Composition (Part 2)

Class Invariants

- class invariant
  - some property of the state of the object that is established by a constructor and maintained between calls to public methods
  - in other words:
    - the constructor ensures that the class invariant holds when the constructor is finished running
      - the invariant does not necessarily hold while the constructor is running
    - every public method ensures that the class invariant holds when the method is finished running
      - the invariant does not necessarily hold while the method is running

Period Class

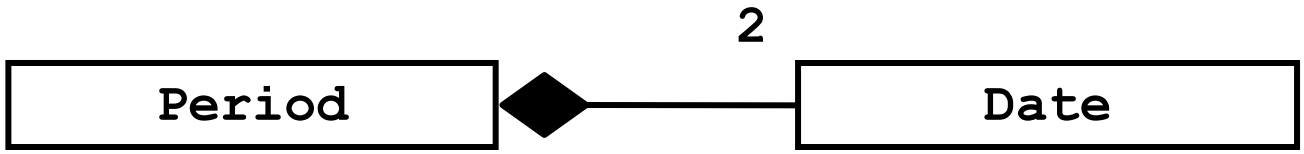
- adapted from Effective Java by Joshua Bloch
  - available online at http://www.informit.com/articles/article.aspx?p=31551&seqNum=2

- we want to implement a class that represents a period of time
  - a period has a start time and an end time
    - end time is always after the start time (this is the class invariant)

Period Class

- we want to implement a class that represents a period of time
  - has-a **`Date`** representing the start of the time period
  - has-a **`Date`** representing the end of the time period
  - class invariant: start of time period is always prior to the end of the time period

Period Class



`Period` is a composition of two `Date` objects

```
public final class Period {
  private Date start;
  private Date end;

  /**
   * @param start beginning of the period.
   * @param end end of the period; must not precede start.
   * @throws IllegalArgumentException if start is after end.
   * @throws NullPointerException if start or end is null
   */
  public Period(Date start, Date end) {
    if (start.compareTo(end) > 0) {
      throw new IllegalArgumentException("start after end");
    }
    this.start = start;
    this.end = end;
  }
```

Test Your Knowledge

1. Is **`Date`** mutable or immutable?
2. Is Period implementing aggregation or composition?
3. Add 1 more line of client code to the following that shows how the client can break the class invariant:

```
Date start = new Date();
Date end = new Date( start.getTime() + 10000 );
Period p = new Period( start, end );
```

4. Fix the constructor.

```
/**
   * @return the start Date of the period
   */
  public Date getStart()
  {
    return this.start;
  }


 /**
   * @return the end Date of the period
   */
  public Date getEnd()
  {
    return this.end;
  }
```

Test Your Knowledge

1. Add 1 more line of client code to the following that shows how the client can break the class invariant using either of the **`start`** or **`end`** methods

```
Date start = new Date();
Date end = new Date( start.getTime() + 10000 );
Period p = new Period( start, end );
```

```
/**
 * Creates a time period by copying another time period.
 * @param other the time period to copy
 */
public Period( Period other )
{
  this.start = other.start;
  this.end = other.end;
}
```

Test Your Knowledge

1. What does the following program print?

```
Date start = new Date();
Date end = new Date( start.getTime() + 10000 );
Period p1 = new Period( start, end );
Period p2 = new Period( p1 );
System.out.println( p1.getStart() == p2.getStart() );
System.out.println( p1.getEnd() == p2.getEnd() );
```

2. Fix the copy constructor.

Date does not provide a copy constructor. To copy a **Date** object **d**:

```
Date d = new Date();
Date dCopy = new Date( d.getTime() );
```

```
/**
 * Sets the start time of the period.
 * @param newStart the new starting time of the period
 * @return true if the new starting time is earlier than
 *         the current end time; false otherwise
 */
public boolean setStart(Date newStart)
{
  boolean ok = false;
  if ( newStart.compareTo(this.end) < 0 )
  {
    this.start = newStart;
    ok = true;
  }
  return ok;
}
```

Test Your Knowledge

1. Add 1 more line of client code to the following that shows how the client can break the class invariant

```
Date start = new Date();
Date end = new Date( start.getTime() + 10000 );
Period p = new Period( start, end );
p.setStart( start );
```

