Memory Allocation

```
public class Point {

   public Point(int x, int y) {
     px = x;
     py = y;
   }

   public void move(int dx,
                    int dy) {
     px += dx;
     py += dy;
   }

   /* instance variables */
   private int px;
   private int py;
}
```

```
public class MyProgram
       extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     p1.move(10, 11);
   }

}
```

Memory Allocation

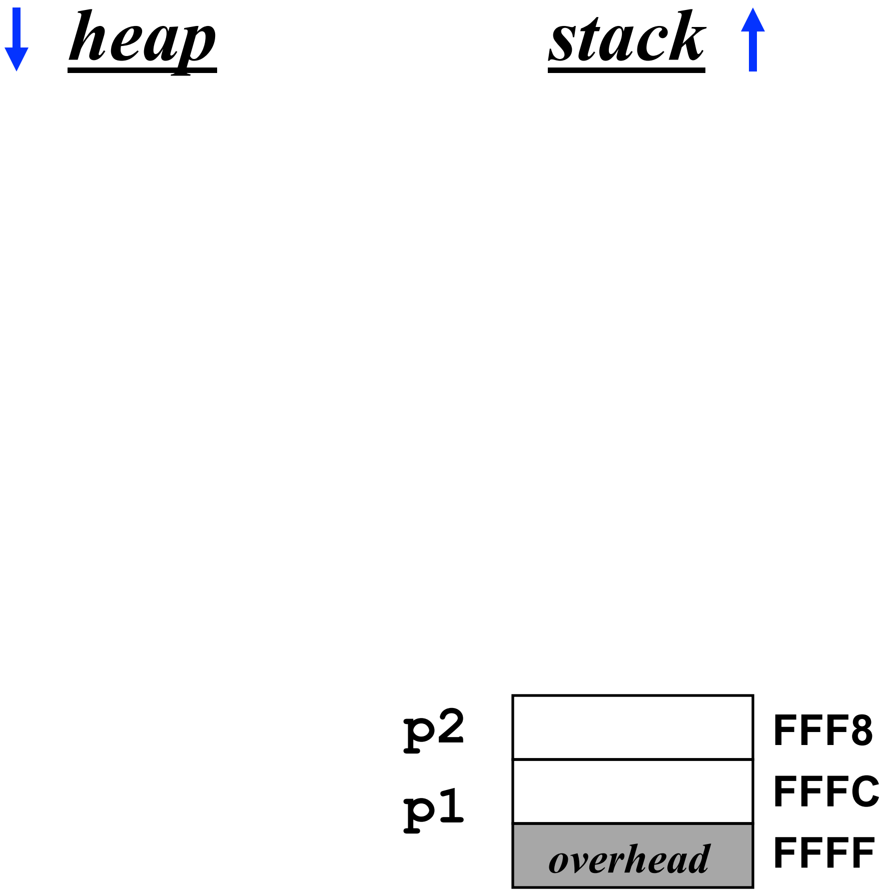
↓ ***heap*** ***stack*** ↑

```
public class MyProgram
       extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     p1.move(10, 11);
   }

}
```

Memory Allocation

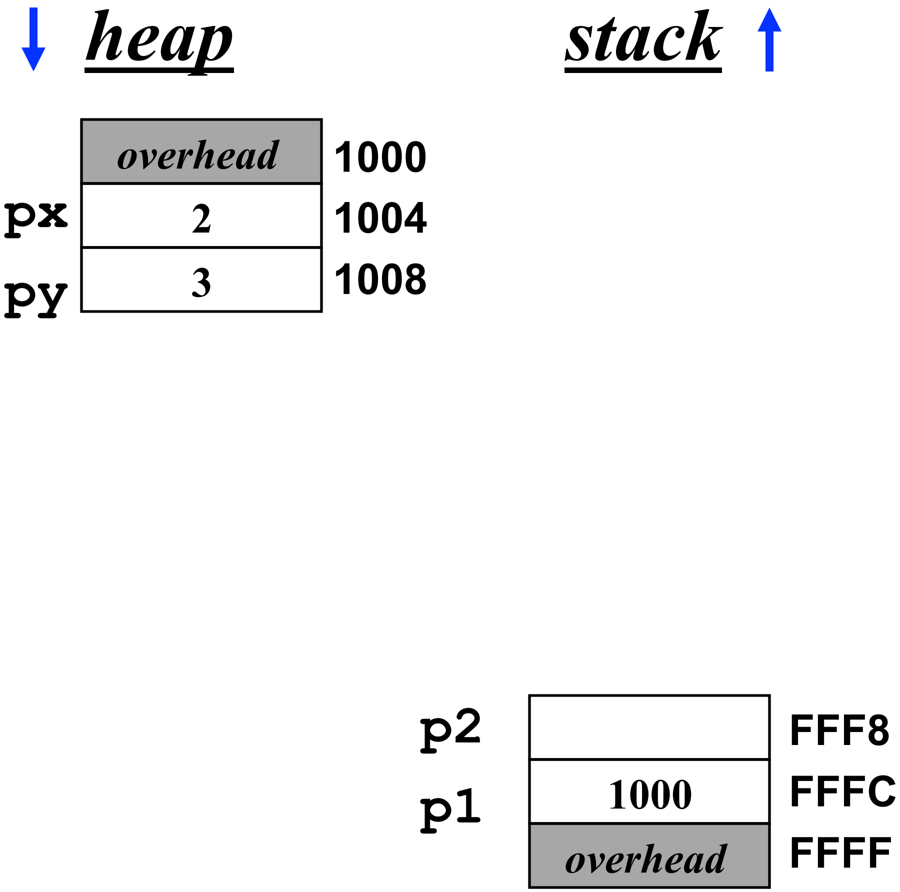


```
public class MyProgram
        extends ConsoleProgram {

   public void run()  {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     p1.move(10, 11);
   }

}
```

Memory Allocation



heap

	overhead	1000
px	2	1004
py	3	1008

stack

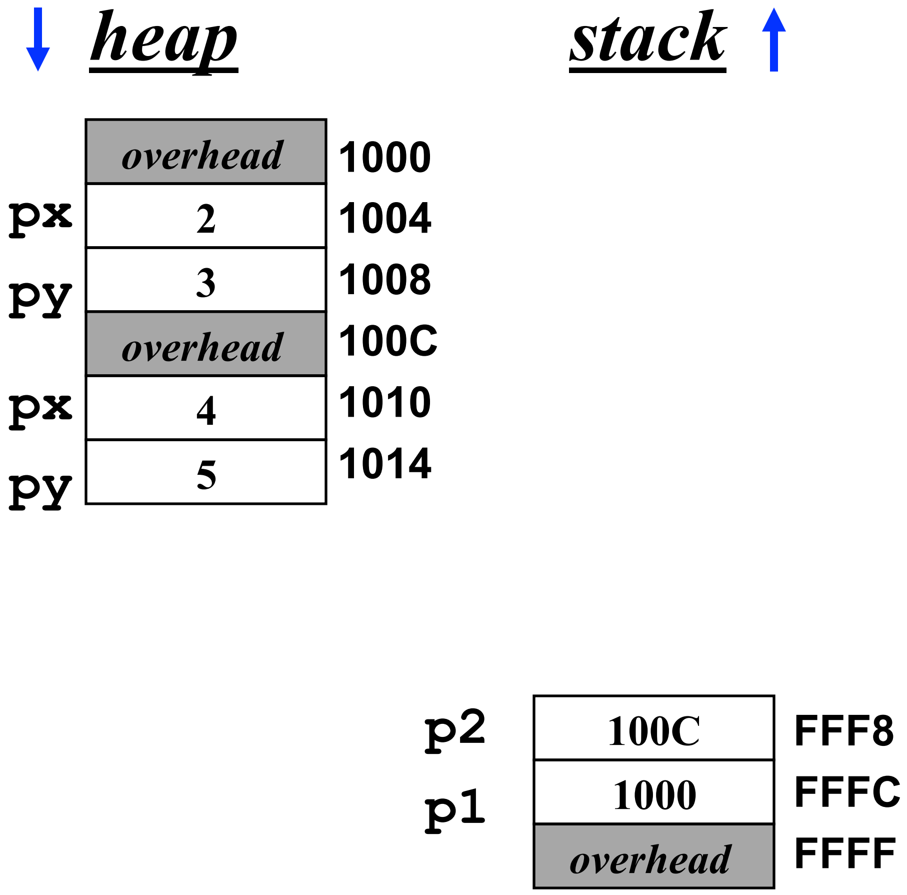
p2		FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
          extends ConsoleProgram {

    public void run() {
       Point p1 = new Point(2, 3);
       Point p2 = new Point(4, 5);
       p1.move(10, 11);
    }

