Aggregation and Composition

Based on slides by Prof. Burton Ma

Aggregation and Composition

- The terms aggregation and composition are used to describe a relationship between objects

- Both terms describe the *has-a* relationship
  - The university has-a collection of departments
  - Each department has-a collection of professors

Aggregation and Composition

- Composition implies ownership
  - If the university disappears then all of its departments disappear
  - A university is a *composition* of departments
- Aggregation does not imply ownership
  - If a department disappears then the professors do not disappear
  - A department is an *aggregation* of professors

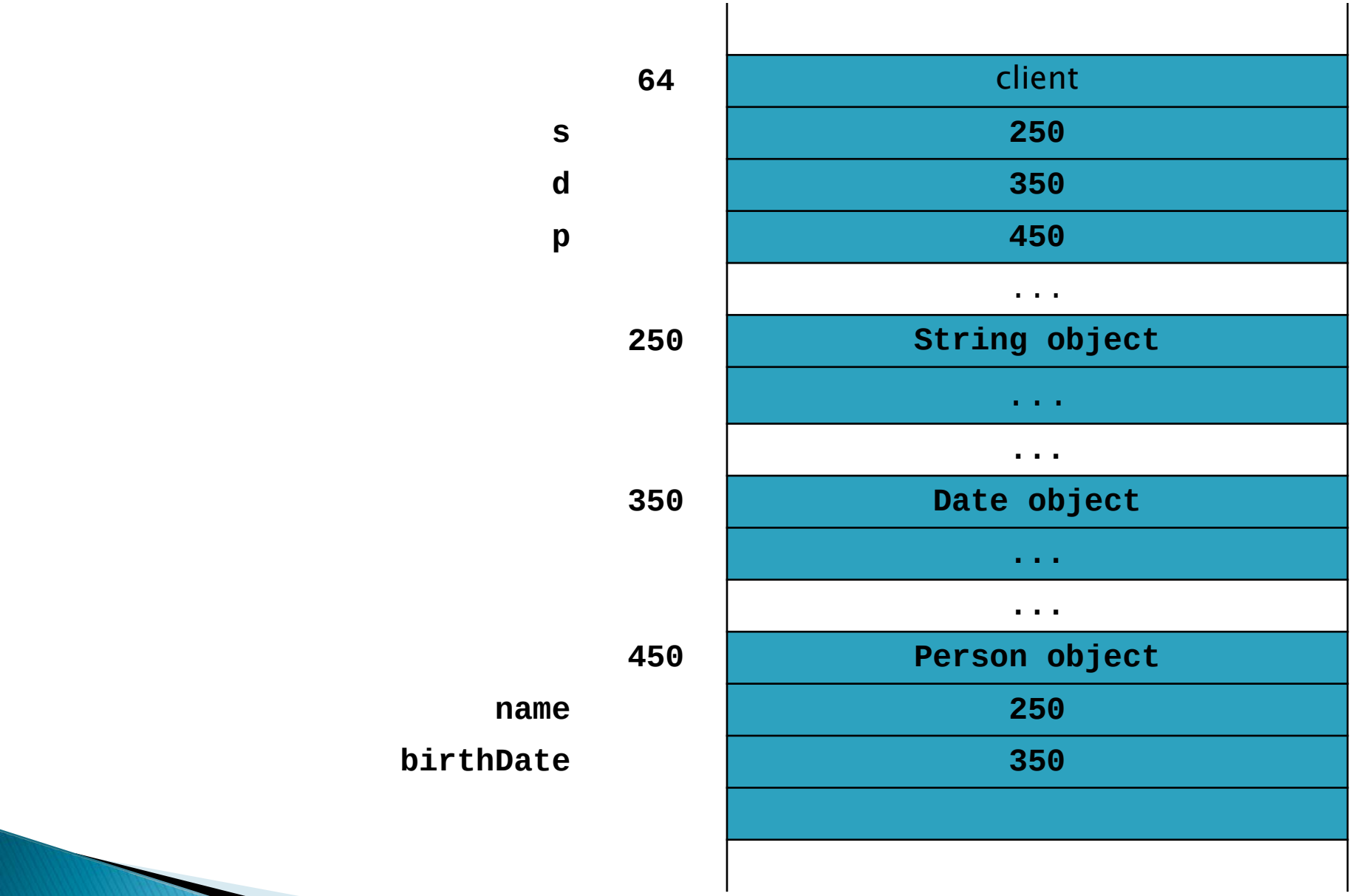
Aggregation

- Suppose a **Person** has a name and a date of birth

```
public class Person
{
  private String name;
  private Date birthDate;

  public Person(String name, Date birthDate)
  {
    this.name = name;
    this.birthDate = birthDate;
  }

  public Date getBirthDate()
  {
    return birthDate;
  }
}
```

- The **`Person`** example uses aggregation
  - Notice that the constructor does not make a copy of the name and birth date objects passed to it
  - The name and birth date objects are shared with the client
  - Both the client and the **`Person`** instance are holding references to the same name and birth date

```
// client code somewhere
String s = "Billy Bob";
Date d = new Date(91, 2, 26);  // March 26, 1991
Person p = new Person(s, d);
```


64
client
s
250
d
350
p
450
...
250
String object
...
...
350
Date object
...
...
450
Person object
name
250
birthDate
350

- What happens when the client modifies the **`Date`** instance?