2. Fix the accessors and **`setStart`**.

Privacy Leaks

- a privacy leak occurs when a class exposes a reference to a non-public field (that is not a primitive or immutable)
  - given a class **`X`** that is a composition of a **`Y`**

```
public class X {
  private Y y;
  // …
}
```

these are all examples of privacy leaks

```
public X(Y y) {
  this.y = y;
}
```

```
public X(X other) {
  this.y = other.y;
}
```

```
public Y getY() {
  return this.y;
}
```

```
public void setY(Y y) {
  this.y = y;
}
```

Consequences of Privacy Leaks

- a privacy leak allows some other object to control the state of the object that leaked the field
  - the object state can become inconsistent
    - example: if a **`CreditCard`** exposes a reference to its expiry **`Date`** then a client could set the expiry date to before the issue date

Consequences of Privacy Leaks

- a privacy leak allows some other object to control the state of the object that leaked the field
  - it becomes impossible to guarantee class invariants
    - example: if a **`Period`** exposes a reference to one of its **`Date`** objects then the end of the period could be set to before the start of the period

Consequences of Privacy Leaks

- a privacy leak allows some other object to control the state of the object that leaked the field
  - composition becomes broken because the object no longer owns its attribute
    - when an object "dies" its parts may not die with it

Recipe for Immutability

- the recipe for immutability in Java is described by Joshua Bloch in the book *Effective Java**

1. Do not provide any methods that can alter the state of the object
2. Prevent the class from being extended
3. Make all fields **`final`**
4. Make all fields **`private`**
5. Prevent clients from obtaining a reference to any mutable fields

revisit when we talk about inheritance

revisit when we talk about composition

*highly recommended reading if you plan on becoming a Java programmer

Immutability and Composition

- why is Item 5 of the Recipe for Immutability needed?

Collections as Attributes

Still Aggregation and Composition

Motivation

- often you will want to implement a class that has-a collection as an attribute
  - a university has-a collection of faculties and each faculty has-a collection of schools and departments
  - a molecule has-a collection of atoms
  - a person has-a collection of acquaintances
  - from the notes, a student has-a collection of GPAs and has-a collection of courses
  - a polygonal model has-a collection of triangles*

*polygons, actually, but triangles are easier to work with

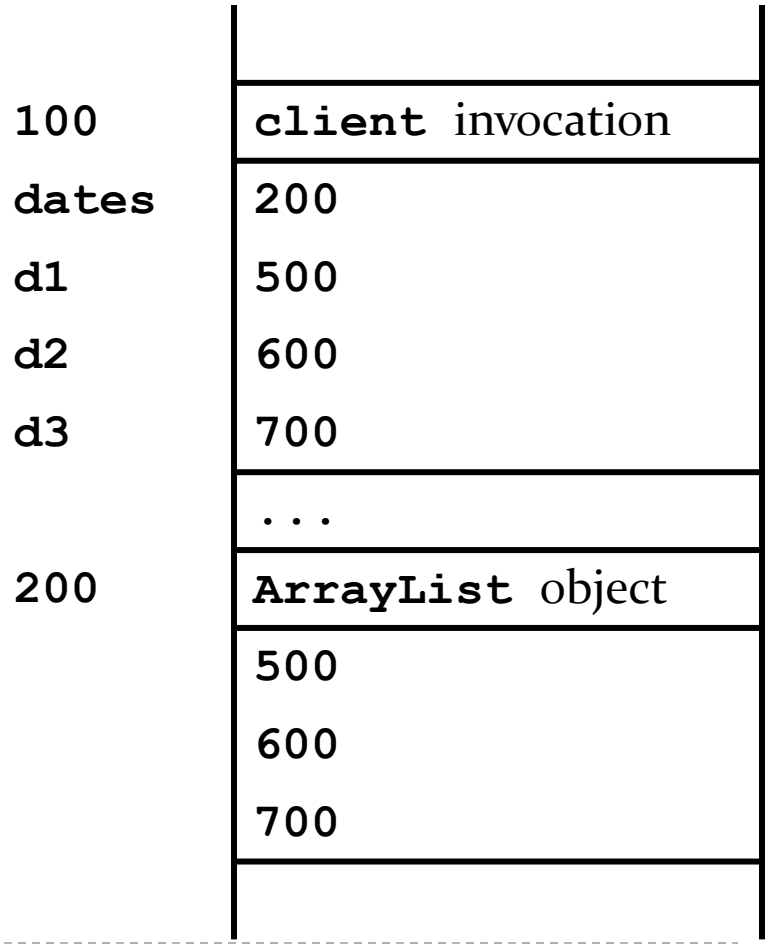
What Does a Collection Hold?