}
```

Memory Allocation



↓ ***heap***

	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014

stack ↑

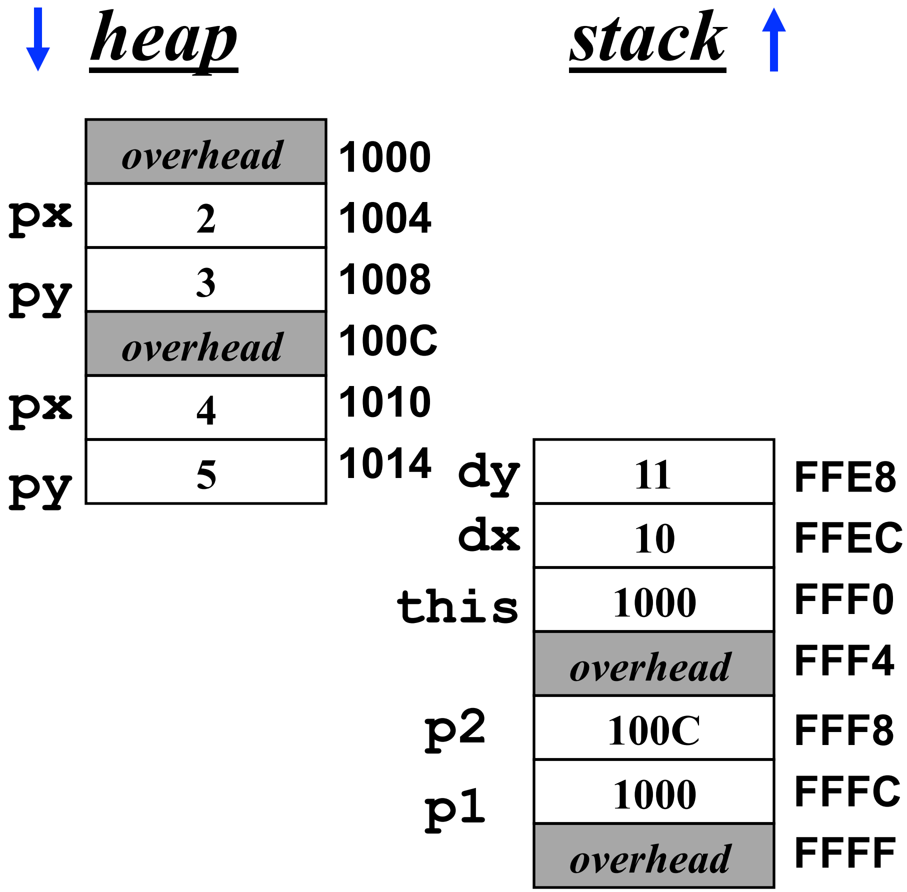
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     p1.move(10, 11);
   }

}
```

Memory Allocation



	heap	
	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014

	stack	
dy	11	FFE8
dx	10	FFEC
this	1000	FFF0
	overhead	FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

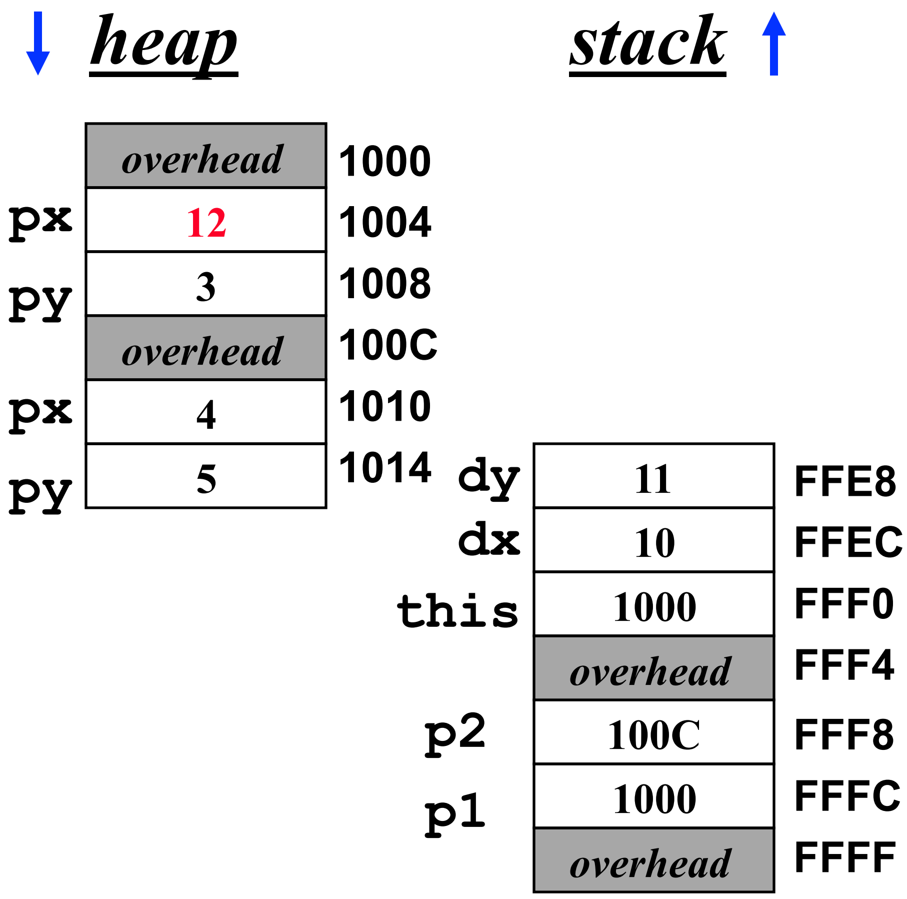
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      p1.move(10, 11);
   }

}
```

```
   public void move(int dx,
                    int dy) {
      px += dx;
      py += dy;
   }
```

Memory Allocation



↓ ***heap***

	overhead	1000
px	12	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014

stack ↑

dy	11	FFE8
dx	10	FFEC
this	1000	FFF0
	overhead	FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

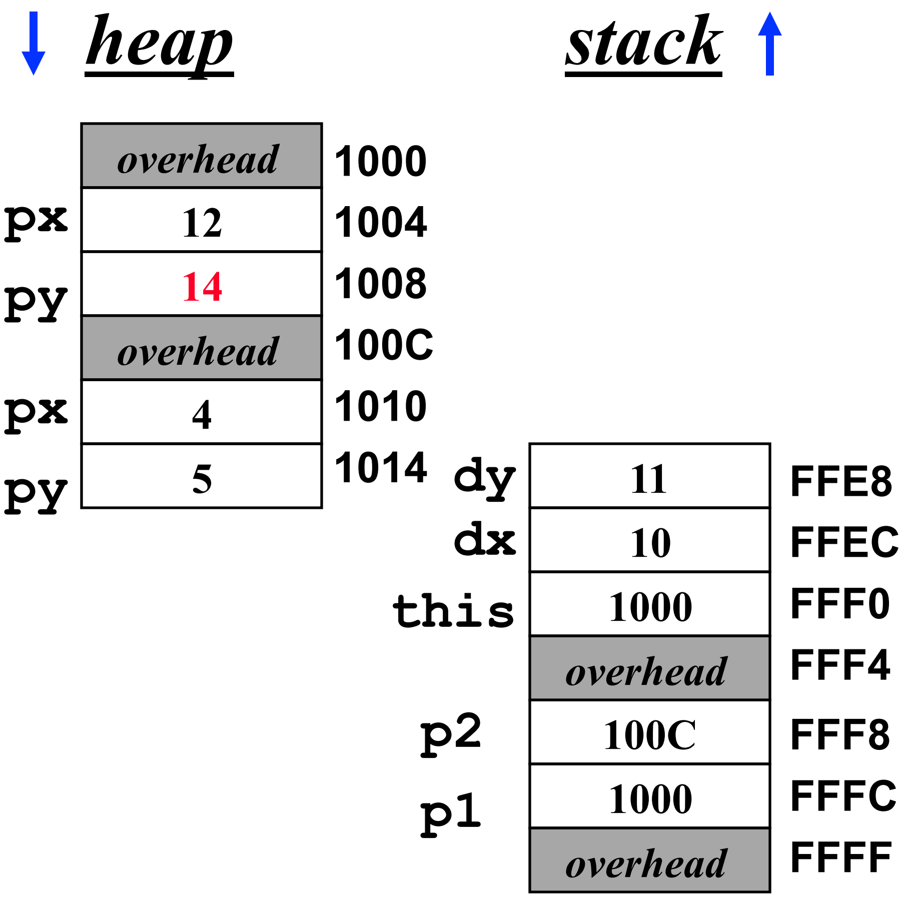
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      p1.move(10, 11);
   }

}
```

```
   public void move(int dx,
                    int dy) {
      px += dx;
      py += dy;
   }
```

Memory Allocation



heap

	overhead	1000
px	12	1004
py	14	1008
	overhead	100C
px	4	1010
py	5	1014

stack

dy	11	FFE8
dx	10	FFEC
this	1000	FFF0
	overhead	FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