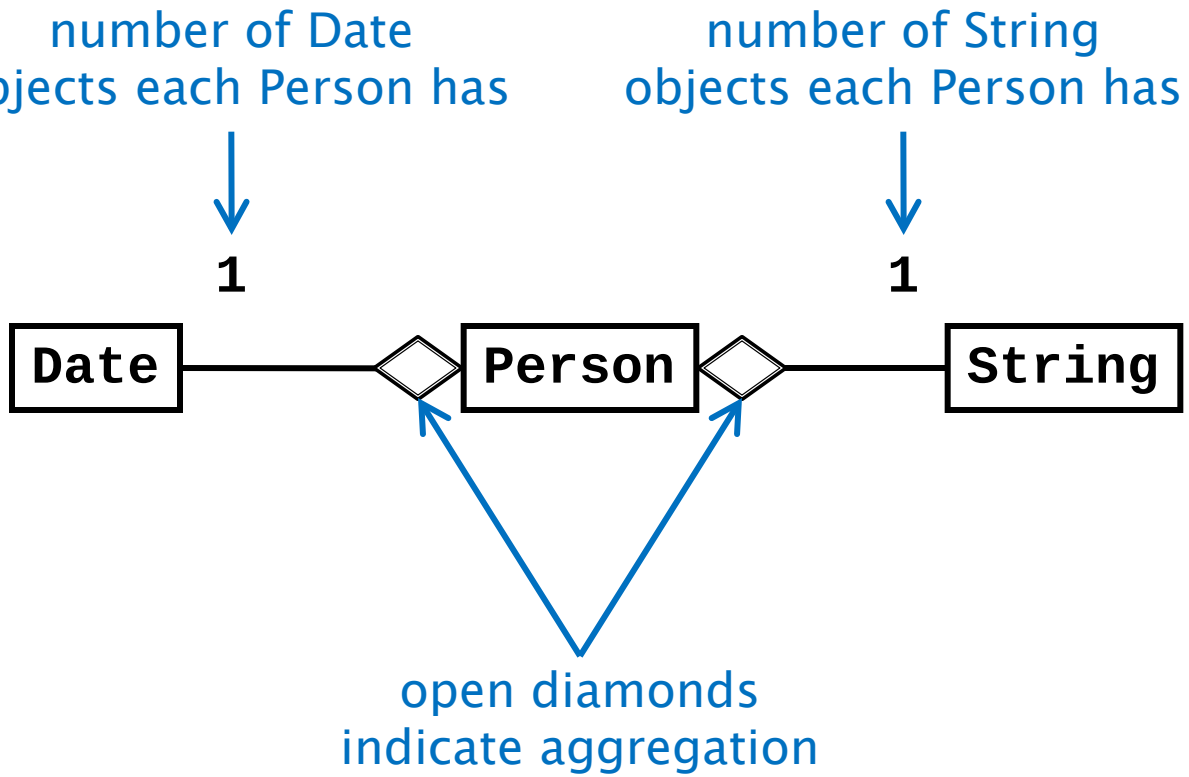
```
// client code somewhere
String s = "Billy Bob";
Date d = new Date(90, 2, 26);  // March 26, 1990
Person p = new Person(s, d);

d.setYear(95);                 // November 3, 1995
d.setMonth(10);
d.setDate(3);
System.out.println( p.getBirthDate() );
```

  - Prints **`Fri Nov 03 00:00:00 EST 1995`**

- Because the **`Date`** instance is shared by the client and the **`Person`** instance:
  - The client can modify the date using **`d`** and the **`Person`** instance **`p`** sees a modified **`birthDate`**
  - The **`Person`** instance **`p`** can modify the date using **`birthDate`** and the client sees a modified date **`d`**

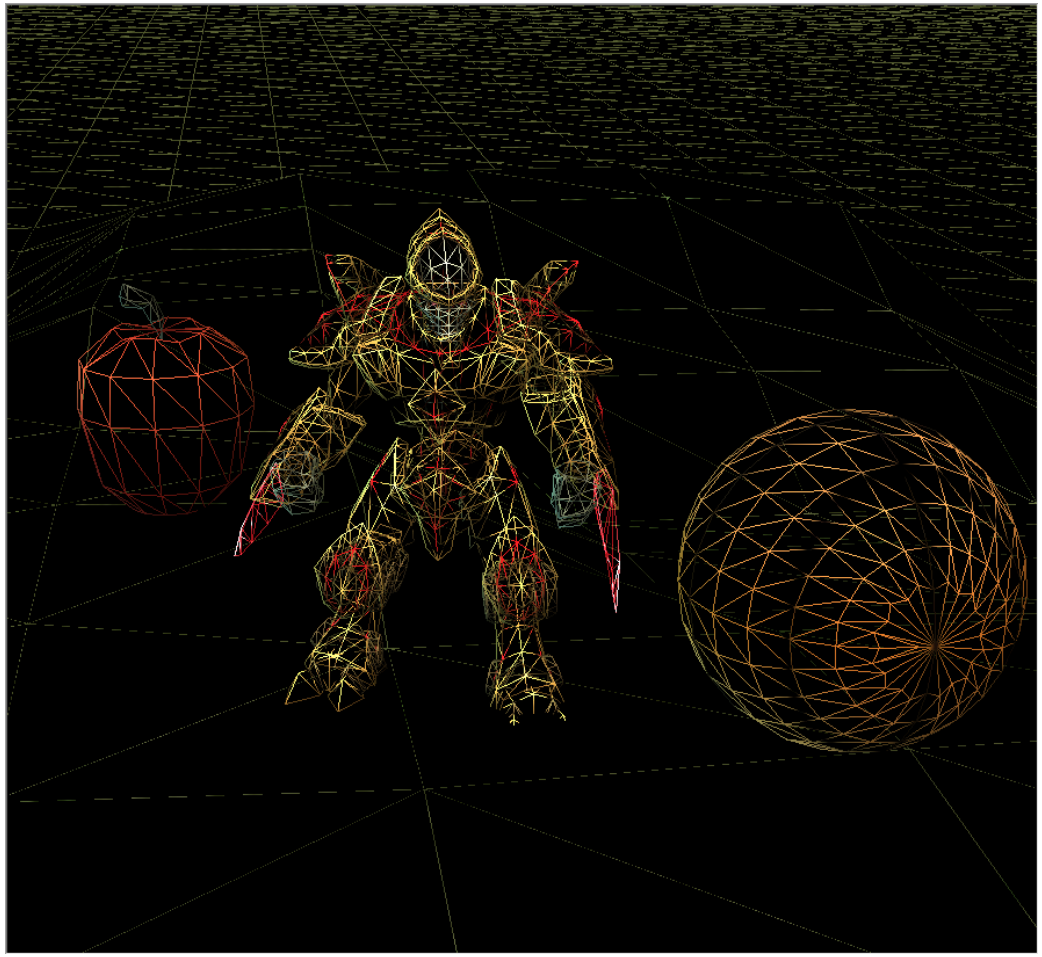
- Note that even though the **`String`** instance is shared by the client and the **`Person`** instance **`p`**, neither the client nor **`p`** can modify the **`String`**
  - Immutable objects make great building blocks for other objects
  - They can be shared freely without worrying about their state