- a collection holds references to instances
  - it does not hold the instances

```
ArrayList<Date> dates =
        new ArrayList<Date>();

Date d1 = new Date();
Date d2 = new Date();
Date d3 = new Date();

dates.add(d1);
dates.add(d2);
dates.add(d3);
```



Test Your Knowledge

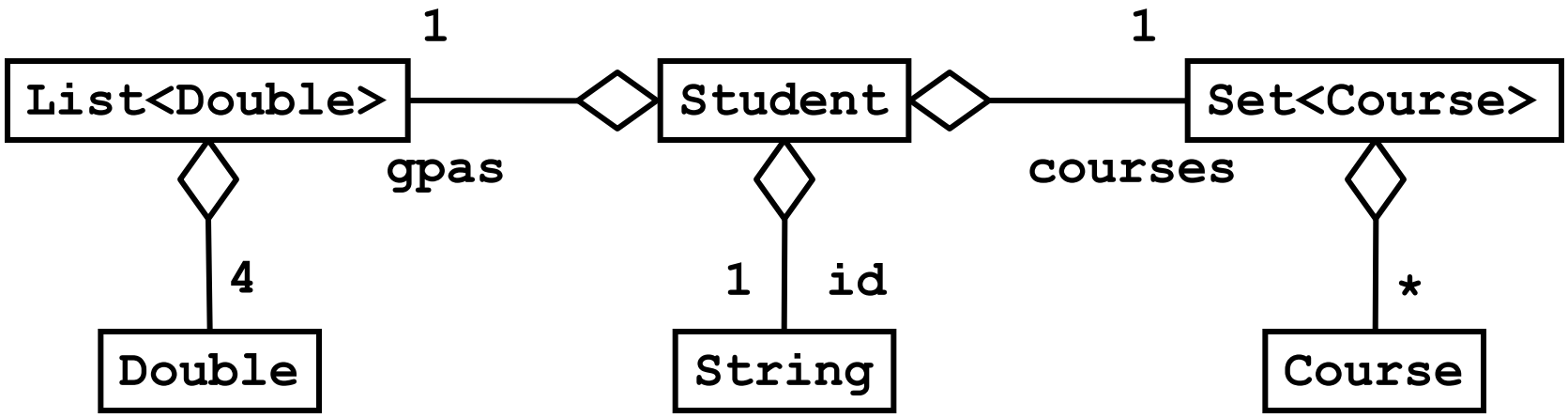
1. What does the following print?

```
ArrayList<Point> pts = new ArrayList<Point>();
Point p = new Point(0., 0., 0.);
pts.add(p);
p.setX( 10.0 );
System.out.println(p);
System.out.println(pts.get(0));
```

2. Is an **`ArrayList<X>`** an aggregation of **`X`** or a composition of **`X`**?

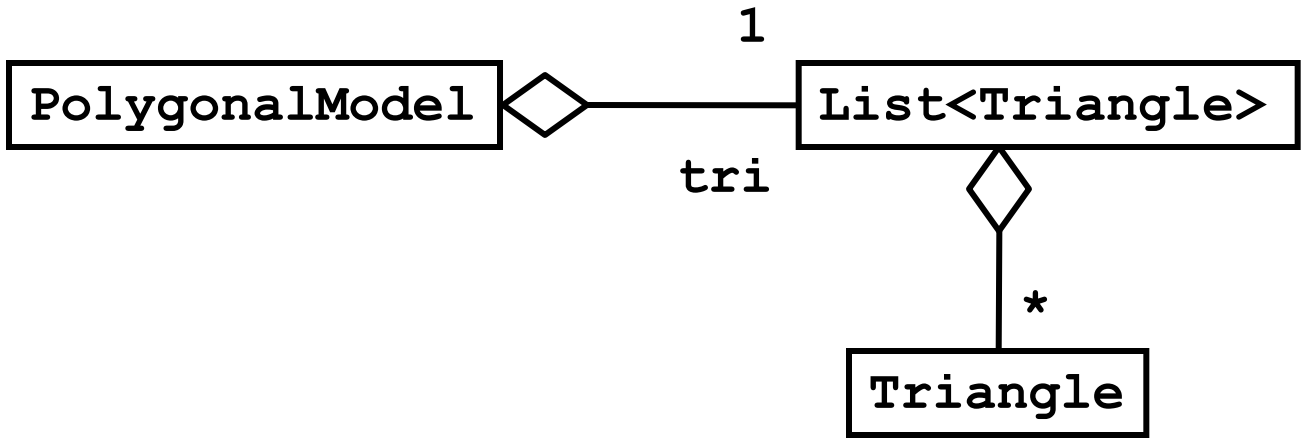
Student Class (from notes)