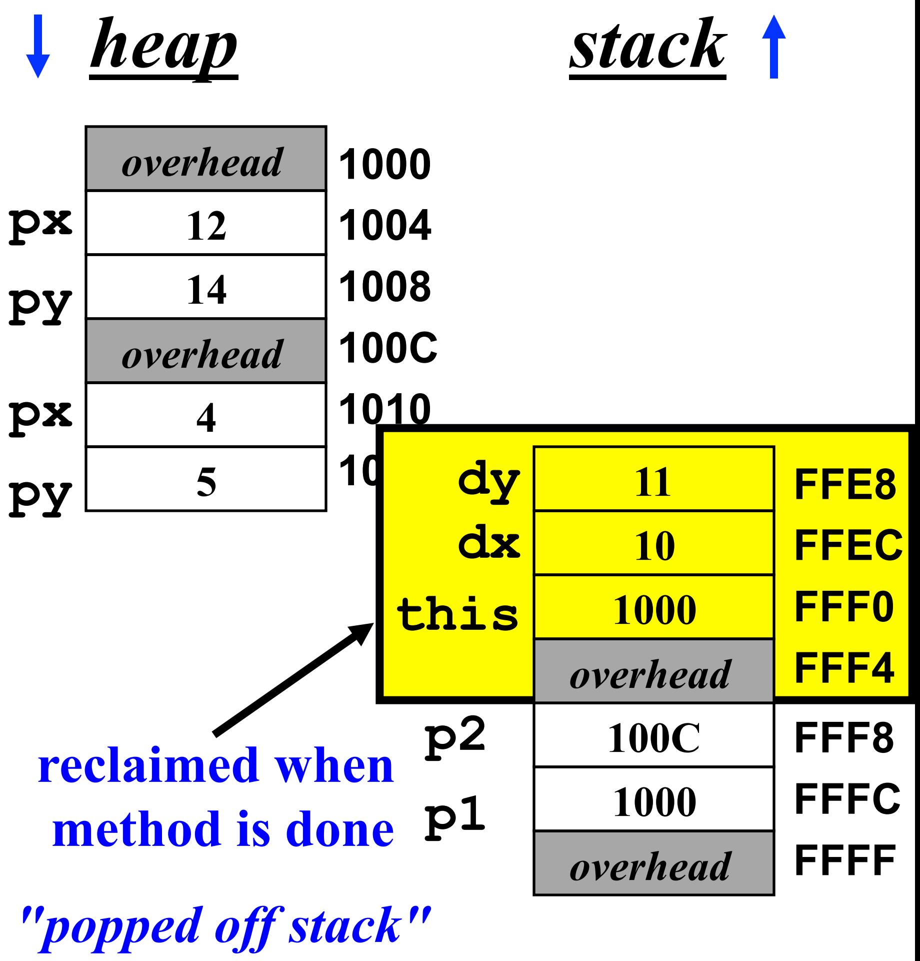
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     p1.move(10, 11);
   }

}
```

```
   public void move(int dx,
                    int dy) {
     px += dx;
     py += dy;
   }
```

Memory Allocation



heap ↓

	overhead	1000
px	12	1004
py	14	1008
	overhead	100C
px	4	1010
py	5	10

stack ↑

dy	11	FFE8
dx	10	FFEC
this	1000	FFF0
	overhead	FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

reclaimed when method is done

"popped off stack"

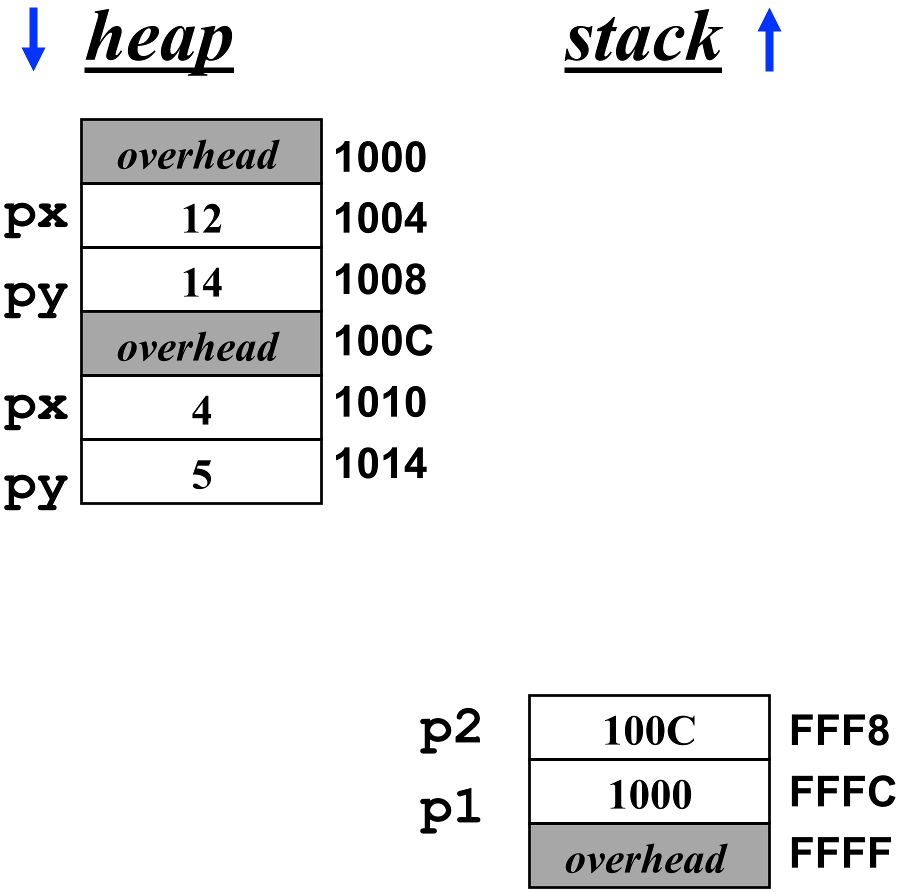
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     p1.move(10, 11);
   }

}
```

```
   public void move(int dx,
                    int dy) {
     px += dx;
     py += dy;
   }
```

Memory Allocation



heap ***stack***

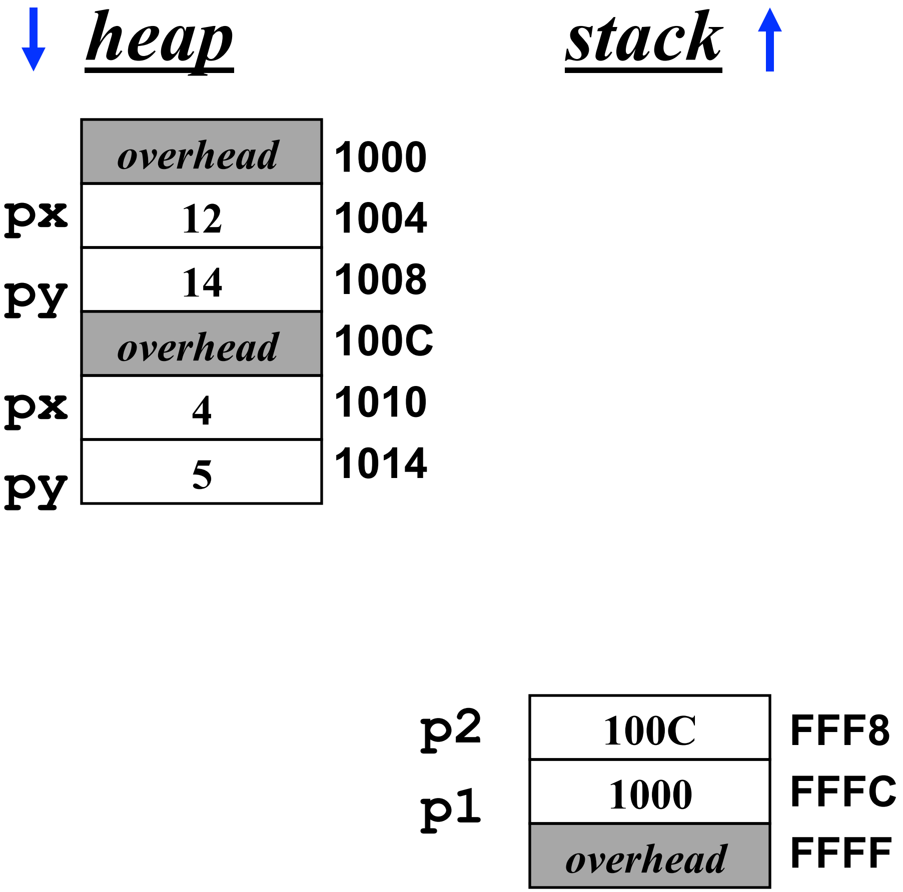
	overhead	1000
px	12	1004
py	14	1008
	overhead	100C
px	4	1010
py	5	1014