UML Class Diagram for Aggregation



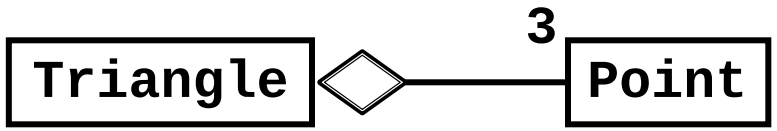
Another Aggregation Example

- 3D videogames use models that are a three-dimensional representations of geometric data
  - The models may be represented by:
    - Three-dimensional points (particle systems)
    - Simple polygons (triangles, quadrilaterals)
    - Smooth, continuous surfaces (splines, parametric surfaces)
    - An algorithm (procedural models)
- Rendering the objects to the screen usually results in drawing triangles
  - Graphics cards have specialized hardware that does this very fast



Aggregation Example

- A **`Triangle`** has 3 three-dimensional **`Point`**s



Triangle
+ Triangle(Point, Point, Point)
+ getA() : Point + getB() : Point + getC() : Point + setA(Point) : void + setB(Point) : void + setC(Point) : void

Point
+ Point(double, double, double)
+ getX() : double + getY() : double + getZ() : double + setX(double) : void + setY(double) : void + setZ(double) : void

Triangle

```
// attributes and constructor

public class Triangle
{
  private Point pA;
  private Point pB;
  private Point pC;

  public Triangle(Point c, Point b, Point c)
  {
    this.pA = a;
    this.pB = b;
    this.pC = c;
  }
```

Triangle

```
// accessors

public Point getA()
{
  return this.pA;
}

public Point getB()
{
  return this.pB;
}

public Point getC()
{
  return this.pC;
}
```

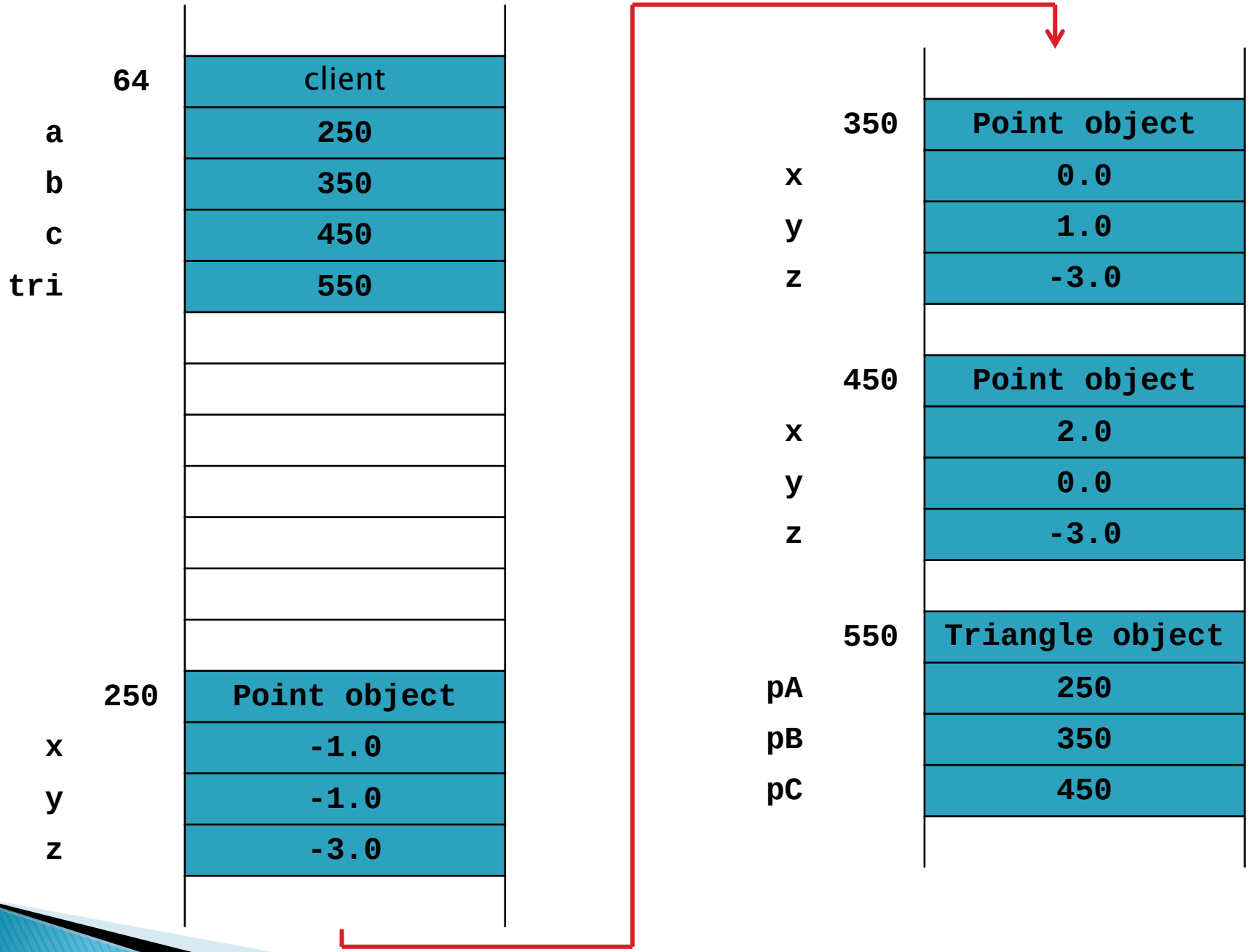
Triangle

```
  // mutators

  public void setA(Point p)
  {
    this.pA = p;
  }

  public void setB(Point p)
  {
    this.pB = p;
  }

  public void setC(Point p)
  {
    this.pC = p;
  }
}
```

