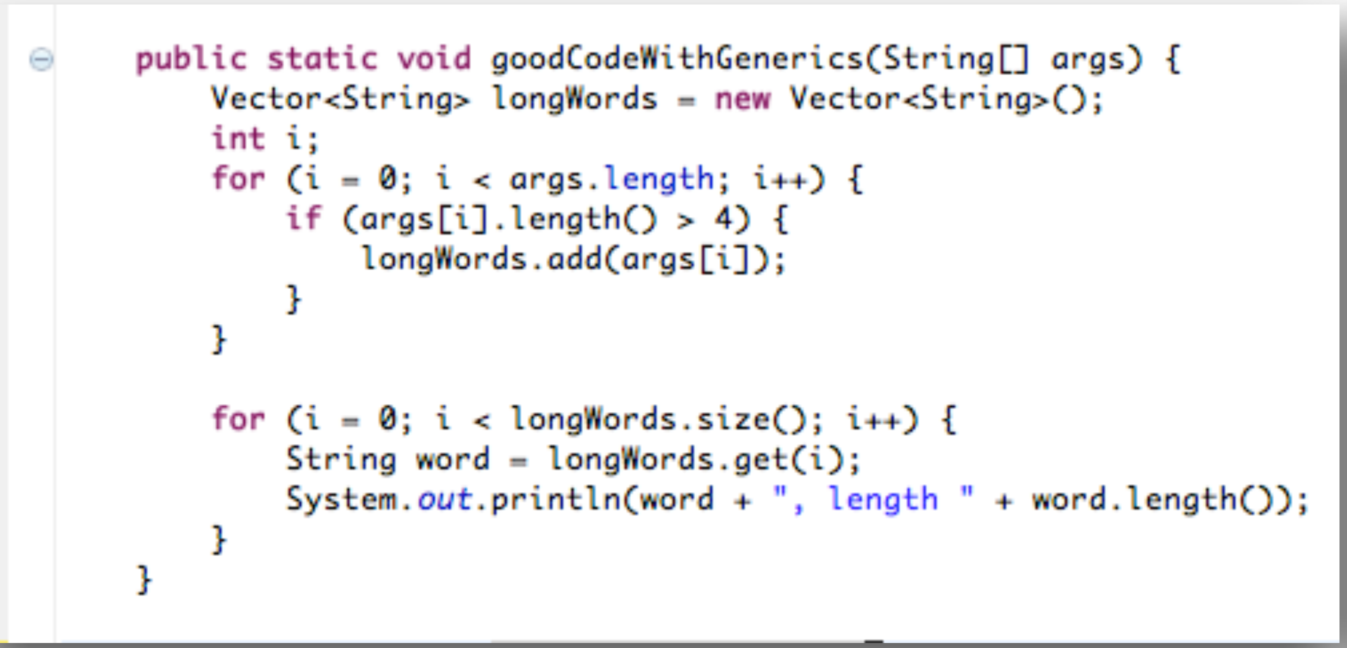


```java
public static void goodCodeWithGenerics(String[] args) {
    Vector<String> longWords = new Vector<String>();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args[i]);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```

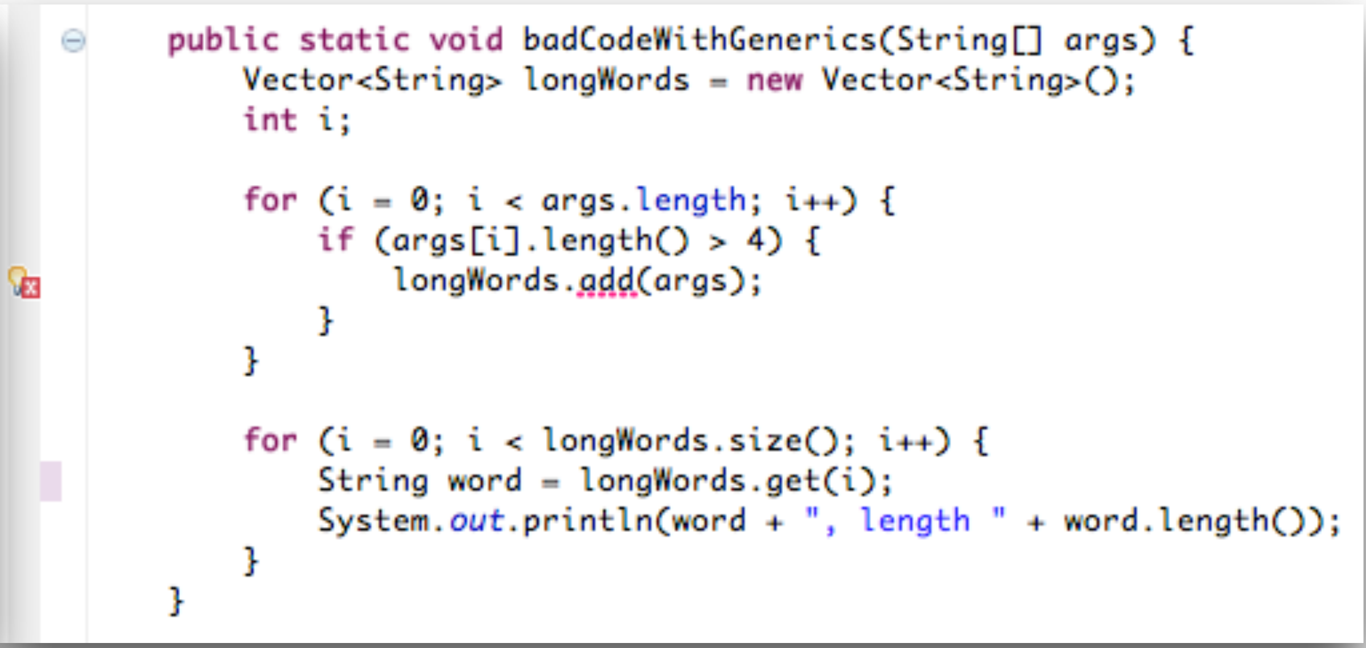
- Questions:
    - What is different about the code with Generics?

GENERICS FROM 10,000 FEET



```java
public static void goodCodeWithGenerics(String[] args) {
    Vector<String> longWords = new Vector<String>();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args[i]);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```