- a Student has-a string id
- a Student has-a collection of yearly GPAs
- a Student has-a collection of courses



PolygonalModel Class

- a polygonal model has-a **`List`** of **`Triangle`**s
  - aggregation
- implements **`Iterable<Triangle>`**
  - allows clients to access each **`Triangle`** sequentially
- class invariant
  - **`List`** never null



Iterable Interface

- implementing this interface allows an object to be the target of the "foreach" statement
- must provide the following method

`Iterator<T> iterator()`
Returns an iterator over a set of elements of type T.

PolygonalModel

```
class PolygonalModel implements Iterable<Triangle>
{
  private List<Triangle> tri;

  public PolygonalModel()
  {
    this.tri = new ArrayList<Triangle>();
  }

  public Iterator<Triangle> iterator()
  {
    return this.tri.iterator();
  }
```

PolygonalModel

```
public void clear()
{
  // removes all Triangles
  this.tri.clear();
}

public int size()
{
  // returns the number of Triangles
  return this.tri.size();
}
```

Collections as Attributes

- when using a collection as an attribute of a class **`X`** you need to decide on ownership issues
  - does **`X`** own or share its collection?
  - if **`X`** owns the collection, does **`X`** own the objects held in the collection?

`X` Shares its Collection with other `X`s

- if `X` shares its collection with other `X` instances, then the copy constructor does not need to create a new collection
  - the copy constructor can simply assign its collection
  - [notes 5.3.3] refer to this as aliasing