Triangle Aggregation

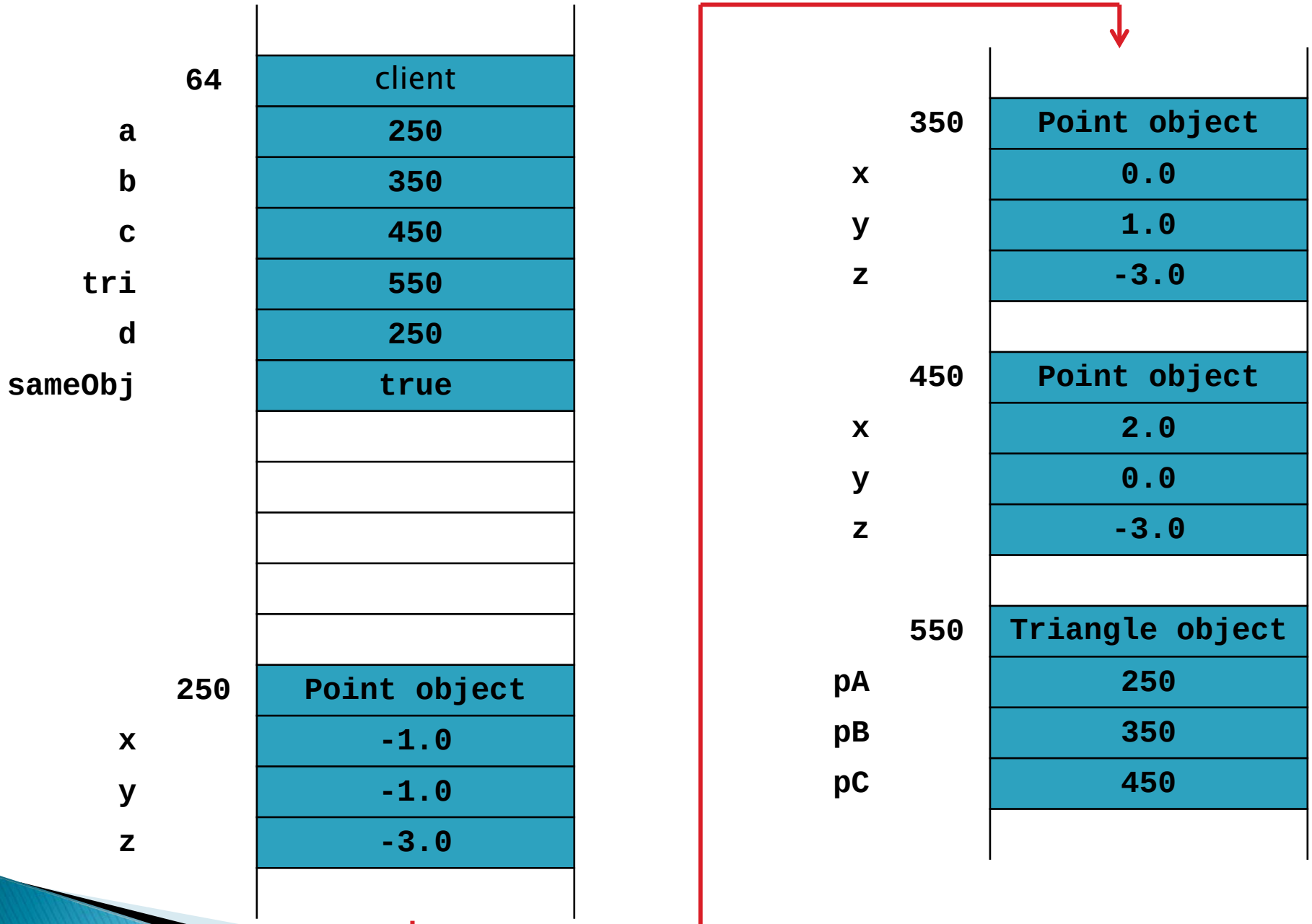
- Implementing **`Triangle`** is very easy
- Attributes (3 **`Point`** references)
  - Are references to existing objects provided by the client
- Accessors
  - Give clients a reference to the aggregated **`Point`**s
- Mutators
  - Set attributes to existing **`Point`**s provided by the client
- We say that the **`Triangle`** attributes are *aliases*

```
// client code

Point a = new Point(-1.0, -1.0, -3.0);
Point b = new Point(0.0, 1.0, -3.0);
Point c = new Point(2.0, 0.0, -3.0);
Triangle tri = new Triangle(a, b, c);
```