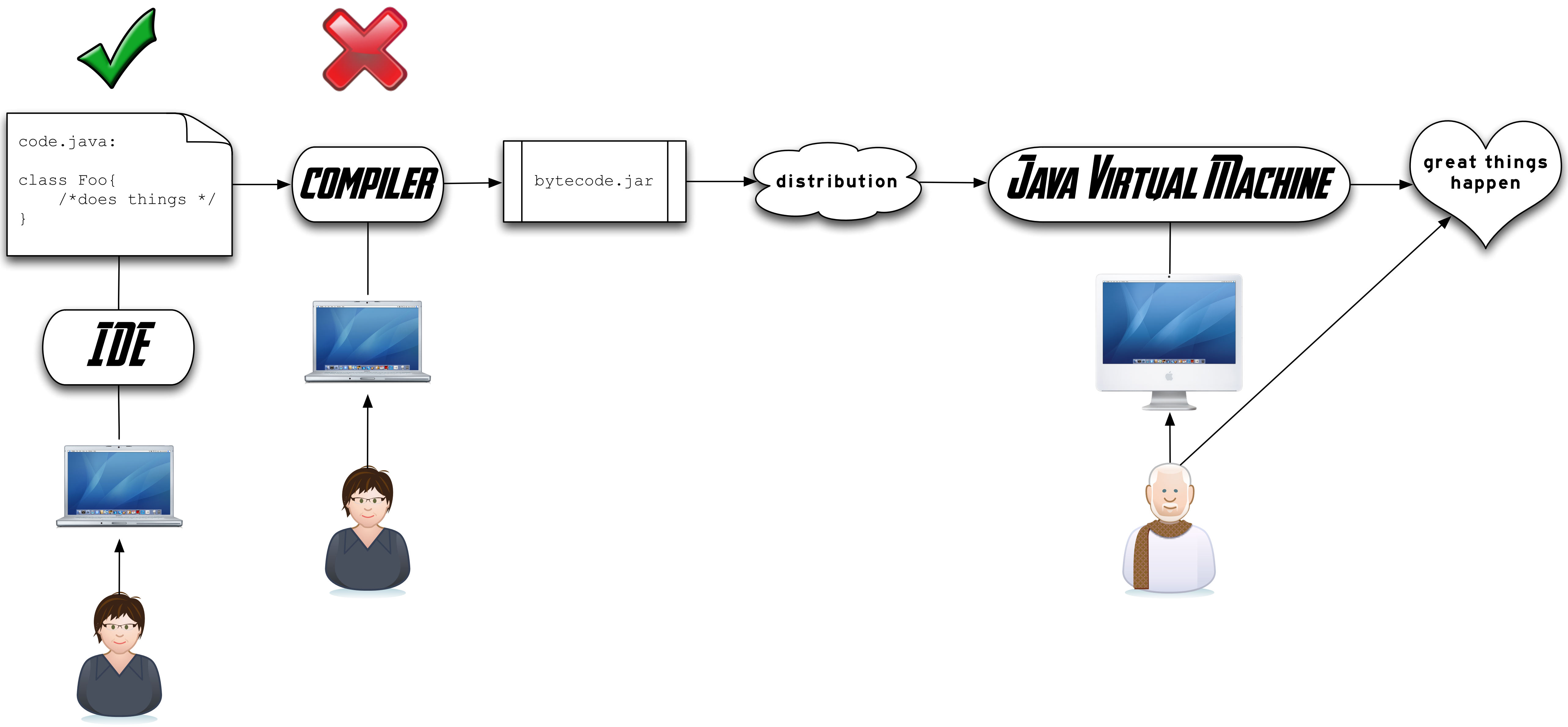
```java
public static void badCodeWithGenerics(String[] args) {
    Vector<String> longWords = new Vector<String>();
    int i;

    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```

- Questions:
  - What happened to the code on the right?

GENERICS FROM 10,000 FEET



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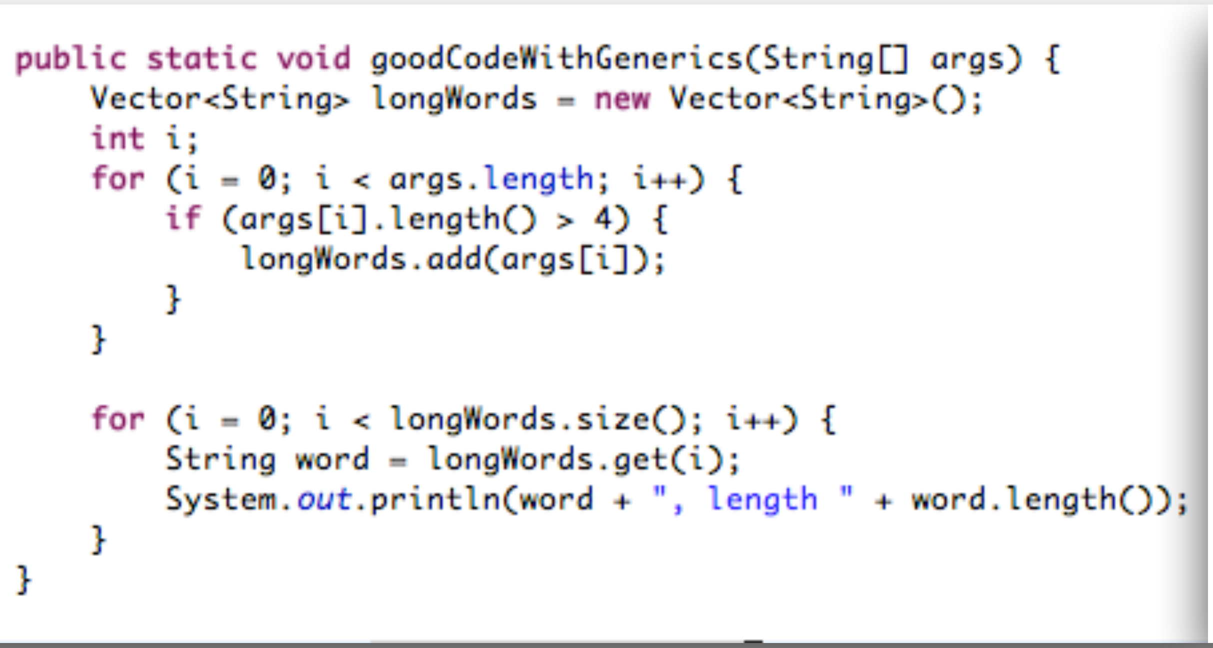
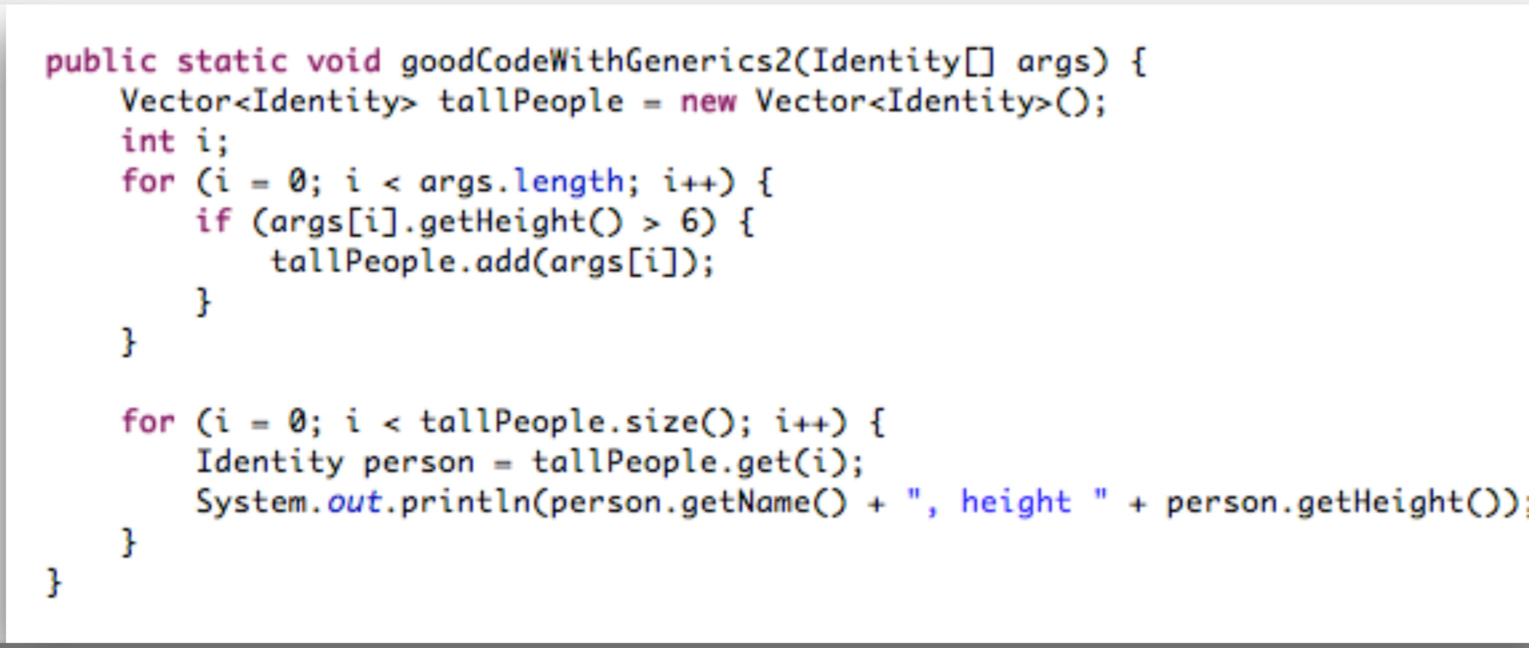


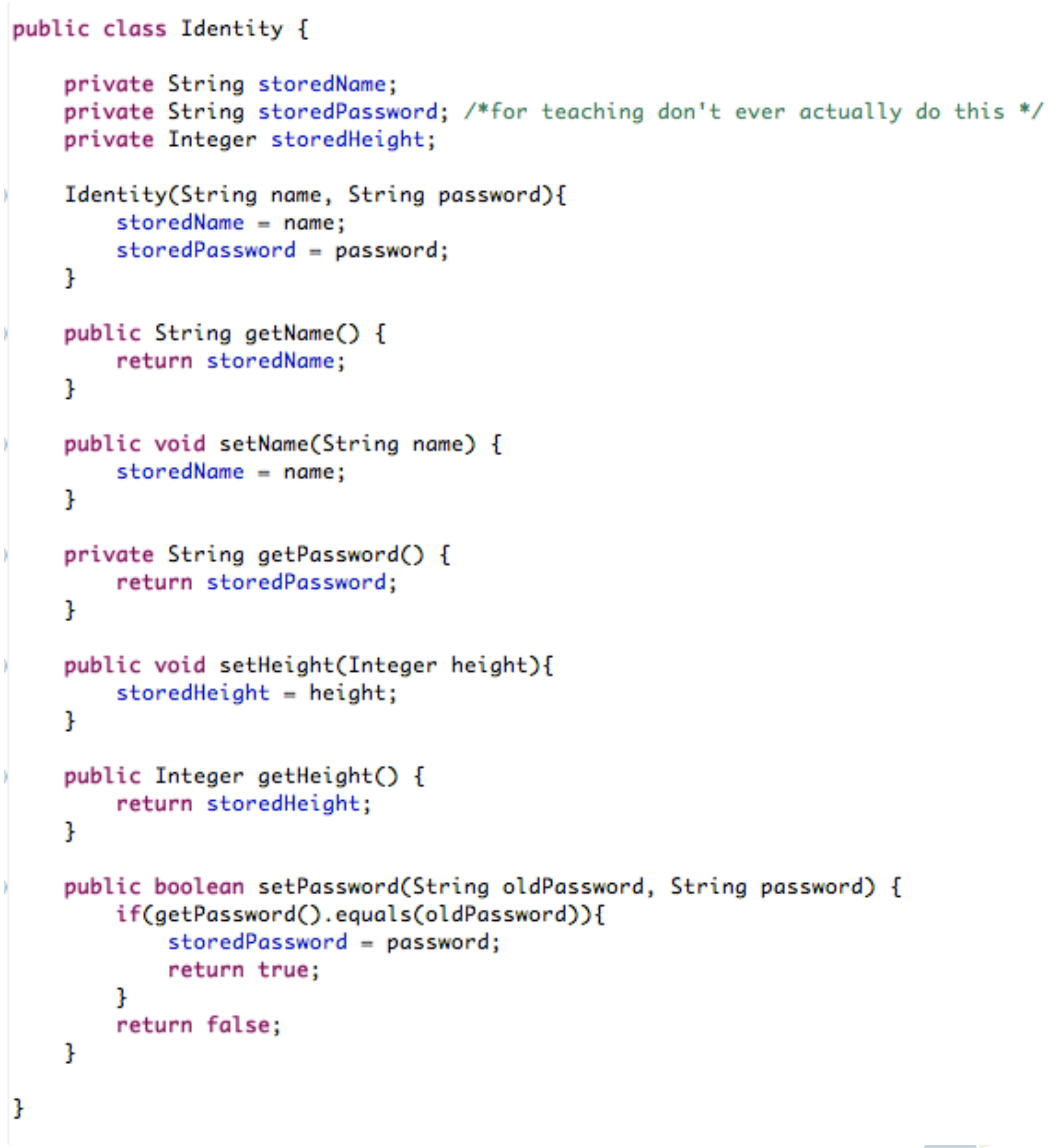
```
public static void goodCodeWithGenerics(String[] args) {
    Vector<String> longWords = new Vector<String>();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].length() > 4) {
            longWords.add(args[i]);
        }
    }