p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      p1.move(10, 11);
      ...
   }
}
```

Pointer Viewpoint



heap

	overhead	1000
px	12	1004
py	14	1008
	overhead	100C
px	4	1010
py	5	1014

stack

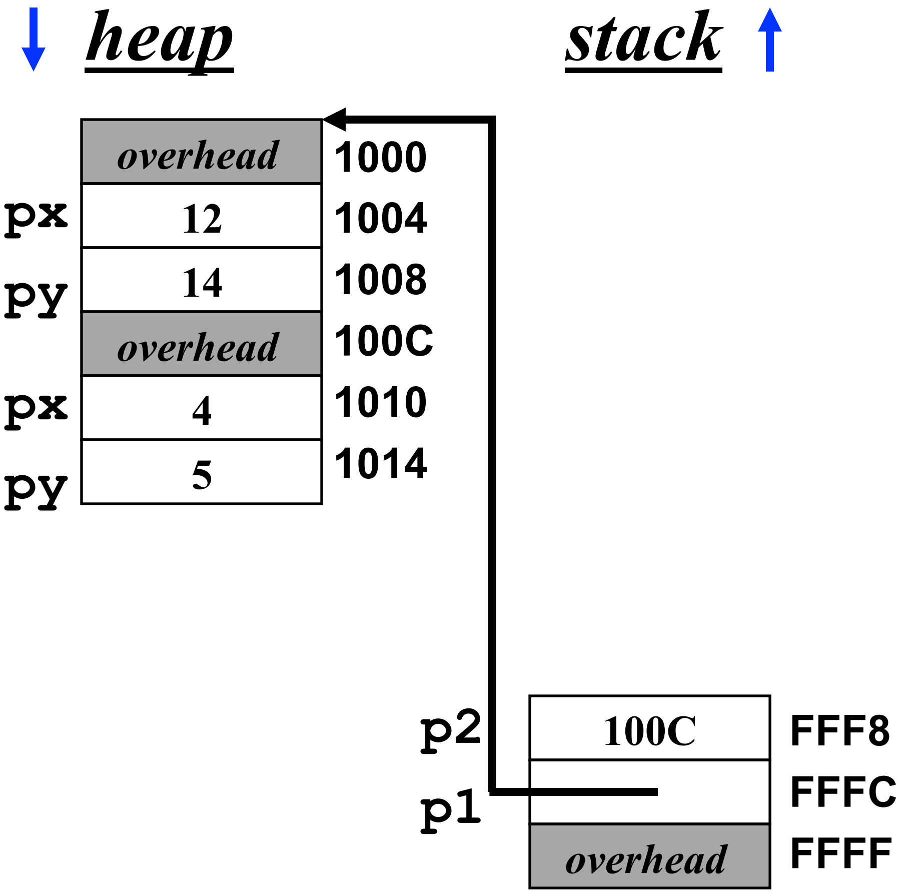
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
          extends ConsoleProgram {

    public void run() {
       Point p1 = new Point(2, 3);
       Point p2 = new Point(4, 5);
       p1.move(10, 11);
       ...
    }

}
```

Pointer Viewpoint



heap ↓

	overhead	1000
px	12	1004
py	14	1008
	overhead	100C
px	4	1010
py	5	1014

stack ↑

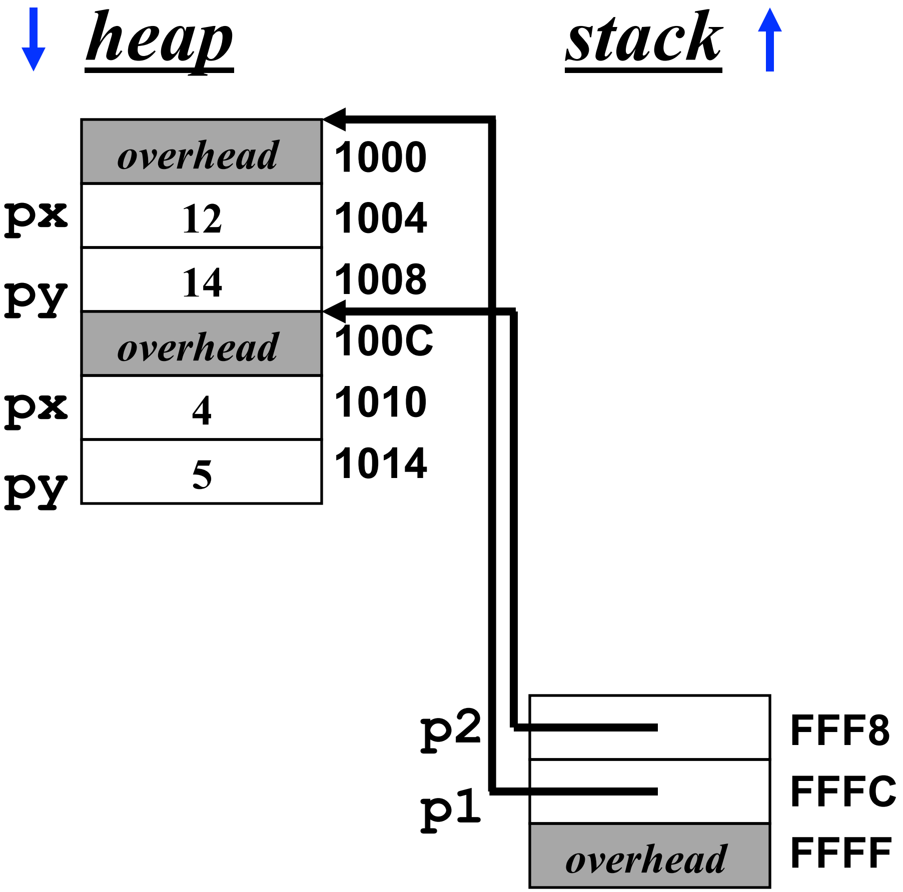
p2	100C	FFF8
p1		FFFC
	overhead	FFFF

```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      p1.move(10, 11);
      ...
   }

}
```

Pointer Viewpoint



heap ***stack***

	overhead	1000
px	12	1004
py	14	1008
	overhead	100C
px	4	1010
py	5	1014

p2		FFF8
p1		FFFC
	overhead	FFFF

```
public class MyProgram
          extends ConsoleProgram {

    public void run() {
       Point p1 = new Point(2, 3);
       Point p2 = new Point(4, 5);
       p1.move(10, 11);
       ...
    }

}
```

Memory Allocation

```
public class Point {

   public Point(int x, int y) {
     px = x;
     py = y;
   }

   /* instance variables */
   private int px;
   private int py;
}

public class Line {

   public Line(Point p1,
               Point p2) {
     beg = p1;
     end = p2;
   }

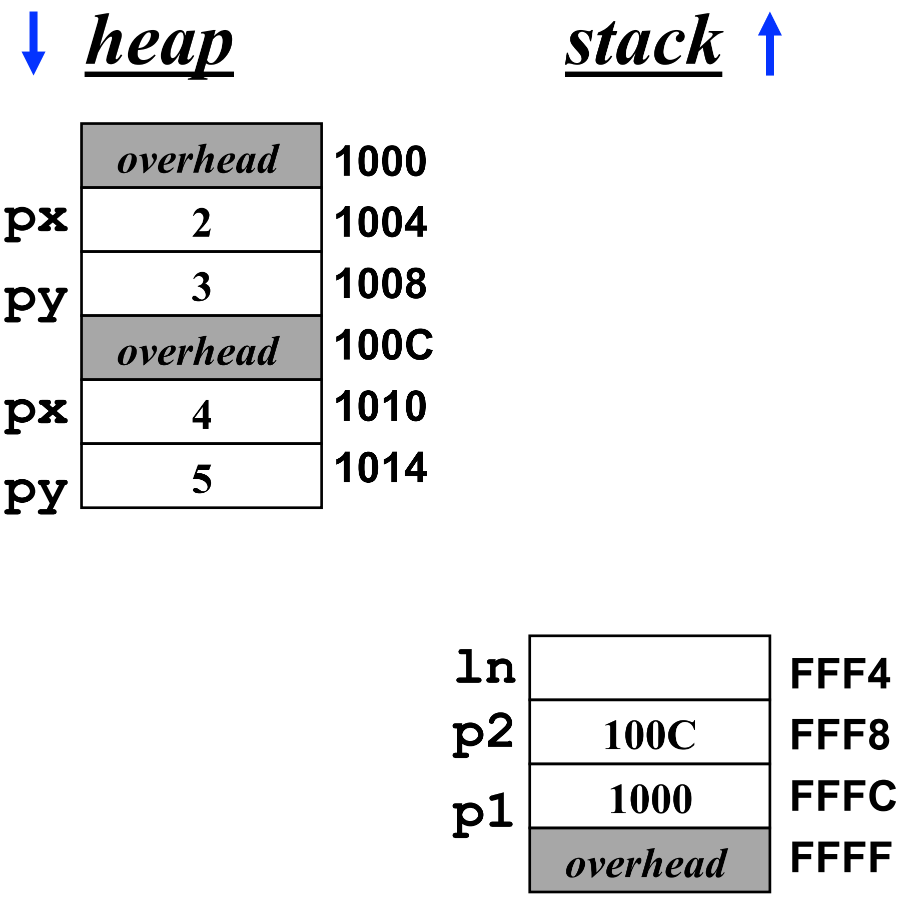
   /* instance variables */
   private Point beg;
   private Point end;
}
```

```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     Line ln = new Line(p1, p2);
   }

}
```