PolygonalModel Copy Constructor 1

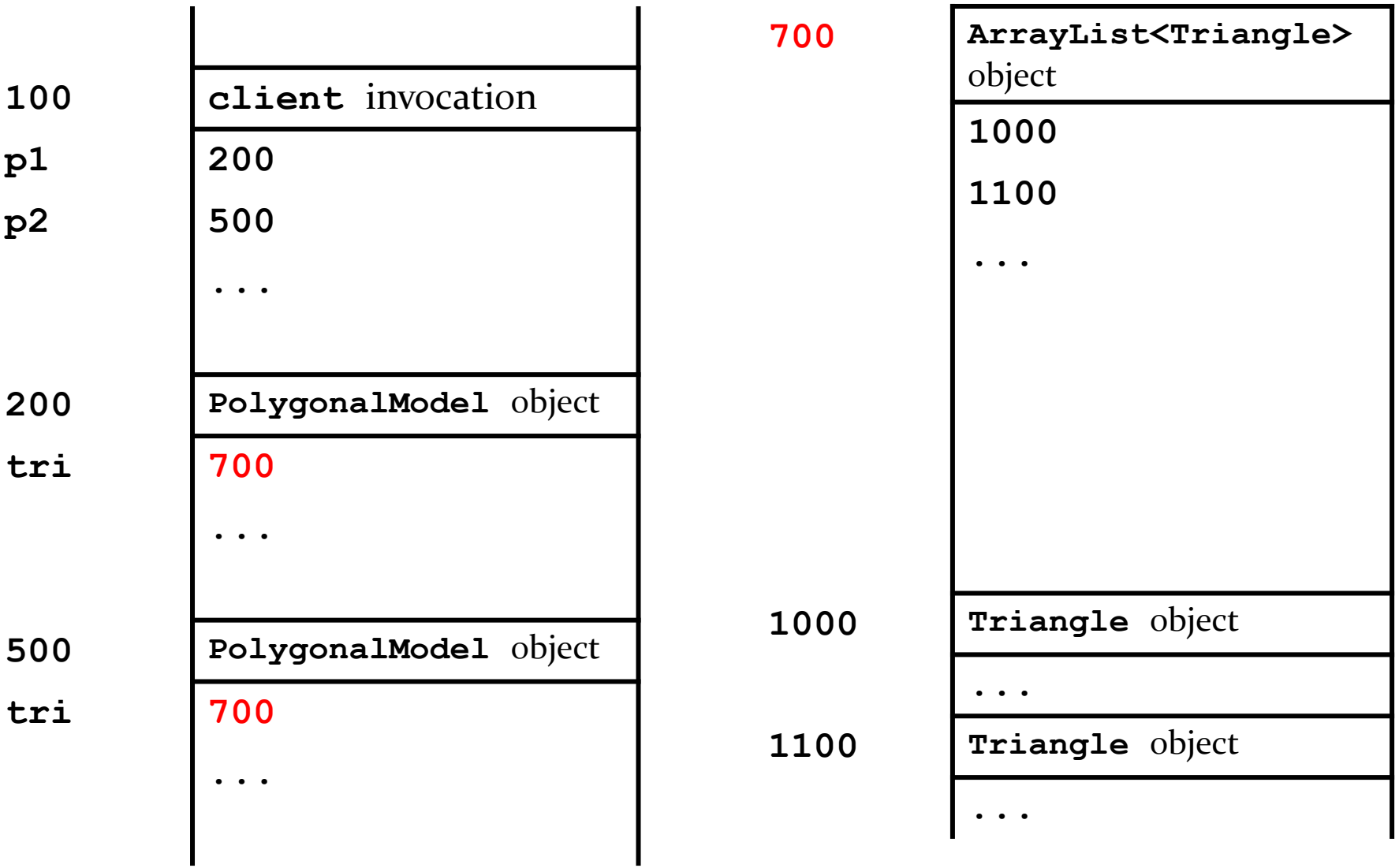
```
public PolygonalModel(PolygonalModel p)
{
  // implements aliasing (sharing) with other
  //   PolygonalModel instances
  this.setTriangles( p.getTriangles() );
}

private List<Triangle> getTriangles()
{ return this.tri; }

private void setTriangles(List<Triangle> tri)
{ this.tri = tri; }
```

alias: no new `List` created

```
PolygonalModel p2 = new PolygonalModel(p1);
```



Test Your Knowledge

1. Suppose you have a **`PolygonalModel p1`** that has 100 **`Triangle`**s. What does the following code print?

```
PolygonalModel p2 = new PolygonalModel(p1);
p2.clear();
System.out.println( p2.size() );
System.out.println( p1.size() );
```

X Owns its Collection: Shallow Copy

- if **`X`** owns its collection but not the objects in the collection then the copy constructor can perform a shallow copy of the collection
- a shallow copy of a collection means
  - **`X`** creates a new collection
  - the references in the collection are aliases for references in the other collection

X Owns its Collection: Shallow Copy

- the hard way to perform a shallow copy

```
// assume there is an ArrayList<Date> dates
ArrayList<Date> sCopy = new ArrayList<Date>();
for(Date d : dates)
{
  sCopy.add(d);
}
```