    for (i = 0; i < longWords.size(); i++) {
        String word = longWords.get(i);
        System.out.println(word + ", length " + word.length());
    }
}
```



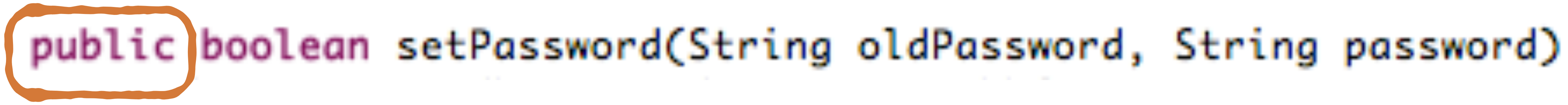
```
public static void goodCodeWithGenerics2(Identity[] args) {
    Vector<Identity> tallPeople = new Vector<Identity>();
    int i;
    for (i = 0; i < args.length; i++) {
        if (args[i].getHeight() > 6) {
            tallPeople.add(args[i]);
        }
    }

    for (i = 0; i < tallPeople.size(); i++) {
        Identity person = tallPeople.get(i);
        System.out.println(person.getName() + ", height " + person.getHeight())
    }
}
```

- Here’s what’s cool:
  - When the developer made the Vector class they had no idea that I was going to use it with Strings
  - I could have used it with some other class

http://docs.oracle.com/javase/tutorial/java/generics/why.html

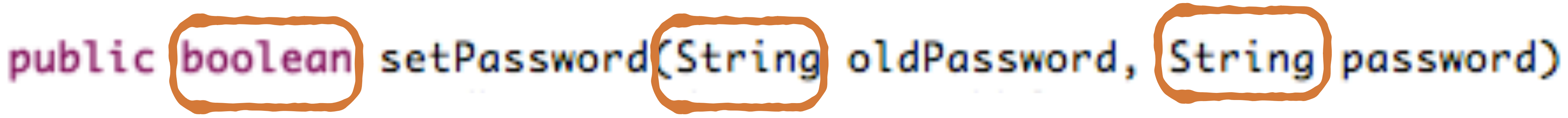


```java
public class Identity {

    private String storedName;
    private String storedPassword; /*for teaching don't ever actually do this */
    private Integer storedHeight;

    Identity(String name, String password){
        storedName = name;
        storedPassword = password;
    }

    public String getName() {
        return storedName;
    }

    public void setName(String name) {
        storedName = name;
    }

    private String getPassword() {
        return storedPassword;
    }

    public void setHeight(Integer height){
        storedHeight = height;
    }

    public Integer getHeight() {
        return storedHeight;
    }

    public boolean setPassword(String oldPassword, String password) {
        if(getPassword().equals(oldPassword)){
            storedPassword = password;
            return true;
        }
        return false;
    }

}
```



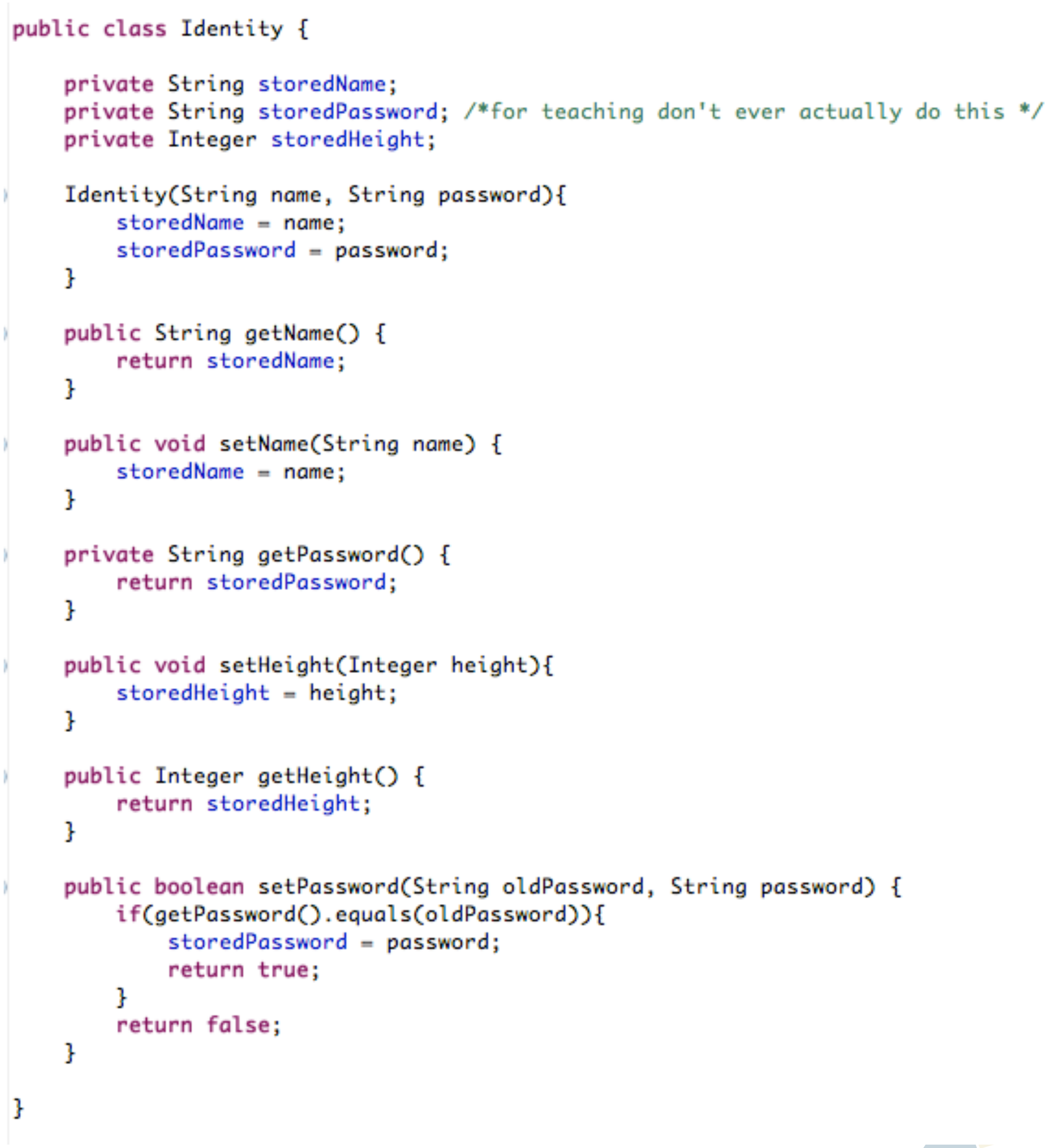
```
public boolean setPassword(String oldPassword, String password)
```

- Components of a method signature
  - visibility
  - return type
  - name
    - full name would include the class (and the package)
    - Identity.setPassword
  - parameter list
    - parameter type
    - parameter name