Memory Allocation



↓ ***heap***

stack ↑

	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014

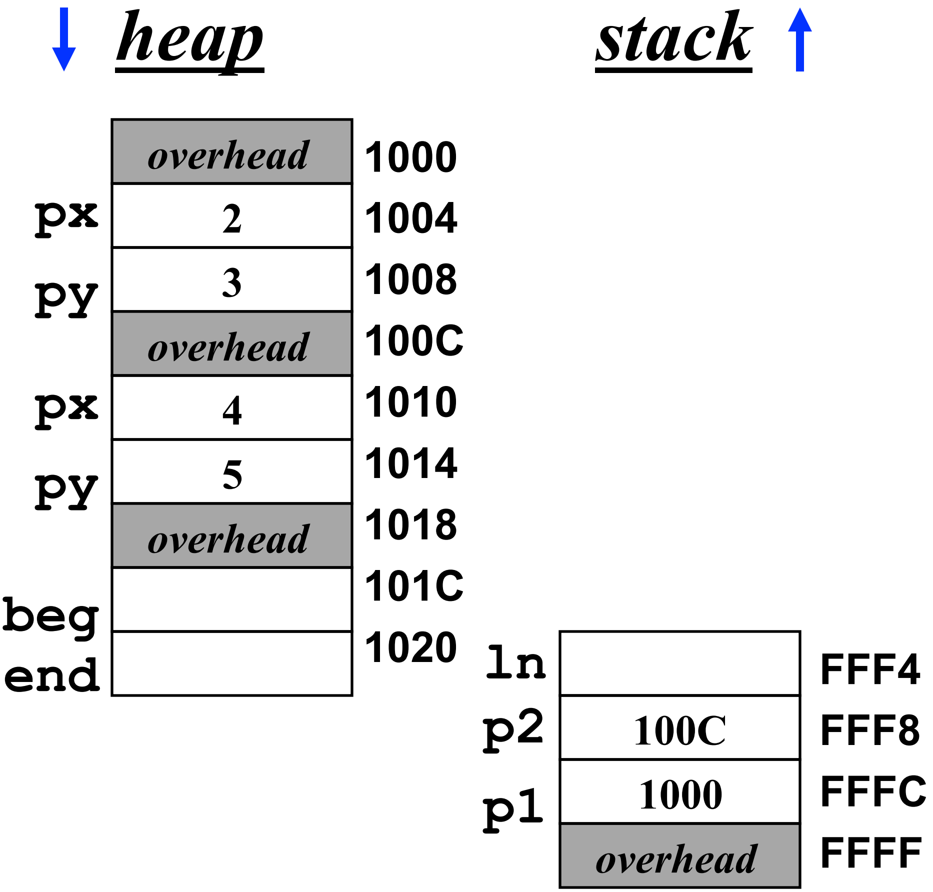
ln		FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
       extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      Line ln = new Line(p1, p2);
   }

}
```

Memory Allocation



	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014
	overhead	1018
beg		101C
end		1020

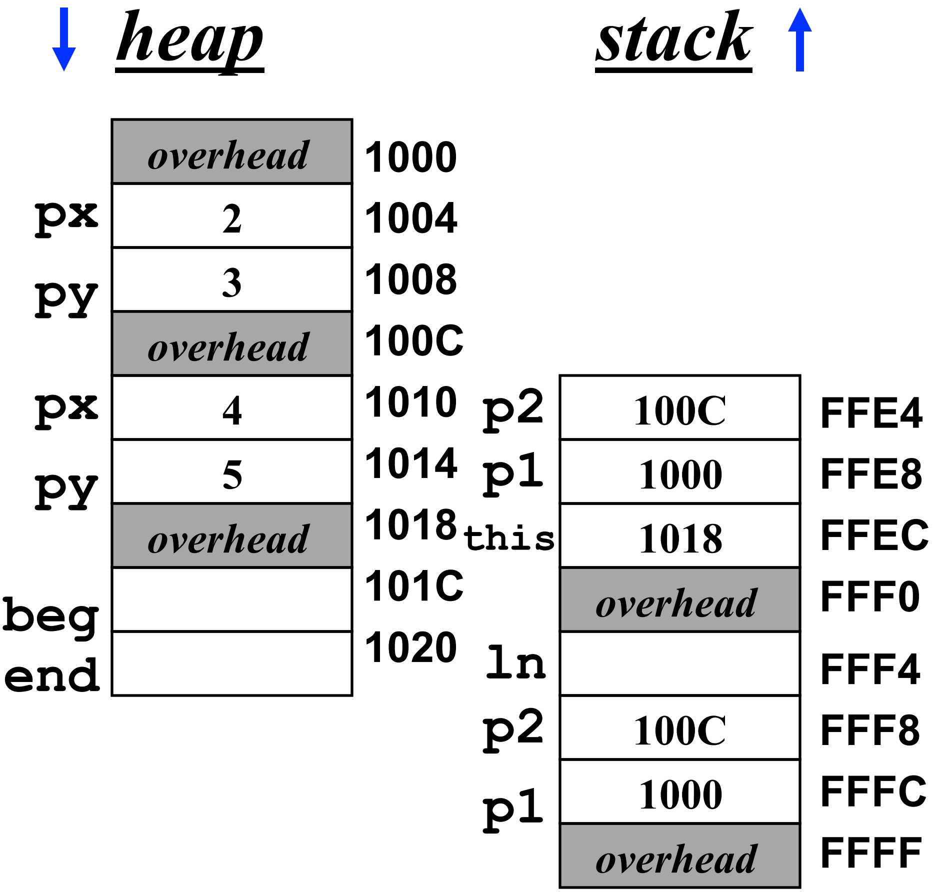
ln		FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
      extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      Line ln = new Line(p1, p2);
   }

}
```

Memory Allocation



	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014
	overhead	1018
beg		101C
end		1020

p2	100C	FFE4
p1	1000	FFE8
this	1018	FFEC
	overhead	FFF0
ln		FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

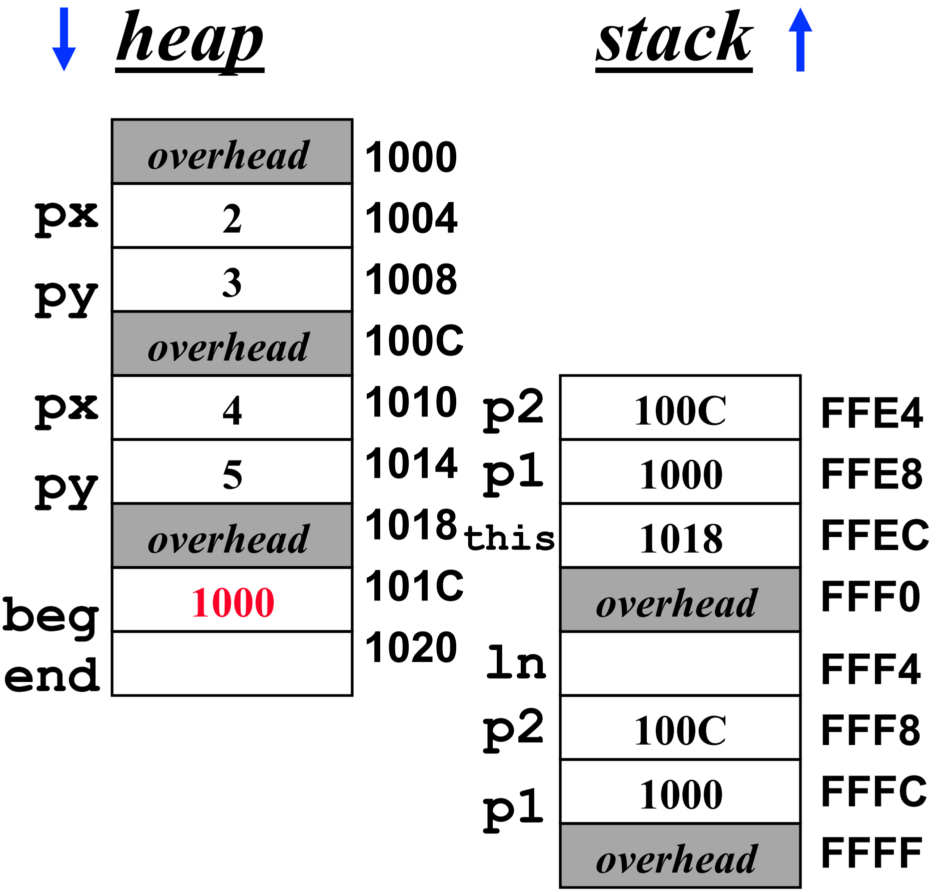
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      Line ln = new Line(p1, p2);
   }