64
client
a
250
b
350
c
450
tri
550
250
Point object
x
-1.0
y
-1.0
z
-3.0
350
Point object
x
0.0
y
1.0
z
-3.0
450
Point object
x
2.0
y
0.0
z
-3.0
550
Triangle object
pA
250
pB
350
pC
450

```
// client code

Point a = new Point(-1.0, -1.0, -3.0);
Point b = new Point(0.0, 1.0, -3.0);
Point c = new Point(2.0, 0.0, -3.0);
Triangle tri = new Triangle(a, b, c);
Point d = tri.getA();
boolean sameObj = a == d;
```

client asks the triangle for one of the triangle points and checks if the point is the same object that was used to create the triangle


64
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a
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c
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tri
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sameObj
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250
Point object
x
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z
-3.0
350
Point object
x
0.0
y
1.0
z
-3.0
450
Point object
x
2.0
y
0.0
z
-3.0
550
Triangle object
pA
250
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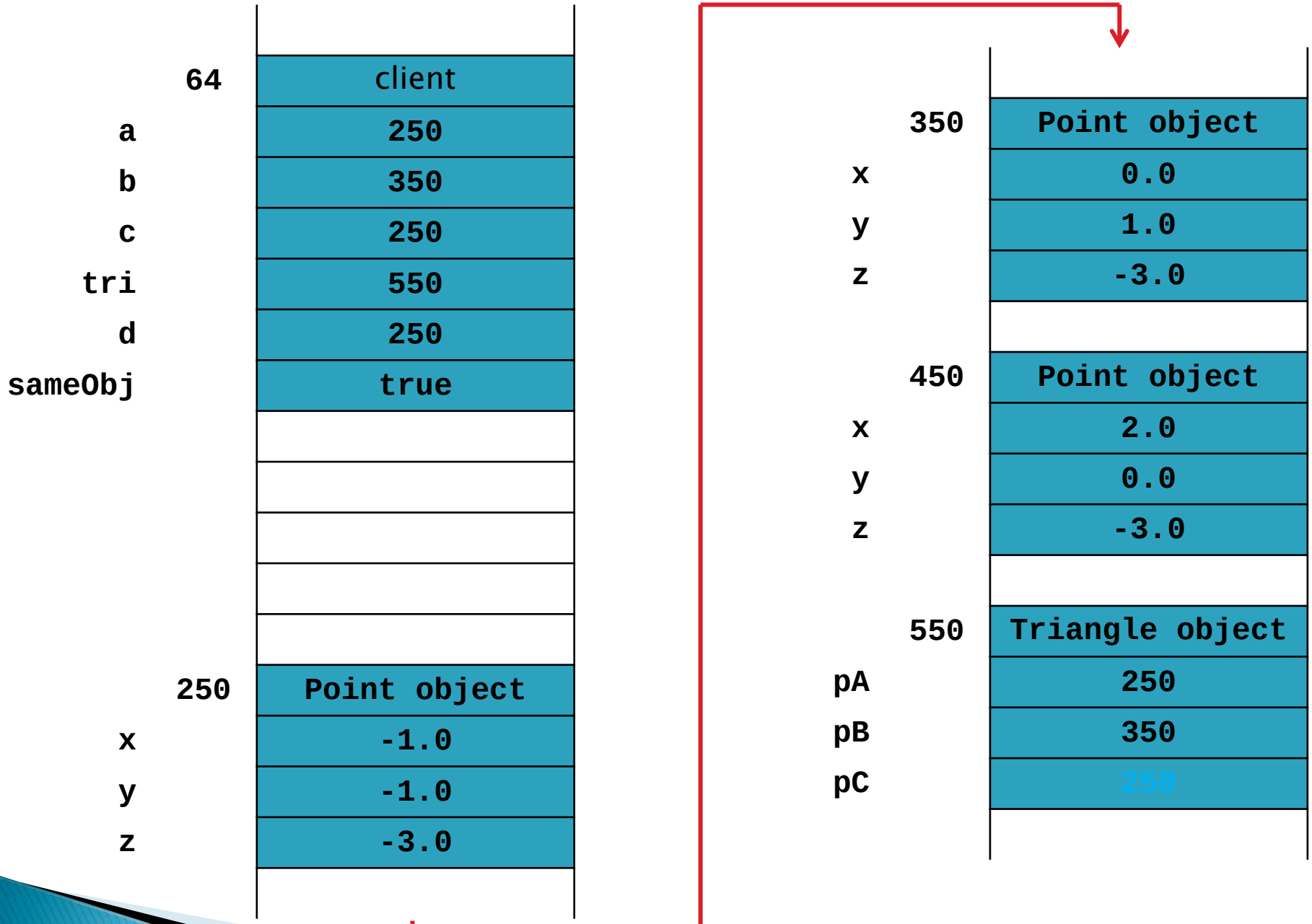
```
// client code

Point a = new Point(-1.0, -1.0, -3.0);
Point b = new Point(0.0, 1.0, -3.0);
Point c = new Point(2.0, 0.0, -3.0);
Triangle tri = new Triangle(a, b, c);
Point d = tri.getA();
boolean sameObj = a == d;
tri.setC(d);
```