```
public boolean setPassword(String oldPassword, String password)
```

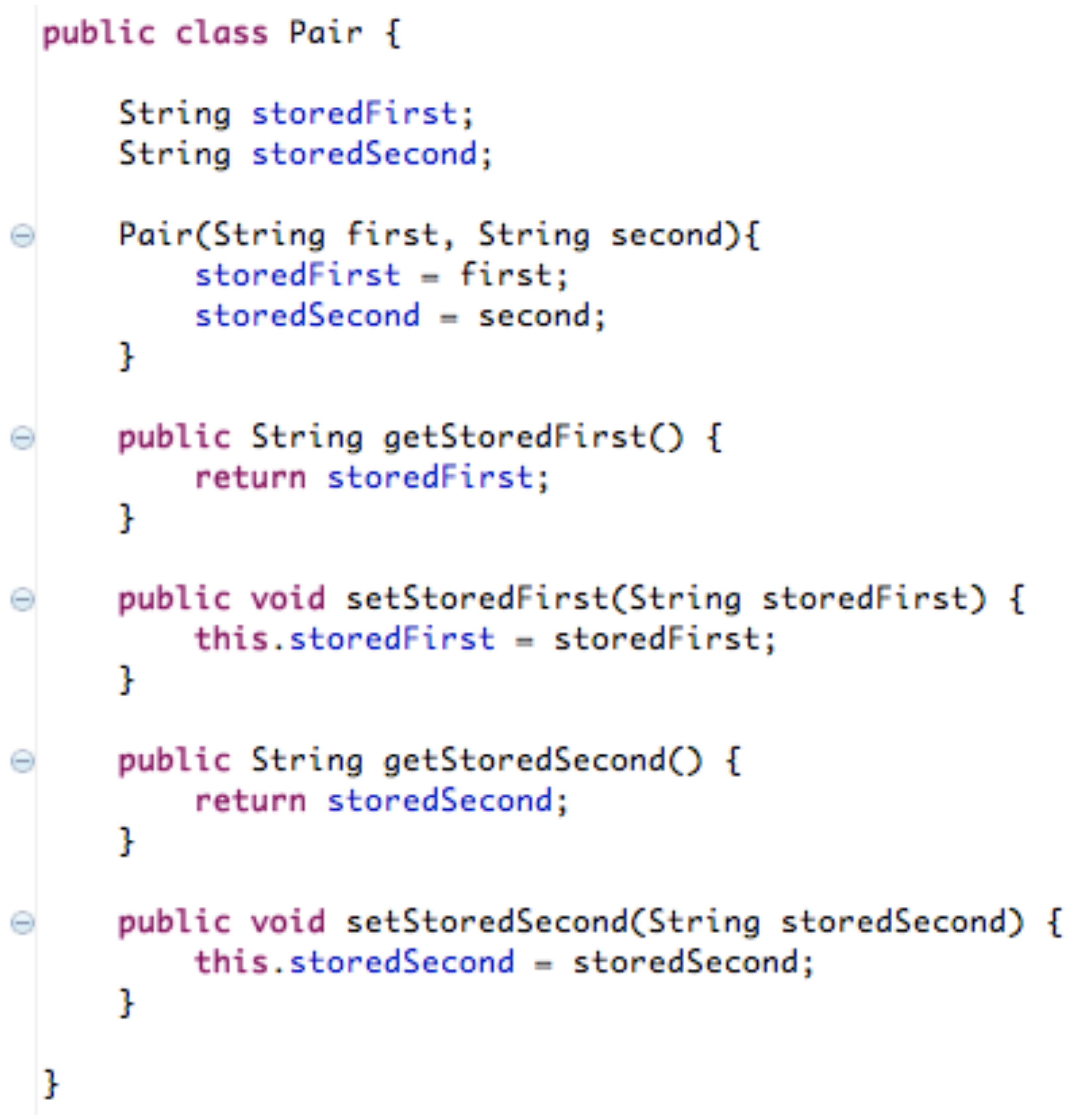
- Generics are a small language within a language for declaring types
- Let’s work through one
- We are clever hackers and we want to let people have first and last names



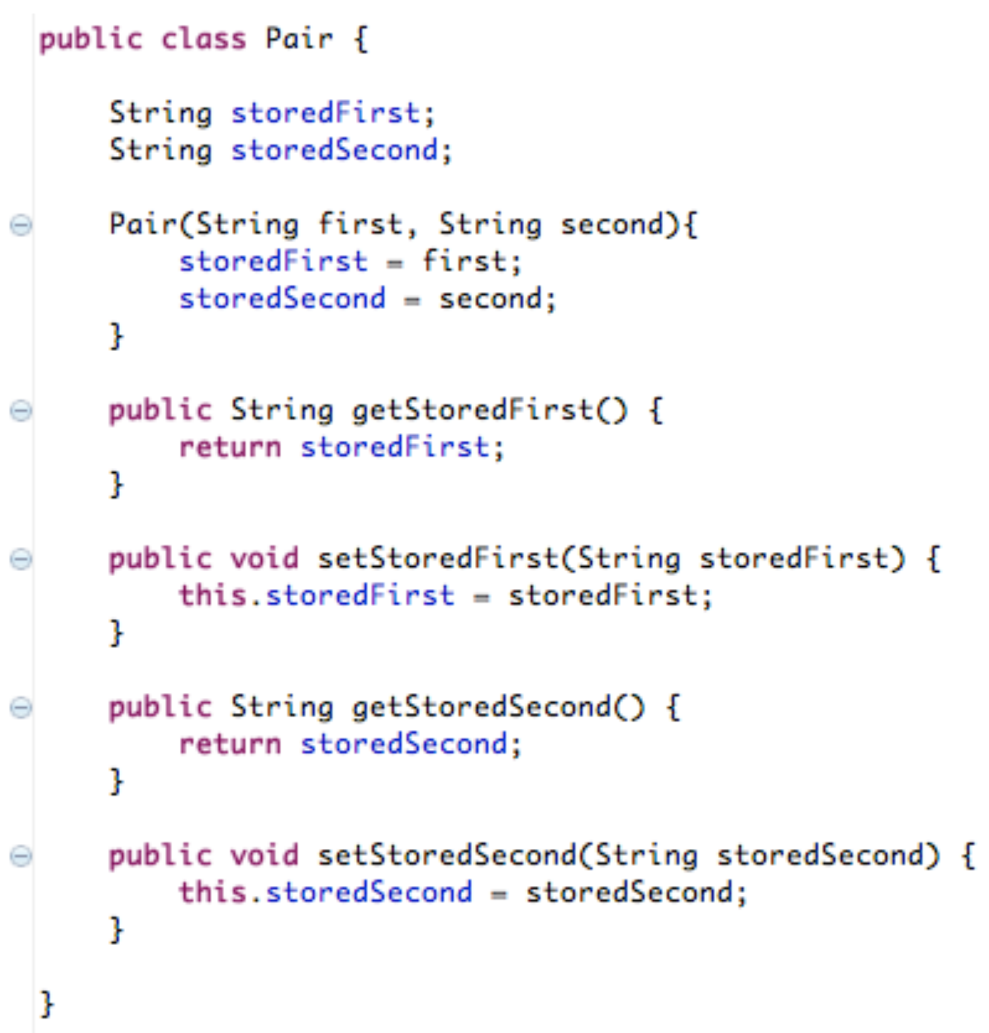
```java
public class Identity {

    private String storedName;
    private String storedPassword; /*for teaching don't ever actually do this */
    private Integer storedHeight;

    Identity(String name, String password){
        storedName = name;
        storedPassword = password;
    }

    public String getName() {
        return storedName;
    }

    public void setName(String name) {
        storedName = name;
    }

    private String getPassword() {
        return storedPassword;
    }

    public void setHeight(Integer height){
        storedHeight = height;
    }

    public Integer getHeight() {
        return storedHeight;
    }

    public boolean setPassword(String oldPassword, String password) {
        if(getPassword().equals(oldPassword)){
            storedPassword = password;
            return true;
        }
        return false;
    }

}
```

- But we also know that we can use this for more than just names

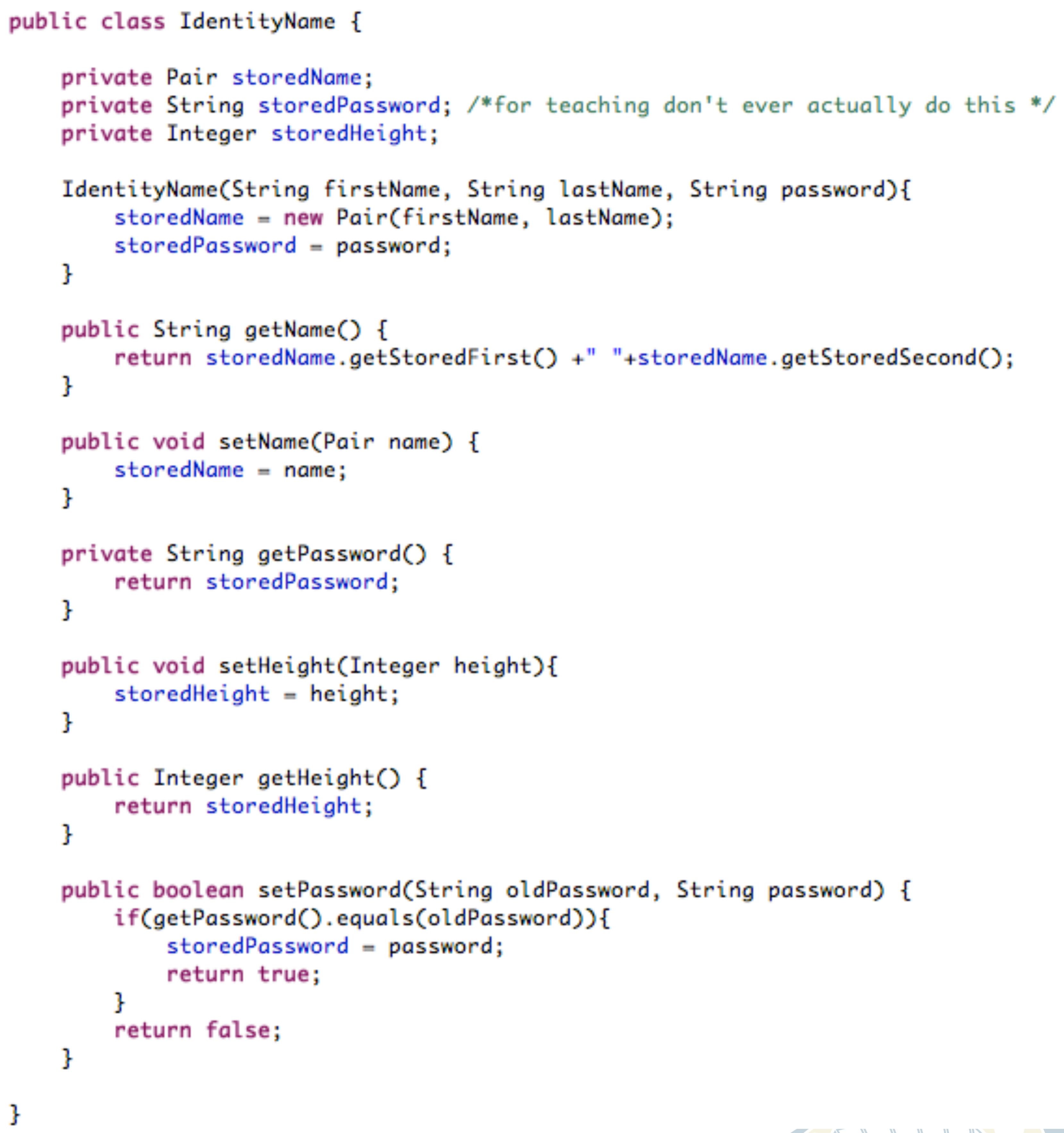
- Let’s abstract it into a general Pair