}
```

```
   public Line(Point p1,
               Point p2) {
         beg = p1;
         end = p2;
   }
```

Memory Allocation



heap

	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014
	overhead	1018
beg	1000	101C
end		1020

stack

p2	100C	FFE4
p1	1000	FFE8
this	1018	FFEC
	overhead	FFF0
ln		FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

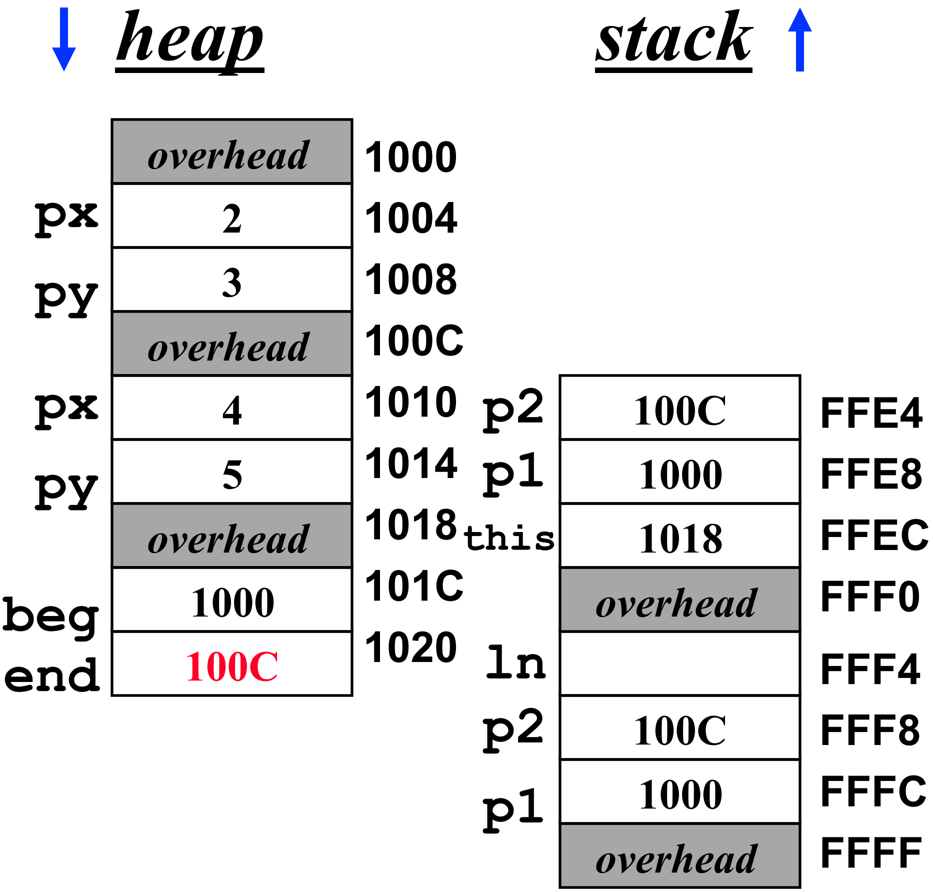
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      Line ln = new Line(p1, p2);
   }

}
```

```
   public Line(Point p1,
               Point p2) {
        beg = p1;
        end = p2;
   }
```

Memory Allocation



heap

	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014
	overhead	1018
beg	1000	101C
end	100C	1020

stack

p2	100C	FFE4
p1	1000	FFE8
this	1018	FFEC
	overhead	FFF0
ln		FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

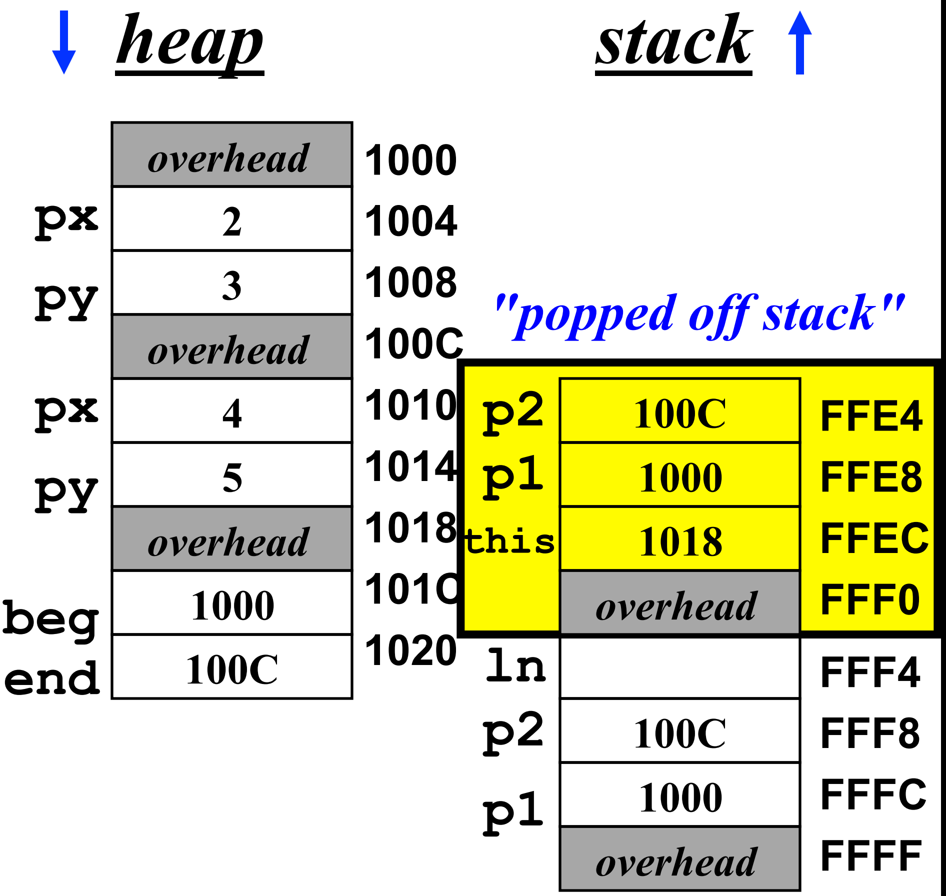
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      Line ln = new Line(p1, p2);
   }

}
```

```
public Line(Point p1,
            Point p2) {
       beg = p1;
       end = p2;
}
```

Memory Allocation



	heap	
	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014
	overhead	1018
beg	1000	101C
end	100C	1020

	stack	
p2	100C	FFE4
p1	1000	FFE8
this	1018	FFEC
	overhead	FFF0
ln		FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

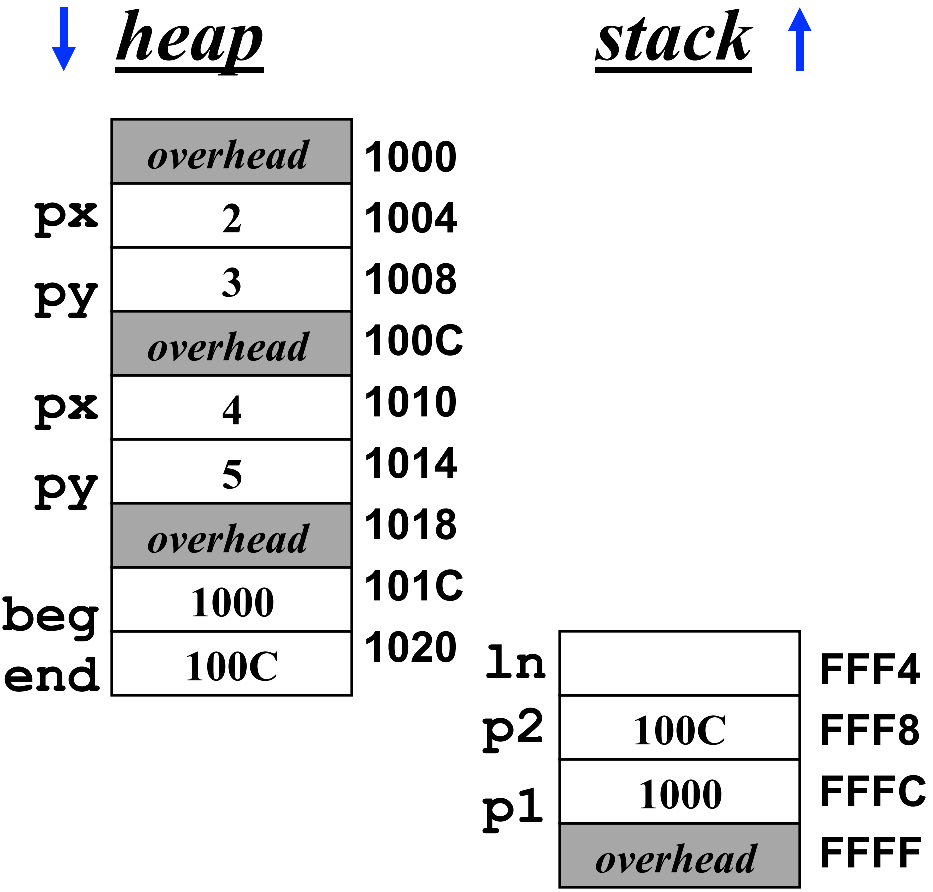
```
public class MyProgram
      extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      Line ln = new Line(p1, p2);
   }