shallow copy: new **`List`** created but elements are all aliases

`add` does not create new objects

X Owns its Collection: Shallow Copy

- the easy way to perform a shallow copy

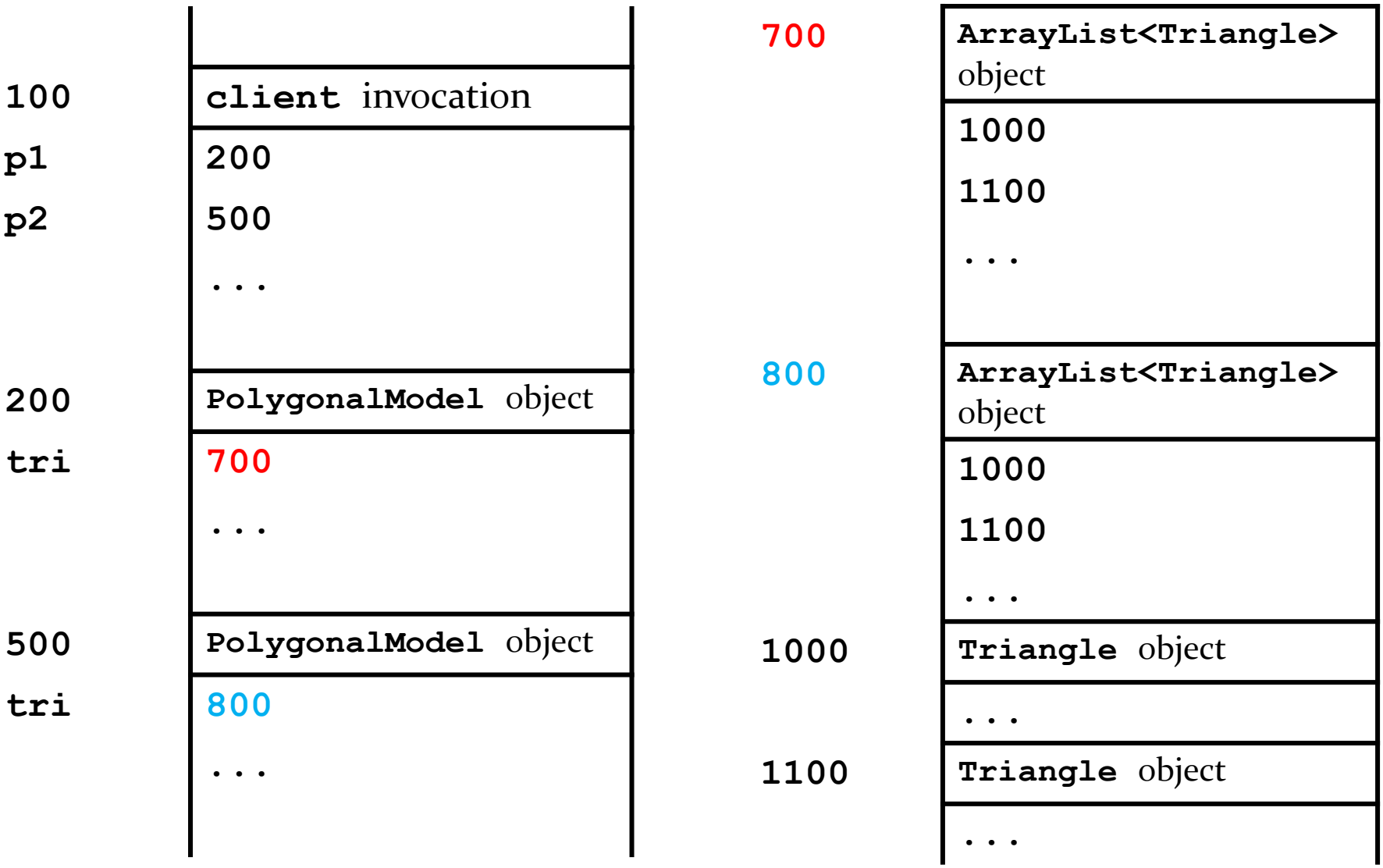
```
// assume there is an ArrayList<Date> dates
ArrayList<Date> sCopy = new ArrayList<Date>(dates);
```

PolygonalModel Copy Constructor 2

```
public PolygonalModel(PolygonalModel p)
{
  // implements shallow copying
  this.tri = new ArrayList<Triangle>(p.getTriangles());
}
```

shallow copy: new **`List`** created, but no new **`Triangle`** objects created

```
PolygonalModel p2 = new PolygonalModel(p1);
```



Test Your Knowledge

2. Suppose you have a **`PolygonalModel p1`** that has 100 **`Triangle`**s. What does the following code print?

```
PolygonalModel p2 = new PolygonalModel(p1);
p2.clear();
System.out.println( p2.size() );
System.out.println( p1.size() );
```

Test Your Knowledge

3. Suppose you have a **`PolygonalModel p1`** that has 100 **`Triangle`**s. What does the following code print?

```
PolygonalModel p2 = new PolygonalModel(p1);
Iterator<Triangle> i1 = p1.iterator();
Iterator<Triangle> i2 = p2.iterator();
System.out.println(i1.next() == i2.next());
```

X Owns its Collection: Deep Copy

- if **`X`** owns its collection and the objects in the collection then the copy constructor must perform a deep copy of the collection
- a deep copy of a collection means
  - **`X`** creates a new collection
  - the references in the collection are references to new objects (that are copies of the objects in other collection)