```java
public class Pair {

    String storedFirst;
    String storedSecond;

    Pair(String first, String second){
        storedFirst = first;
        storedSecond = second;
    }

    public String getStoredFirst() {
        return storedFirst;
    }

    public void setStoredFirst(String storedFirst) {
        this.storedFirst = storedFirst;
    }

    public String getStoredSecond() {
        return storedSecond;
    }

    public void setStoredSecond(String storedSecond) {
        this.storedSecond = storedSecond;
    }

}
```



```java
public class Pair {

    String storedFirst;
    String storedSecond;

    Pair(String first, String second){
        storedFirst = first;
        storedSecond = second;
    }

    public String getStoredFirst() {
        return storedFirst;
    }

    public void setStoredFirst(String storedFirst) {
        this.storedFirst = storedFirst;
    }

    public String getStoredSecond() {
        return storedSecond;
    }

    public void setStoredSecond(String storedSecond) {
        this.storedSecond = storedSecond;
    }

}
```

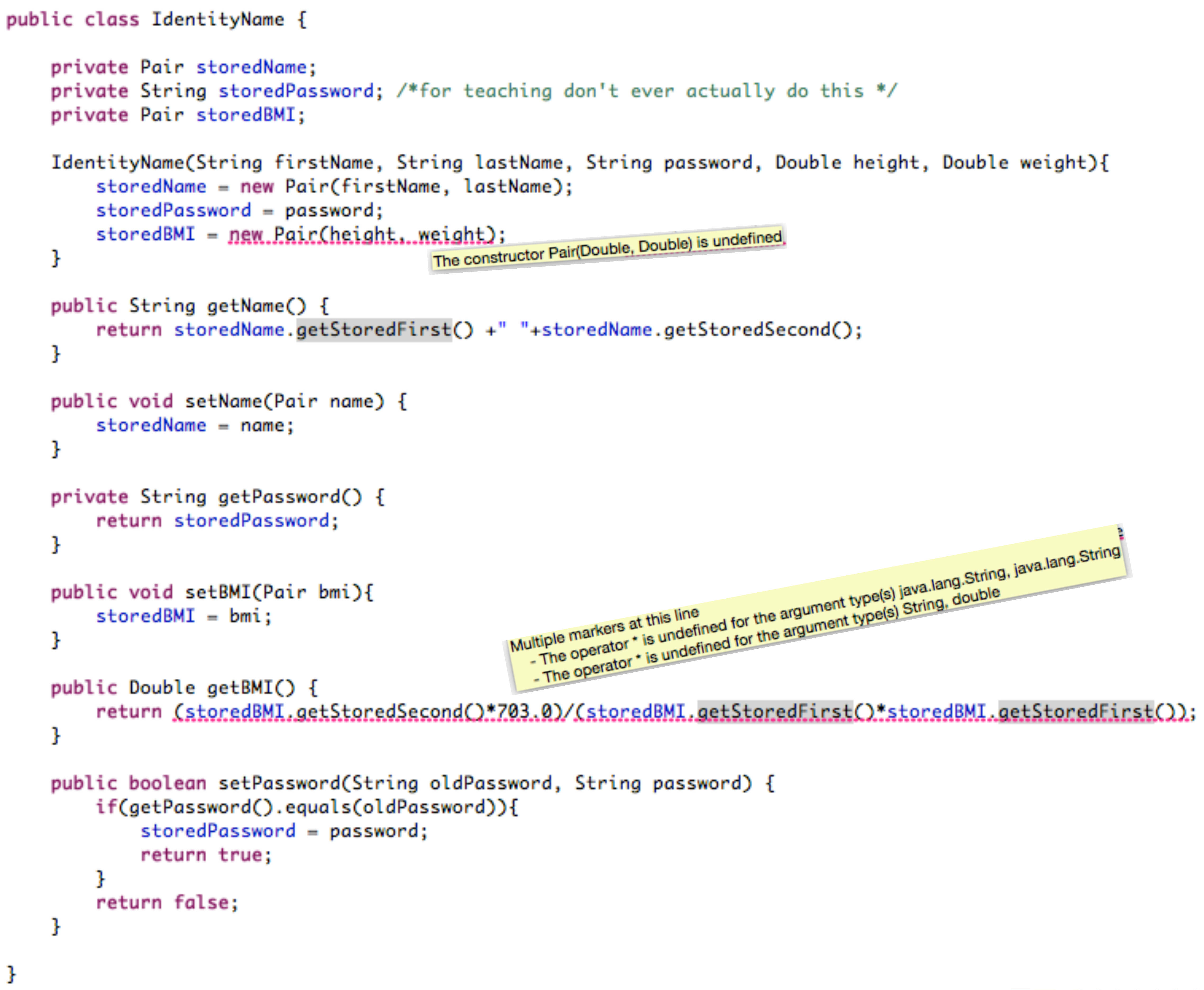


```java
public class IdentityName {

    private Pair storedName;
    private String storedPassword; /*for teaching don't ever actually do this */
    private Integer storedHeight;

    IdentityName(String firstName, String lastName, String password){
        storedName = new Pair(firstName, lastName);
        storedPassword = password;
    }

    public String getName() {
        return storedName.getStoredFirst() +" "+storedName.getStoredSecond();
    }

    public void setName(Pair name) {
        storedName = name;
    }

    private String getPassword() {
        return storedPassword;
    }

    public void setHeight(Integer height){
        storedHeight = height;
    }

    public Integer getHeight() {
        return storedHeight;
    }

    public boolean setPassword(String oldPassword, String password) {
        if(getPassword().equals(oldPassword)){
            storedPassword = password;
            return true;
        }
        return false;
    }

}
```

- Mission Accomplished!

- Word has spread far and wide and now we’ve been hired by an EMR company

- They want us to add BMI to our Identity class
  - That’s a height and weight combo
  - Hey! That sounds like another Pair!
  - We’ve already done that right?



```java
public class IdentityName {

    private Pair storedName;
    private String storedPassword; /*for teaching don't ever actually do this */
    private Pair storedBMI;

    IdentityName(String firstName, String lastName, String password, Double height, Double weight){
        storedName = new Pair(firstName, lastName);
        storedPassword = password;
        storedBMI = new Pair(height, weight);
    }

    public String getName() {
        return storedName.getStoredFirst() +" "+storedName.getStoredSecond();
    }

    public void setName(Pair name) {
        storedName = name;
    }

    private String getPassword() {
        return storedPassword;
    }

    public void setBMI(Pair bmi){
        storedBMI = bmi;
    }

    public Double getBMI() {
        return (storedBMI.getStoredSecond()*703.0)/(storedBMI.getStoredFirst()*storedBMI.getStoredFirst());
    }

    public boolean setPassword(String oldPassword, String password) {
        if(getPassword().equals(oldPassword)){
            storedPassword = password;
            return true;
        }
        return false;
    }