client asks the triangle to set one point of the triangle to **d**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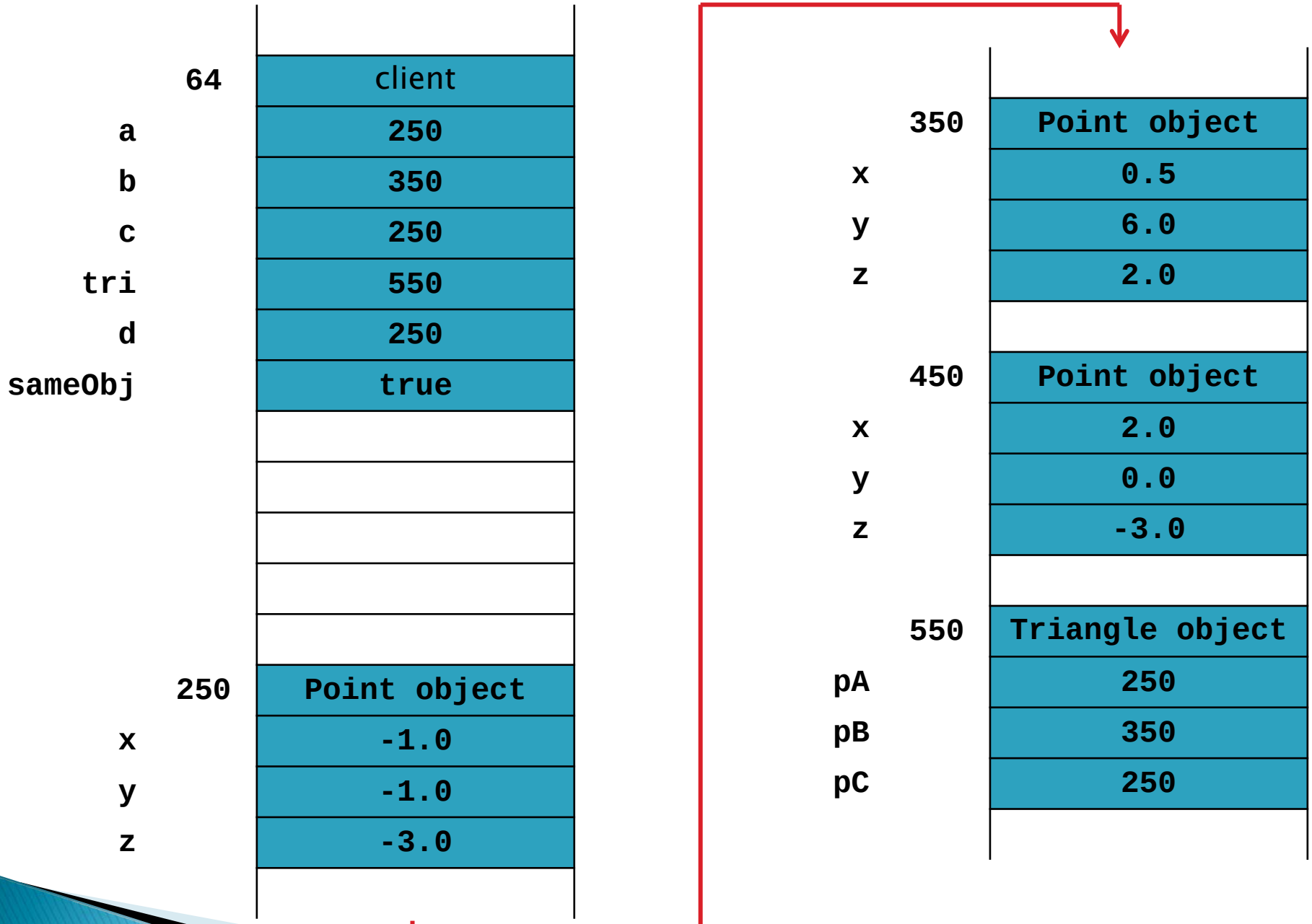
sameObj
true
250
Point object
x
-1.0
y
-1.0
z
-3.0
350
Point object
x
0.0
y
1.0
z
-3.0
450
Point object
x
2.0
y
0.0
z
-3.0
550
Triangle object
pA
250
pB
350
pC
250

```
// client code

Point a = new Point(-1.0, -1.0, -3.0);
Point b = new Point(0.0, 1.0, -3.0);
Point c = new Point(2.0, 0.0, -3.0);
Triangle tri = new Triangle(a, b, c);
Point d = tri.getA();
boolean sameObj = a == d;
tri.setC(d);
b.setX(0.5);
b.setY(6.0);
b.setZ(2.0);
```

client changes the coordinates of one of the points (without asking the triangle for the point first)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sameObj
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Point object
x
-1.0
y
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350
Point object
x
0.5
y
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Point object
x
2.0
y
0.0
z
-3.0
550
Triangle object
pA
250
pB
350
pC
250

Triangle Aggregation

- If a client gets a reference to one of the triangle's points, then the client can change the position of the point *without asking the triangle*

```
pointB = new Point(0.0, 1.0, -3.0);
tri = new Triangle(new Point(-1.0, -1.0, -3.0),
                   pointB,
                   new Point(2.0, 0.0, -3.0));

// Draw triangle
gl.glBegin(GL2.GL_TRIANGLES);
gl.glColor3f(0.0f, 1.0f, 1.0f); // set the color
gl.glVertex3d(tri.getA().getX(),
              tri.getA().getY(),
              tri.getA().getZ());
gl.glVertex3d(tri.getB().getX(),
              tri.getB().getY(),
              tri.getB().getZ());
gl.glVertex3d(tri.getC().getX(),
              tri.getC().getY(),
              tri.getC().getZ());
gl.glEnd();

// the client moves a point without help from the triangle
delta += 0.05f;
pointB.setY(1.0 + Math.sin(delta));
```

client and triangle share a reference to **`pointB`**

draw the triangle by asking **`tri`** for the coordinates of each of its points

client uses **`pointB`** to change the point coordinates

Composition

- Recall that an object of type **X** that is composed of an object of type **Y** means
  - **X** has-a **Y** object *and*
  - **X** owns the **Y** object
- In other words

> The **X** object, and only the **X** object, is responsible for its **Y** object