X Owns its Collection: Deep Copy

- how to perform a deep copy

```
// assume there is an ArrayList<Date> dates
ArrayList<Date> dCopy = new ArrayList<Date>();
for(Date d : dates)
{
  dCopy.add(new Date(d.getTime());
}
```

deep copy: new **`List`** created and new elements created

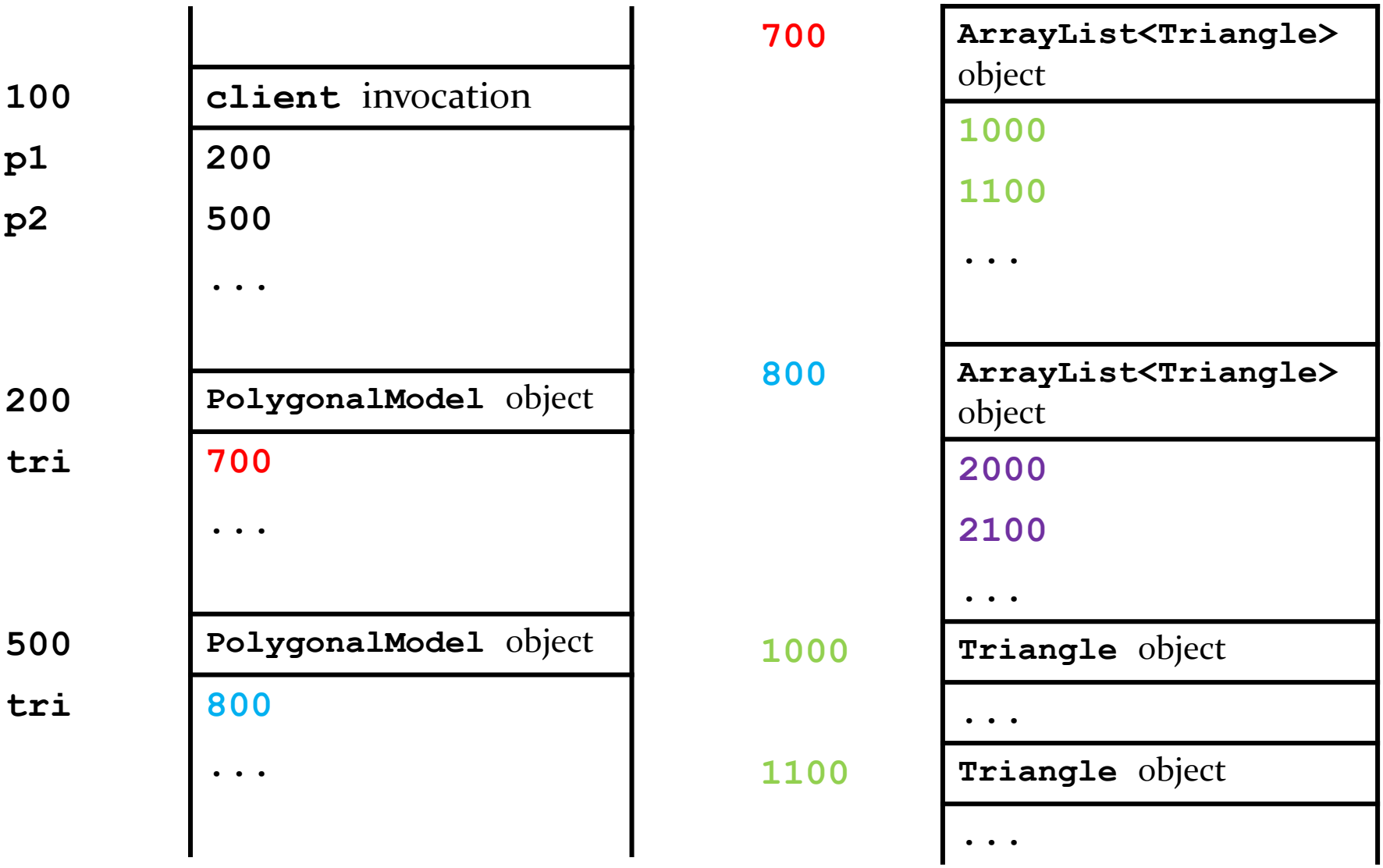
constructor invocation creates a new object