}
```

The constructor Pair(Double, Double) is undefined

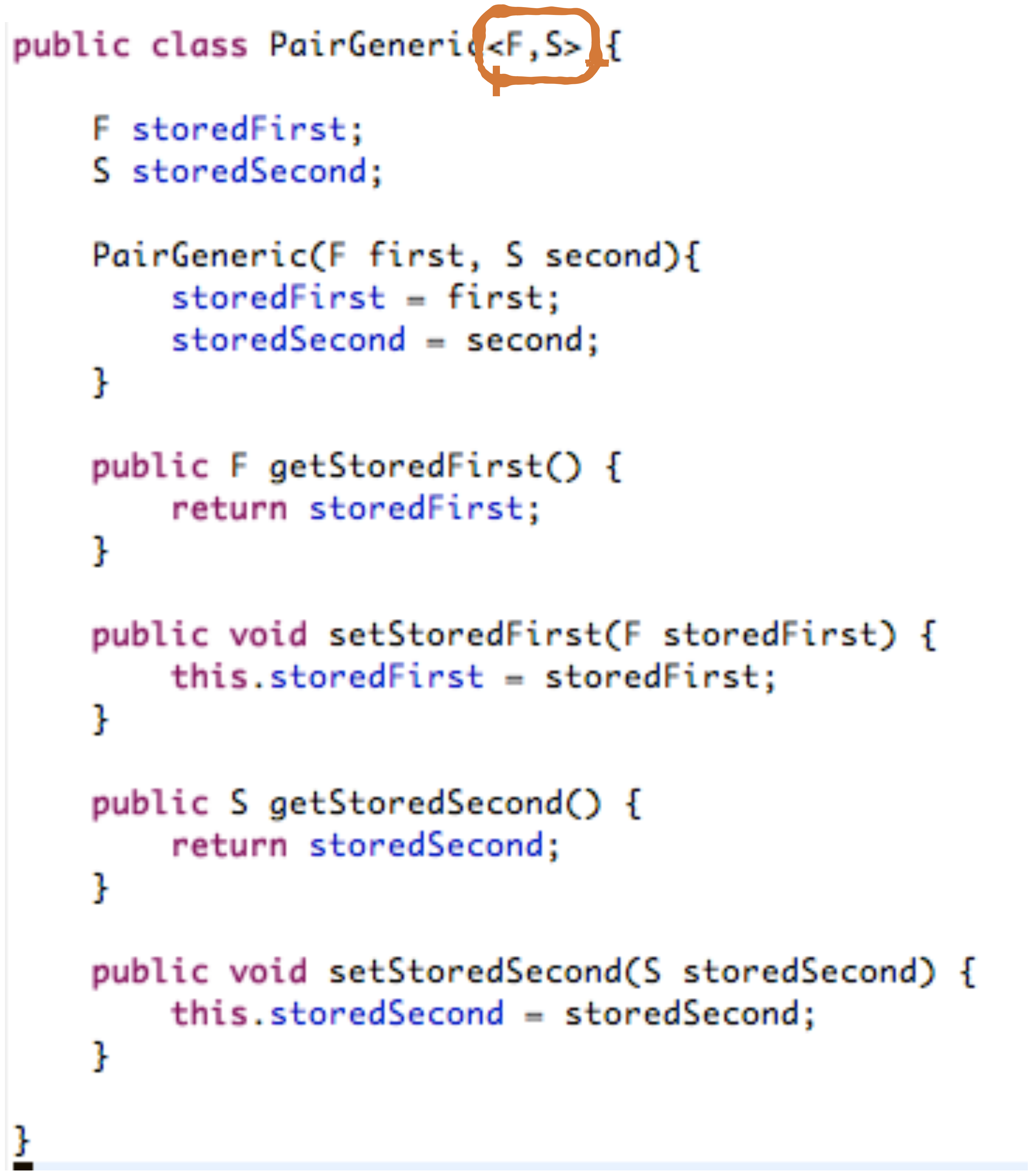
Multiple markers at this line
- The operator * is undefined for the argument type(s) java.lang.String, java.lang.String
- The operator * is undefined for the argument type(s) String, double

- Hmm…
- That’s easy enough to fix. Let’s just make another Pair class…

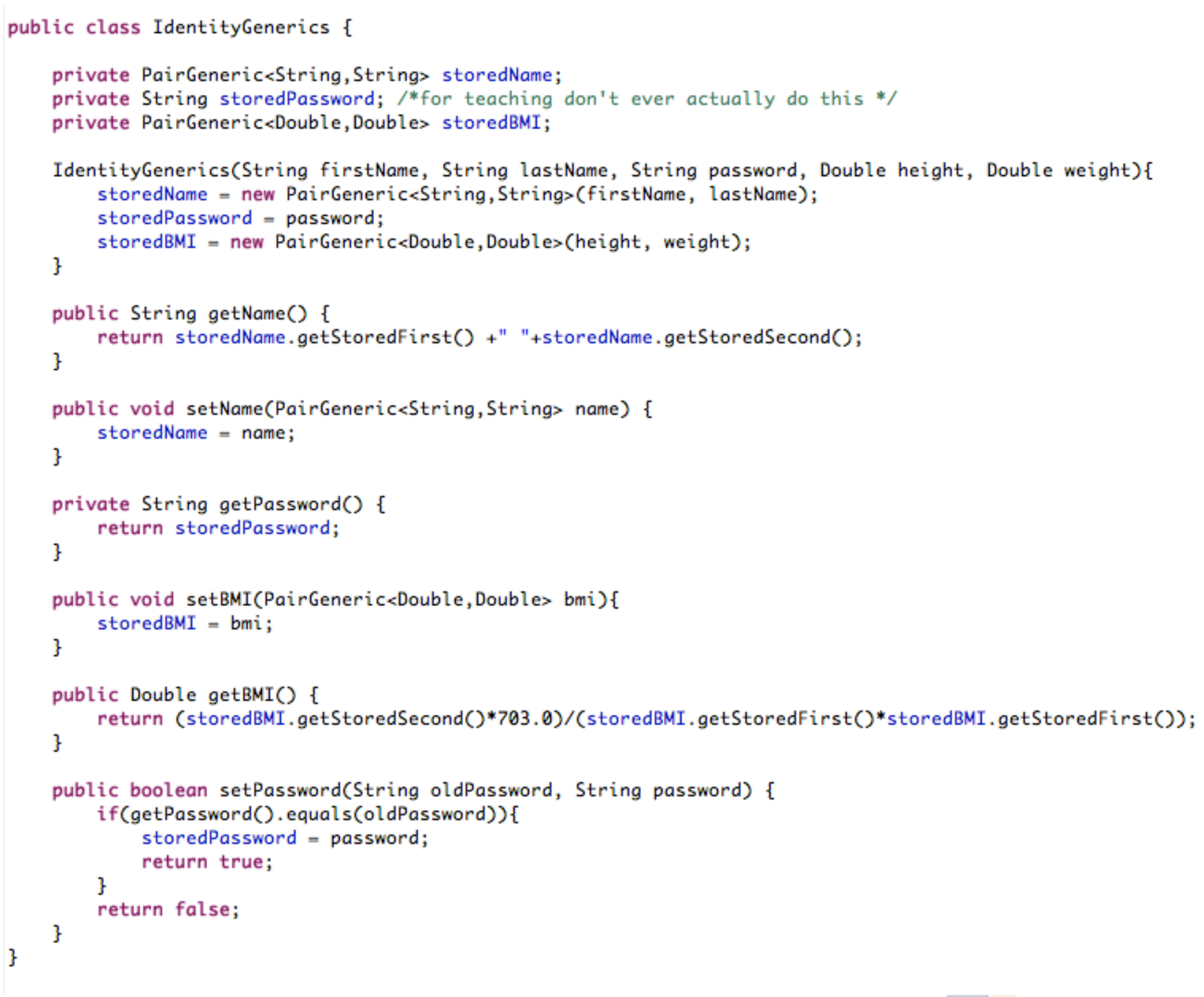
- Conceptually our Pair class is agnostic to what kind of type gets used with it
  - it doesn't really matter
  - But the Java language is tying our hands
- But we are stuck having to define a new class for every single application that needs a different type

- **Enter Generics**

- Generics let you manipulate parameters without knowing their type, but without losing static type checking in the compiler



```java
public class PairGeneric<F,S> {

    F storedFirst;
    S storedSecond;

    PairGeneric(F first, S second){
        storedFirst = first;
        storedSecond = second;
    }

    public F getStoredFirst() {
        return storedFirst;
    }

    public void setStoredFirst(F storedFirst) {
        this.storedFirst = storedFirst;
    }

    public S getStoredSecond() {
        return storedSecond;
    }

    public void setStoredSecond(S storedSecond) {
        this.storedSecond = storedSecond;
    }

}
```



```java
public class IdentityGenerics {

    private PairGeneric<String,String> storedName;
    private String storedPassword; /*for teaching don't ever actually do this */
    private PairGeneric<Double,Double> storedBMI;

    IdentityGenerics(String firstName, String lastName, String password, Double height, Double weight){
        storedName = new PairGeneric<String,String>(firstName, lastName);
        storedPassword = password;
        storedBMI = new PairGeneric<Double,Double>(height, weight);
    }

    public String getName() {
        return storedName.getStoredFirst() +" "+storedName.getStoredSecond();
    }

    public void setName(PairGeneric<String,String> name) {
        storedName = name;
    }

    private String getPassword() {
        return storedPassword;
    }

    public void setBMI(PairGeneric<Double,Double> bmi){
        storedBMI = bmi;
    }

    public Double getBMI() {
        return (storedBMI.getStoredSecond()*703.0)/(storedBMI.getStoredFirst()*storedBMI.getStoredFirst());
    }

    public boolean setPassword(String oldPassword, String password) {
        if(getPassword().equals(oldPassword)){
            storedPassword = password;
            return true;
        }
        return false;
    }
}
```

- Now, mission accomplished
- That’s 80% of everything to know about Generics
- It’s basically that easy, but there are some details that you need to know
- The final 20%….

Generics and primitive types don't play well together

- You can't plug in a primitive type to a Generic

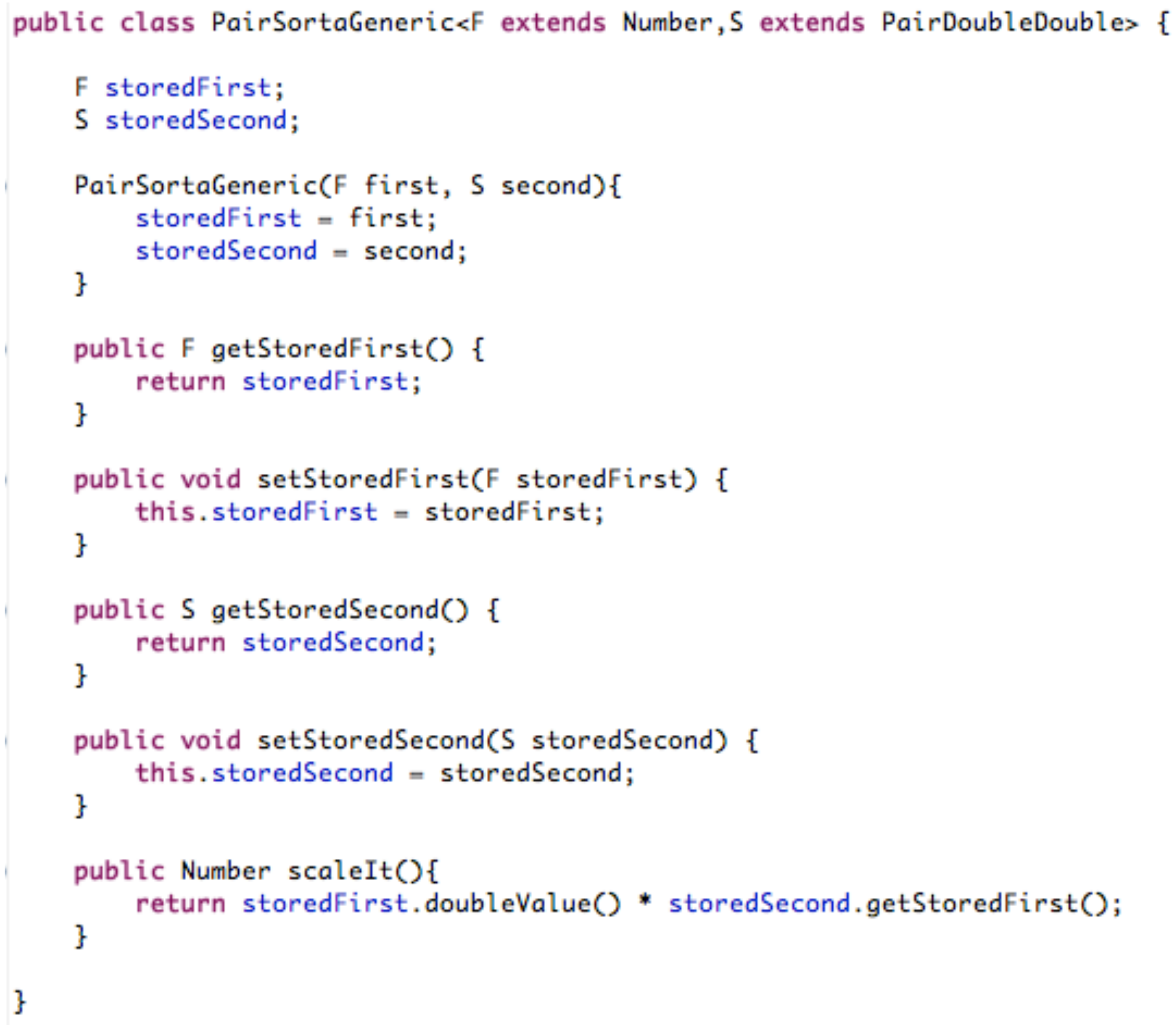
```
int foo = 1;
int bar = 2;
new PairGeneric<int,int>(foo,bar);
```

- You can't use a Generic in an Array (it's primitive)