Composition

The **X** object, and only the **X** object, is responsible for its **Y** object

- This means that the **X** object will generally not share references to its **Y** object with clients
  - Constructors will create new **Y** objects
  - Accessors will return references to new **Y** objects
  - Mutators will store references to new **Y** objects
- The "new **Y** objects" are called *defensive copies*

Composition & the Default Constructor

the **X** object, and only the **X** object, is responsible for its **Y** object

- If a default constructor is defined it must create a suitable **Y** object

```
public X()
{
  // create a suitable Y; for example
  this.y = new Y( /* suitable arguments */ );
}
```

defensive copy

Composition & Copy Constructor

the **X** object, and only the **X** object, is responsible for its **Y** object

- If a copy constructor is defined it must create a new **Y** that is a deep copy of the other **X** object's **Y** object

```
public X(X other)
{
  // create a new Y that is a copy of other.y
  this.y = new Y(other.getY());
}
```

defensive copy

Composition & Copy Constructor

- What happens if the **X** copy constructor does not make a deep copy of the other **X** object's **Y** object?

```
// don't do this
public X(X other)
{
  this.y = other.y;
}
```

  - Every **X** object created with the copy constructor ends up sharing its **Y** object
    - If one **X** modifies its **Y** object, all **X** objects will end up with a modified **Y** object
    - What is this an example of?

Composition & Other Constructors

the **X** object, and only the **X** object, is responsible for its **Y** object

- a constructor that has a **Y** parameter must first deep copy and then validate the **Y** object

```
public X(Y y)
{
  // create a copy of y
  Y copyY = new Y(y);
  // validate; will throw an exception if copyY is
invalid
  this.checkY(copyY);
  this.y = copyY;
}
```

defensive copy

Composition and Other Constructors

- Why is the deep copy required?

> the **X** object, and only the **X** object, is responsible for its **Y** object

  - If the constructor does this

```
// don't do this for composition
public X(Y y)
{
  this.y = y;
}
```

  then the client and the **X** object will share the same **Y** object

    - This is a privacy leak

Composition and Accessors

the **X** object, and only the **X** object, is responsible for its **Y** object

- Never return a reference to an attribute; always return a deep copy

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

defensive copy

Composition and Accessors

- Why is the deep copy required?

  the **X** object, and only the **X** object, is responsible for its **Y** object

  - If the accessor does this

```
// don't do this for composition
public Y getY()
{
  return this.y;
}
```

    then the client and the **X** object will share the same **Y** object

    - This is a privacy leak

Composition and Mutators

> the **X** object, and only the **X** object, is responsible for its **Y** object

- If **X** has a method that sets its **Y** object to a client-provided **Y** object then the method must make a deep copy of the client-provided **Y** object and validate it

```
public void setY(Y y)
{
  Y copyY = new Y(y);
  // validate; will throw an exception if copyY is invalid
  this.checkY(copyY);
  this.y = copyY;
}
```

defensive copy

Composition and Mutators

- Why is the deep copy required?

> the **X** object, and only the **X** object, is responsible for its **Y** object

  - If the mutator does this

```
// don't do this for composition
public void setY(Y y)
{
  this.y = y;
}
```

  then the client and the **X** object will share the same **Y** object

    - This is a privacy leak

Period Class

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

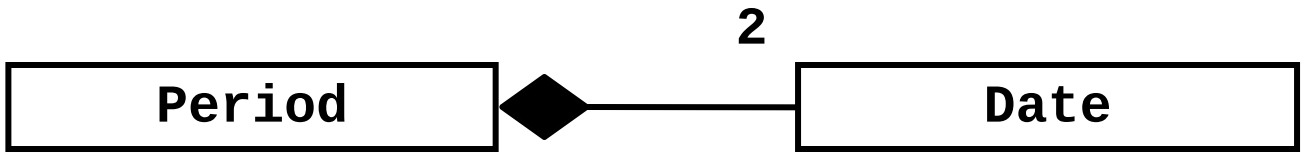
- We want to implement a class that represents a period of time
  - A period has a start time and an end time
    - End time is always after the start time

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

- Class invariant
  - Some property of the state of the object that is established by a constructor and maintained between calls to public methods