PolygonalModel Copy Constructor 3

```
public PolygonalModel(PolygonalModel p)
{
  // implements deep copying
  this.tri = new ArrayList<Triangle>();
  for (Triangle t : p.getTriangles()) {
    this.tri.add(new Triangle(t));
  }
}
```

deep copy: new **`List`** created, and new **`Triangle`** objects created

```
PolygonalModel p2 = new PolygonalModel(p1);
```



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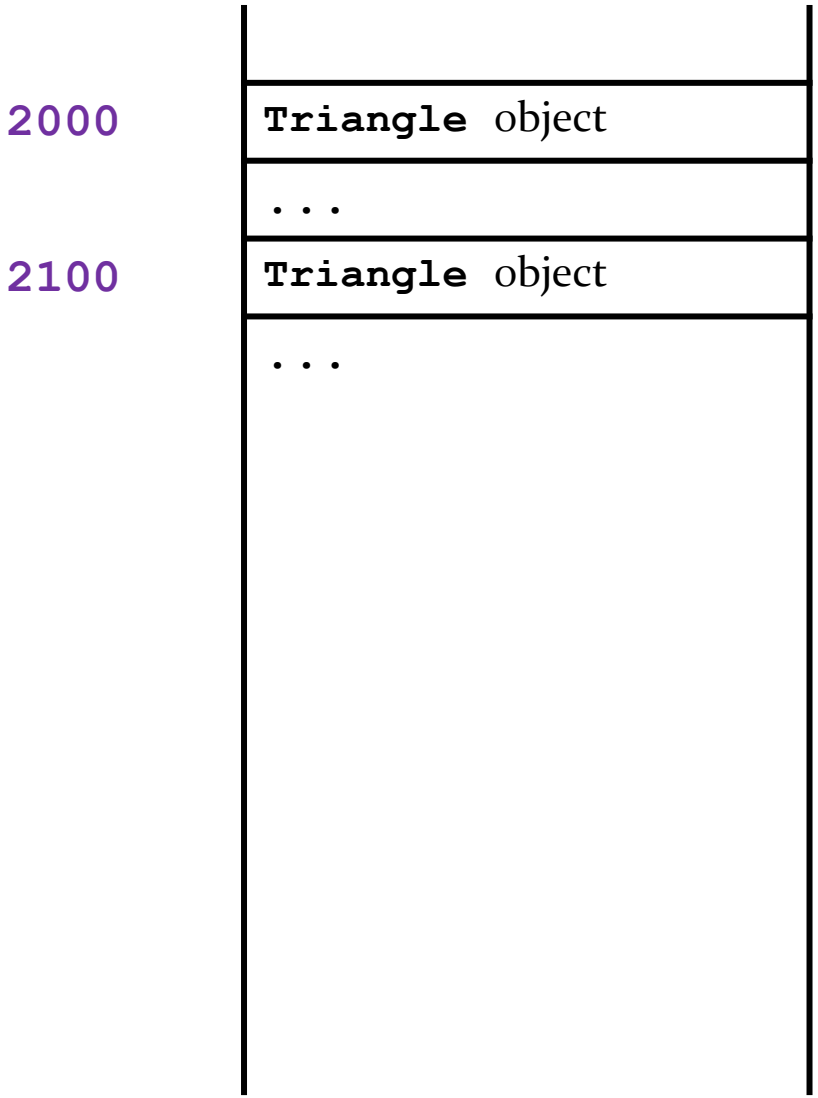
2000
Triangle object
...
2100
Triangle object
...

Test Your Knowledge

4. Suppose you have a **`PolygonalModel p1`** that has 100 **`Triangle`**s. What does the following code print?

```
PolygonalModel p2 = new PolygonalModel(p1);
p2.clear();
System.out.println( p2.size() );
System.out.println( p1.size() );
```

Test Your Knowledge

5. Suppose you have a **`PolygonalModel p1`** that has 100 **`Triangle`**s. What does the following code print?

```
PolygonalModel p2 = new PolygonalModel(p1);
Iterator<Triangle> i1 = p1.iterator();
Iterator<Triangle> i2 = p2.iterator();
System.out.println(i1.next() == i2.next());
System.out.println(i1.next().equals(i2.next()));
```