```
Pair[] foo = new Pair[100];
PairGeneric<Double,Double>[] bar = new PairGeneric<Double,Double>[100];
```

Sometimes you care just a little bit about the type

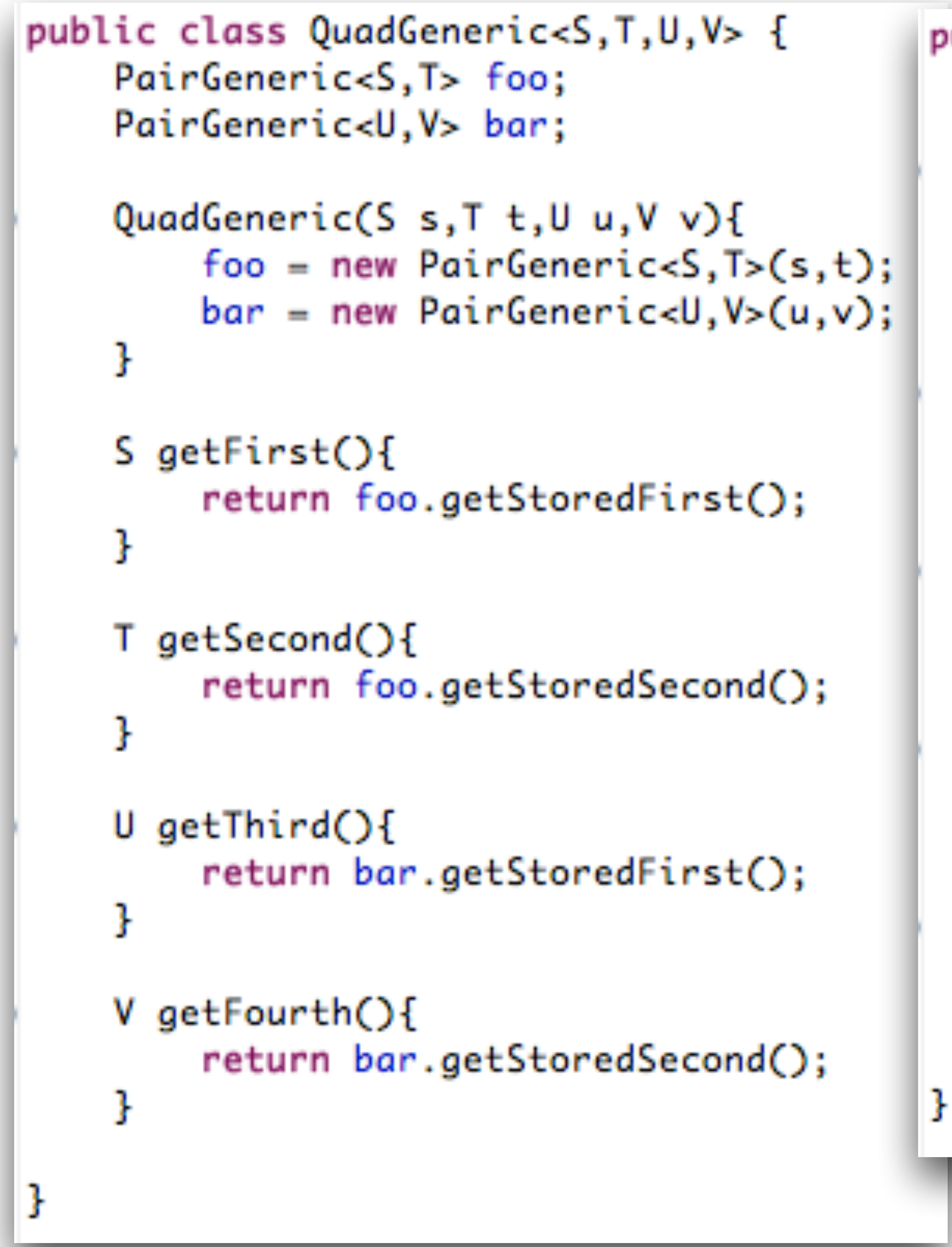
- When writing a Generic you actually have a little more control over how a developer uses it



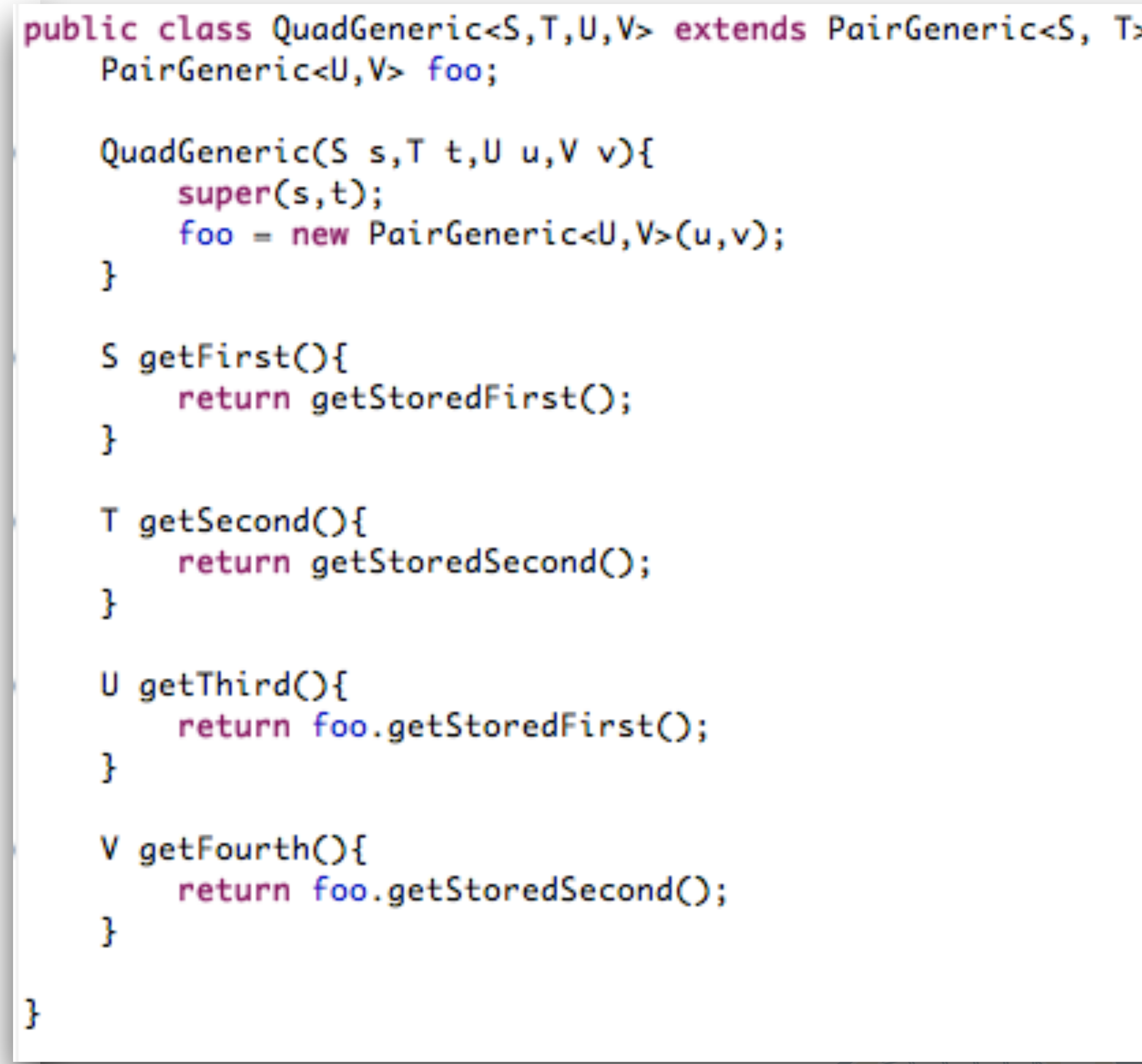
```
public class PairSortaGeneric<F extends Number,S extends PairDoubleDouble> {

    F storedFirst;
    S storedSecond;

    PairSortaGeneric(F first, S second){
        storedFirst = first;
        storedSecond = second;
    }

    public F getStoredFirst() {
        return storedFirst;
    }

    public void setStoredFirst(F storedFirst) {
        this.storedFirst = storedFirst;
    }

    public S getStoredSecond() {
        return storedSecond;
    }

    public void setStoredSecond(S storedSecond) {
        this.storedSecond = storedSecond;
    }

    public Number scaleIt(){
        return storedFirst.doubleValue() * storedSecond.getStoredFirst();
    }

}
```

Generics can be extended

- How could you make a Quad?