Period Class



`Period` is a compostion 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 = new Date(start.getTime());
    this.end = new Date(end.getTime());
  }
```

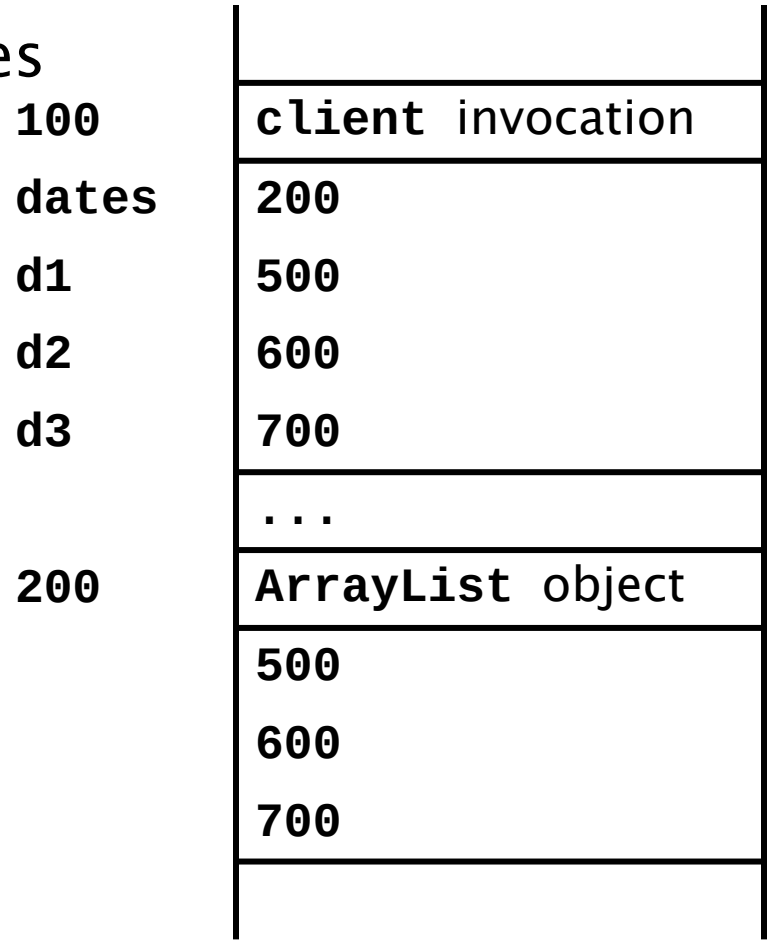
Collections as Attributes

- 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
  - A student has-a collection of GPAs and has-a collection of courses
  - A polygonal model has-a collection of triangles

What Does a Collection Hold?

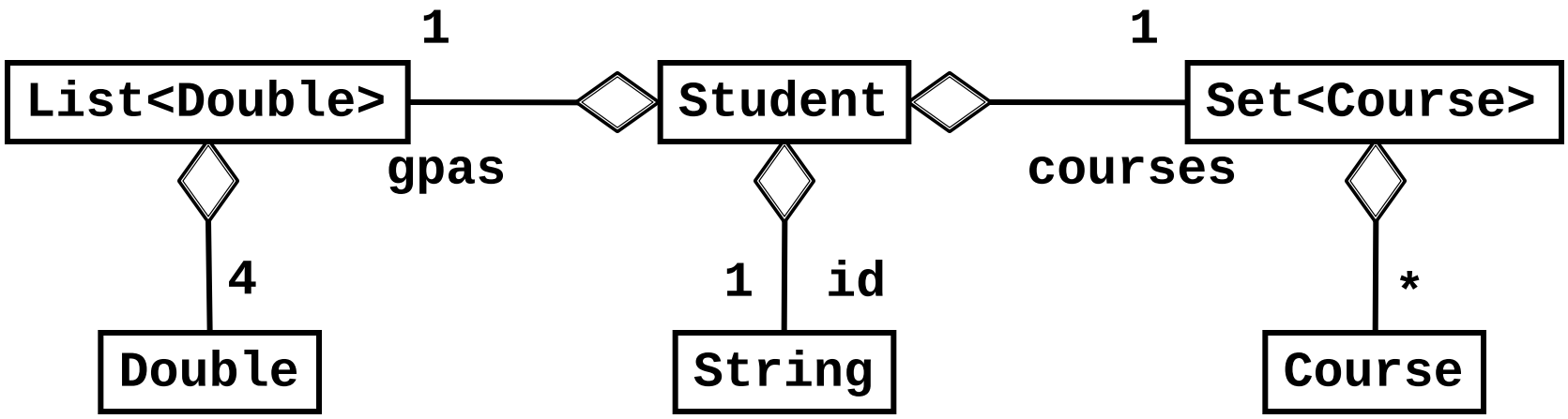
- A collection holds references to instances
  - It does not hold the instances

```
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);
```



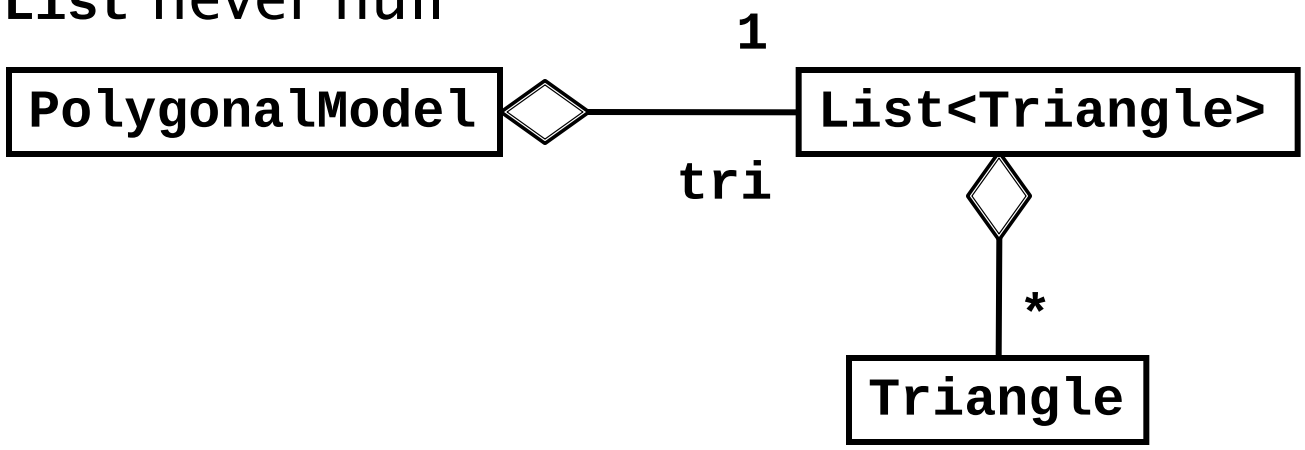
Student Class

- 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 **`Triangles`**
  - Aggregation
- Implements **`Iterable<Triangle>`**
  - Allows clients to access each **`Triangle`** sequentially
- Class invariant
  - **`List`** never null



PolygonalModel

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

  public PolygonalModel()
  {
    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 xs

- 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
  - The text 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

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);
}
```

add does not create new objects

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

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);
```

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> sCopy = new ArrayList<Date>();
for(Date d : dates)
{
  sCopy.add(new Date(d.getTime());
}
```

constructor invocation creates a new object

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