}
```

```
public Line(Point p1,
            Point p2) {
      beg = p1;
      end = p2;
}
```

Memory Allocation



↓ ***heap***

	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014
	overhead	1018
beg	1000	101C
end	100C	1020

stack ↑

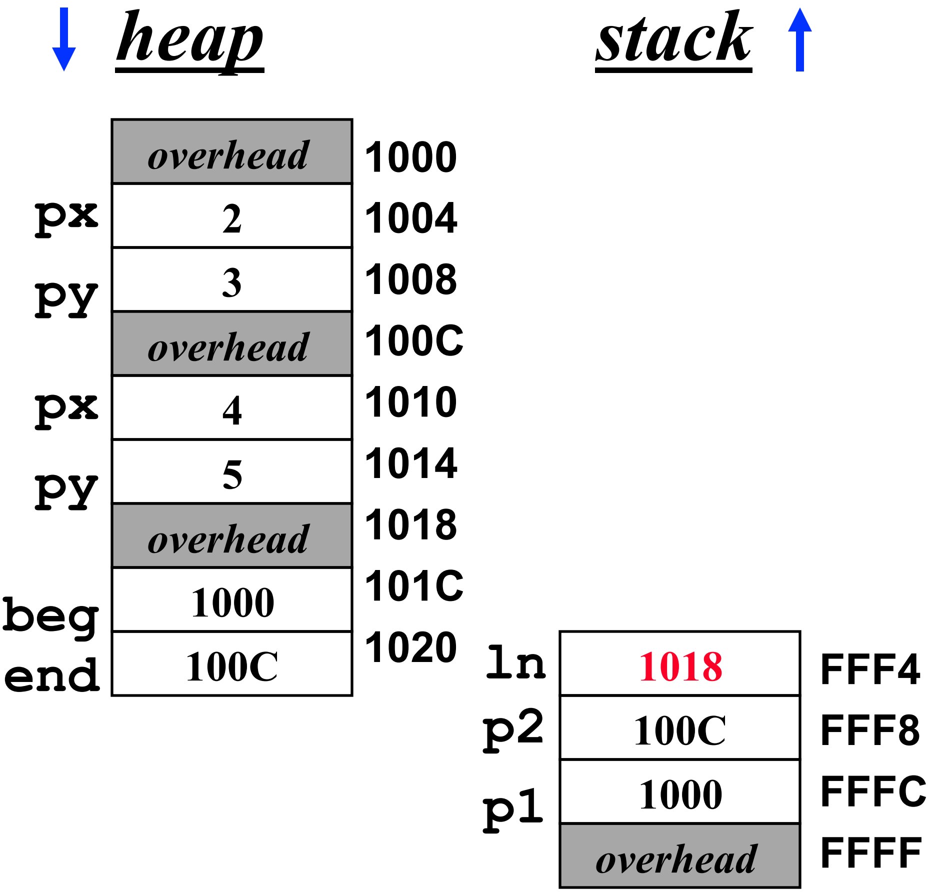
ln		FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     Line ln = new Line(p1, p2);
   }

}
```

Memory Allocation



↓ ***heap***

	overhead	1000
px	2	1004
py	3	1008
	overhead	100C
px	4	1010
py	5	1014
	overhead	1018
beg	1000	101C
end	100C	1020

stack ↑

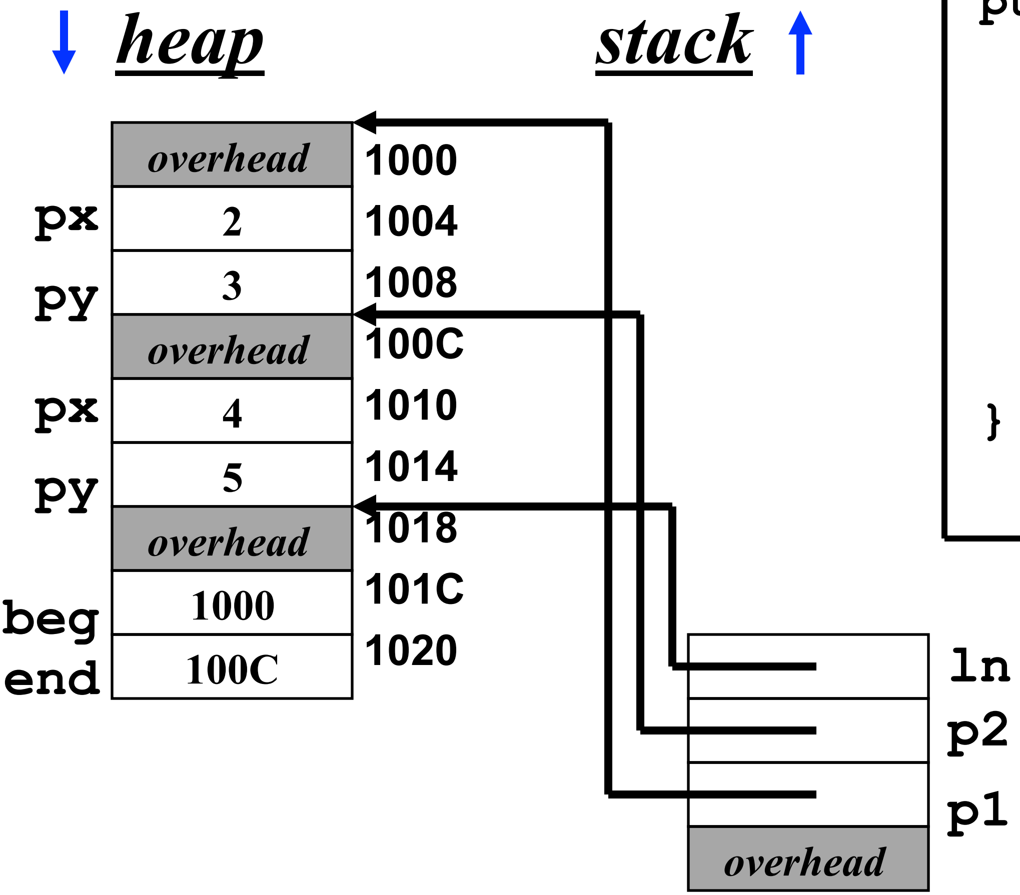
ln	1018	FFF4
p2	100C	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(2, 3);
      Point p2 = new Point(4, 5);
      Line ln = new Line(p1, p2);
   }

}
```

Pointer Viewpoint

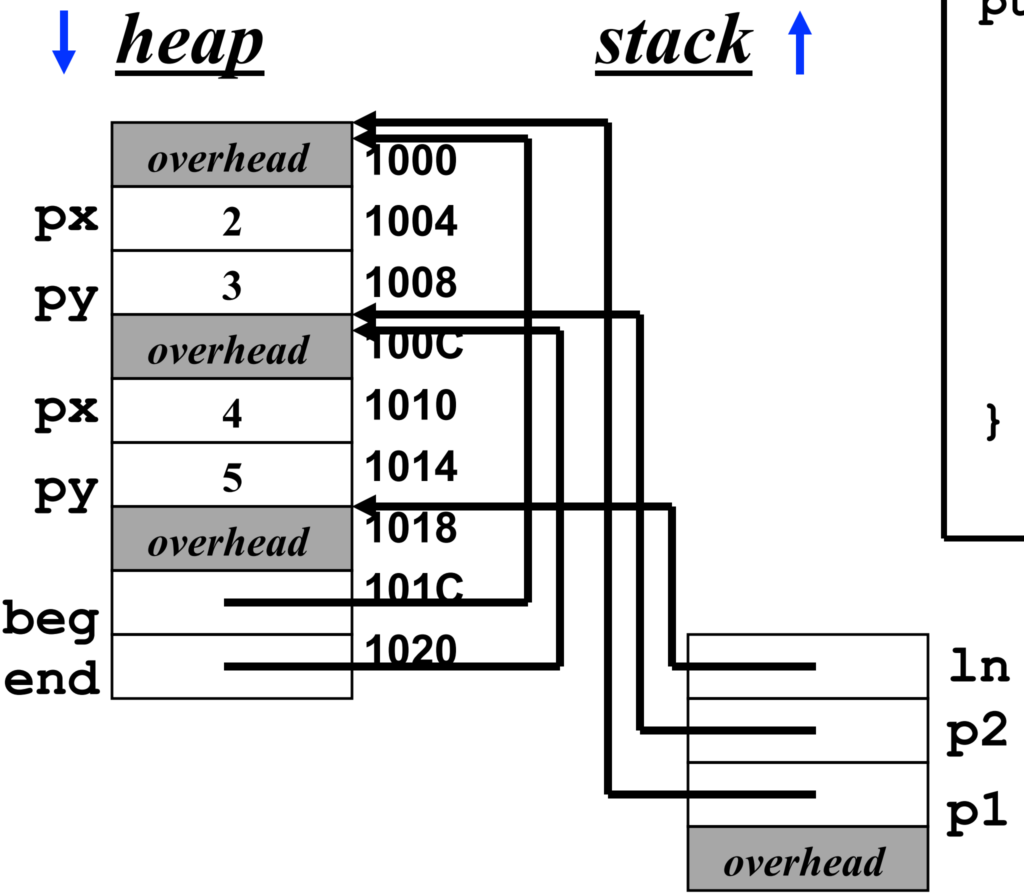


```
public class MyProgram
       extends ConsoleProgram {

   public void run() {
     Point p1 = new Point(2, 3);
     Point p2 = new Point(4, 5);
     Line ln = new Line(p1, p2);
   }

}
```

Pointer Viewpoint



```
public class MyProgram
       extends ConsoleProgram {

  public void run() {
    Point p1 = new Point(2, 3);
    Point p2 = new Point(4, 5);
    Line ln = new Line(p1, p2);
  }