```
public class QuadGeneric<S,T,U,V> {
    PairGeneric<S,T> foo;
    PairGeneric<U,V> bar;

    QuadGeneric(S s,T t,U u,V v){
        foo = new PairGeneric<S,T>(s,t);
        bar = new PairGeneric<U,V>(u,v);
    }

    S getFirst(){
        return foo.getStoredFirst();
    }

    T getSecond(){
        return foo.getStoredSecond();
    }

    U getThird(){
        return bar.getStoredFirst();
    }

    V getFourth(){
        return bar.getStoredSecond();
    }

}
```



```
public class QuadGeneric<S,T,U,V> extends PairGeneric<S, T>
    PairGeneric<U,V> foo;

    QuadGeneric(S s,T t,U u,V v){
        super(s,t);
        foo = new PairGeneric<U,V>(u,v);
    }

    S getFirst(){
        return getStoredFirst();
    }

    T getSecond(){
        return getStoredSecond();
    }

    U getThird(){
        return foo.getStoredFirst();
    }

    V getFourth(){
        return foo.getStoredSecond();
    }

}
```

Generic Types are Atomic

```
Object someObject = new Object();
Integer someInteger = new Integer(10);
someObject = someInteger;   // OK
```

```
public void someMethod(Number n) { /* ... */ }

someMethod(new Integer(10));   // OK
someMethod(new Double(10.1));   // OK
```

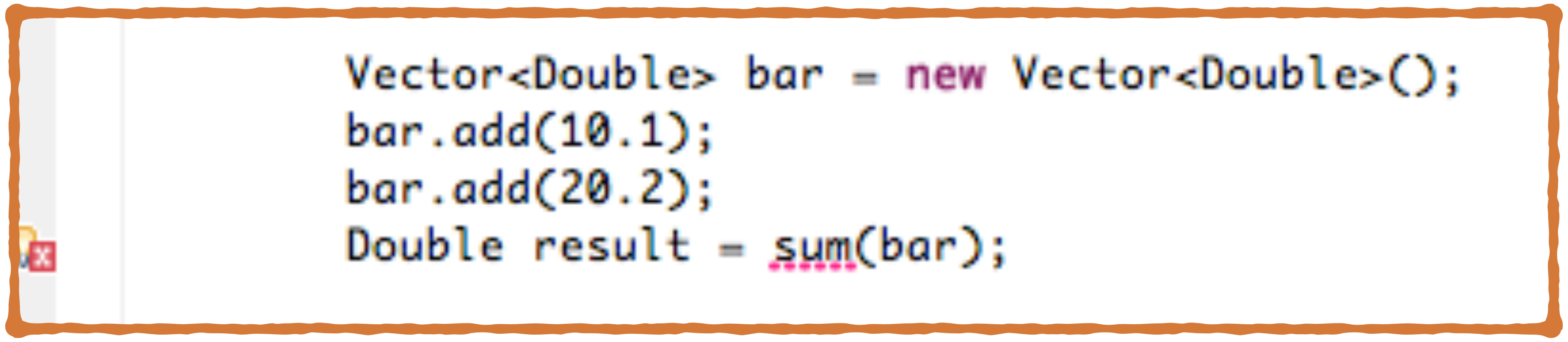
```
Integer foo = new Integer(10);
Double bar = new Double(10.1);
PairGeneric<Number,Number> p= new PairGeneric<Number,Number>(foo,bar);
```

- You cannot inherit just a portion of a type

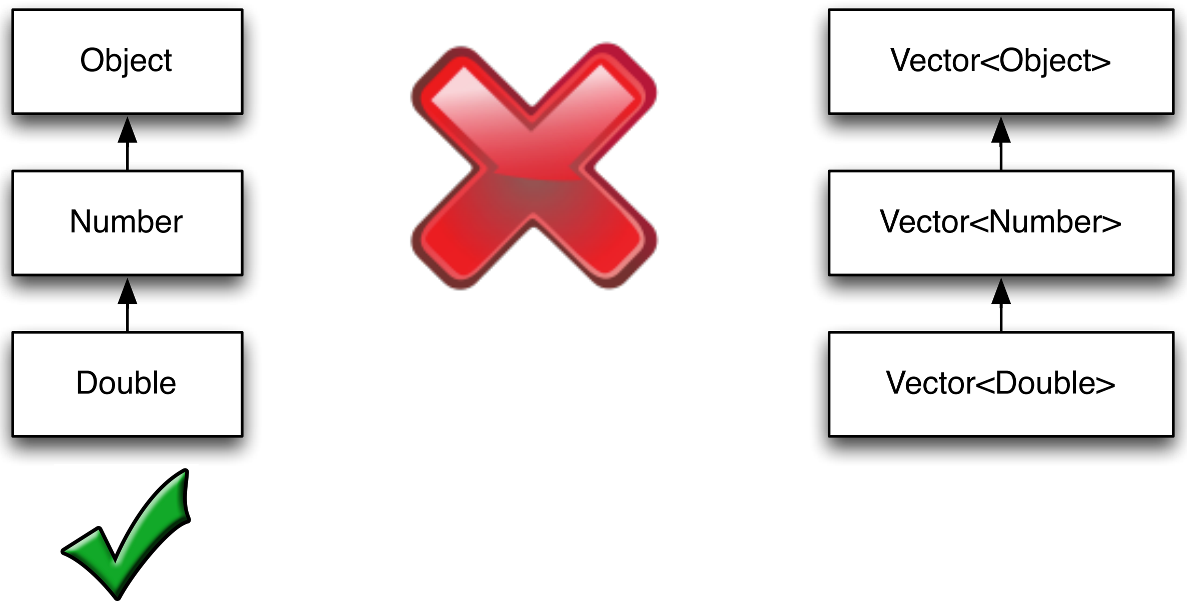
Generic Types are Atomic

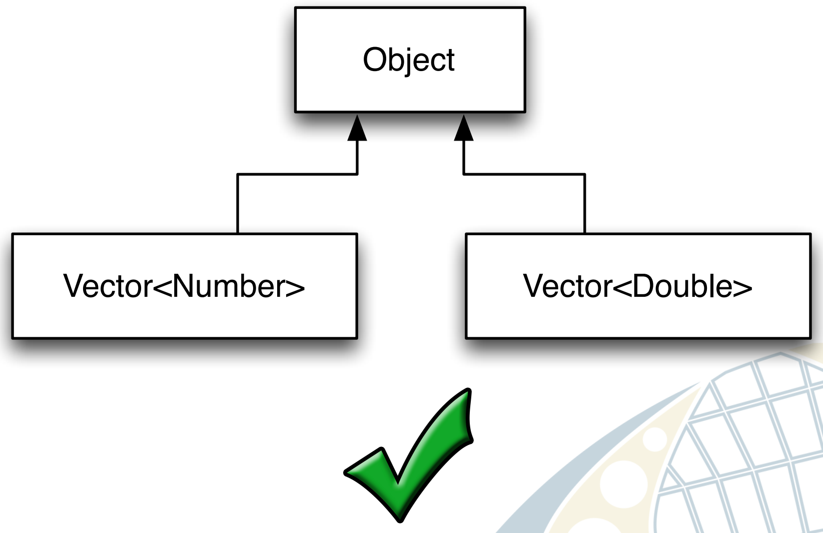
- You cannot inherit just a portion of a type

```
public Double sum(Vector<Number> v) {
   double running = 0.0;
   for(int i = 0 ; i < v.size(); i++){
      running += v.get(i).doubleValue();
   }
   return running;
}
```



```
Vector<Double> bar = new Vector<Double>();
bar.add(10.1);
bar.add(20.2);
Double result = sum(bar);
```





http://docs.oracle.com/javase/tutorial/java/generics/inheritance.html

Work it out

- Will the following code compile?

```
public class Algorithm{
    public T max(T x, T y) {
        return x > y ? x : y;
    }
}
```

Generics from 10,000 feet

- Generics enable types (classes and interfaces) to be parameterized.
- The input to Generics are types
- The output of Generics are new types
- They are like parameters in methods
  - but they are about types, not data, not values
  - they are meta-data
- They let you re-use the same code with different inputs.

http://docs.oracle.com/javase/tutorial/java/generics/why.html

Generics from 10,000 feet

- Benefits:
  - Write less code (code re-use)
  - Enabling programmers to implement generic algorithms.

  - Stronger type checks at compile time.
  - More errors are found at compile-time through static checking

http://docs.oracle.com/javase/tutorial/java/generics/why.html

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