}
```

Another Example

```
public class MyProgram
       extends ConsoleProgram {
  public void run() {
    Point p1 = new Point(1, 2);
    Point p2 = p1;
    p2.move(3, 4);

    Point p3;
    p3.move(1, 1);
  }
}
```

Another Example

↓ ***heap*** ***stack*** ↑

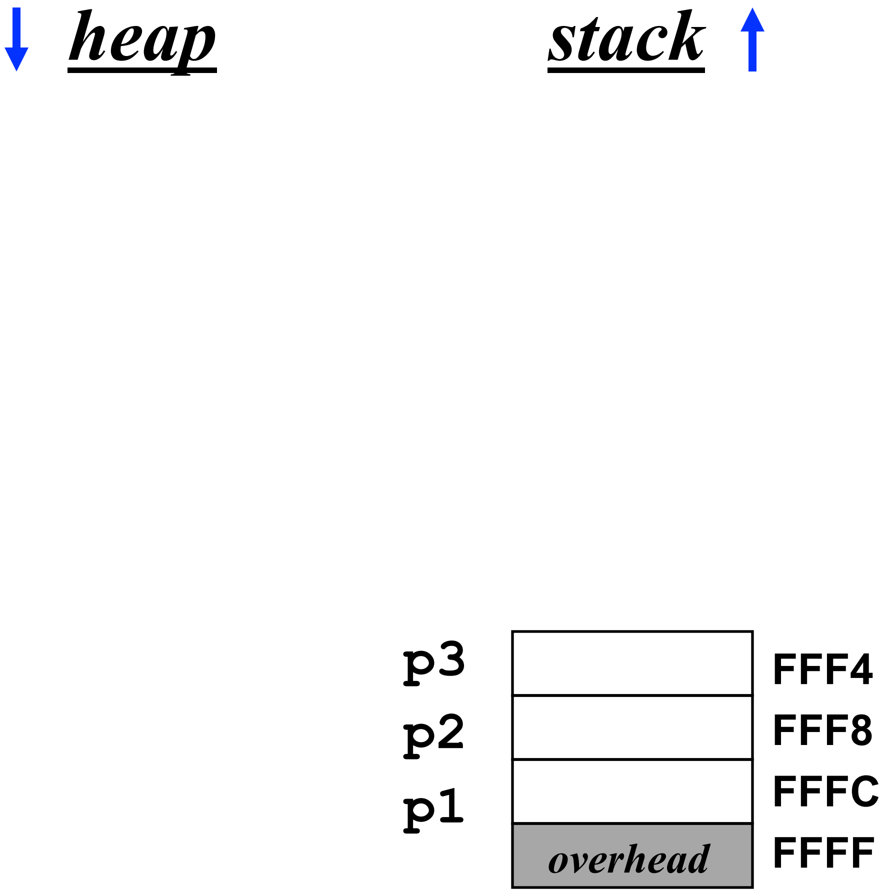
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(1, 2);
      Point p2 = p1;
      p2.move(3, 4);

      Point p3;
      p3.move(1, 1);
   }

}
```

Another Example



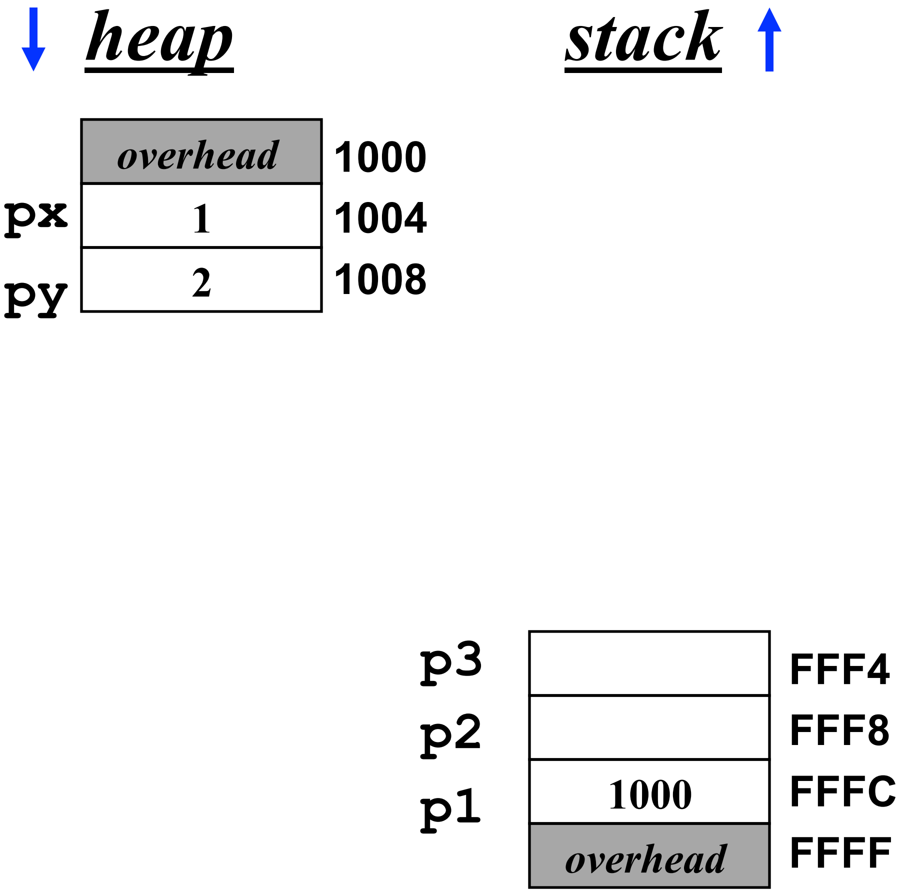
```
public class MyProgram
       extends ConsoleProgram {

  public void run() {
    Point p1 = new Point(1, 2);
    Point p2 = p1;
    p2.move(3, 4);

    Point p3;
    p3.move(1, 1);
  }

}
```

Another Example



heap

	overhead	1000
px	1	1004
py	2	1008

stack

p3		FFF4
p2		FFF8
p1	1000	FFFC
	overhead	FFFF

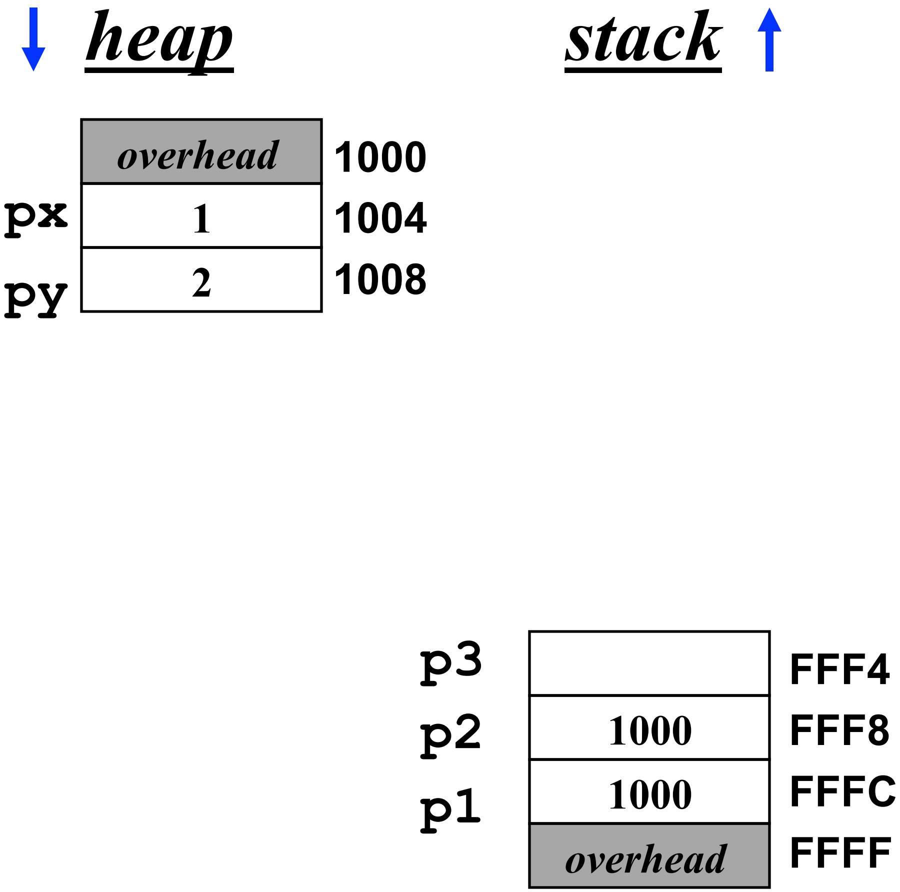
```
public class MyProgram
        extends ConsoleProgram {

    public void run() {
        Point p1 = new Point(1, 2);
        Point p2 = p1;
        p2.move(3, 4);

        Point p3;
        p3.move(1, 1);
    }

}
```

Another Example



heap

	overhead	1000
px	1	1004
py	2	1008

stack

p3		FFF4
p2	1000	FFF8
p1	1000	FFFC
	overhead	FFFF

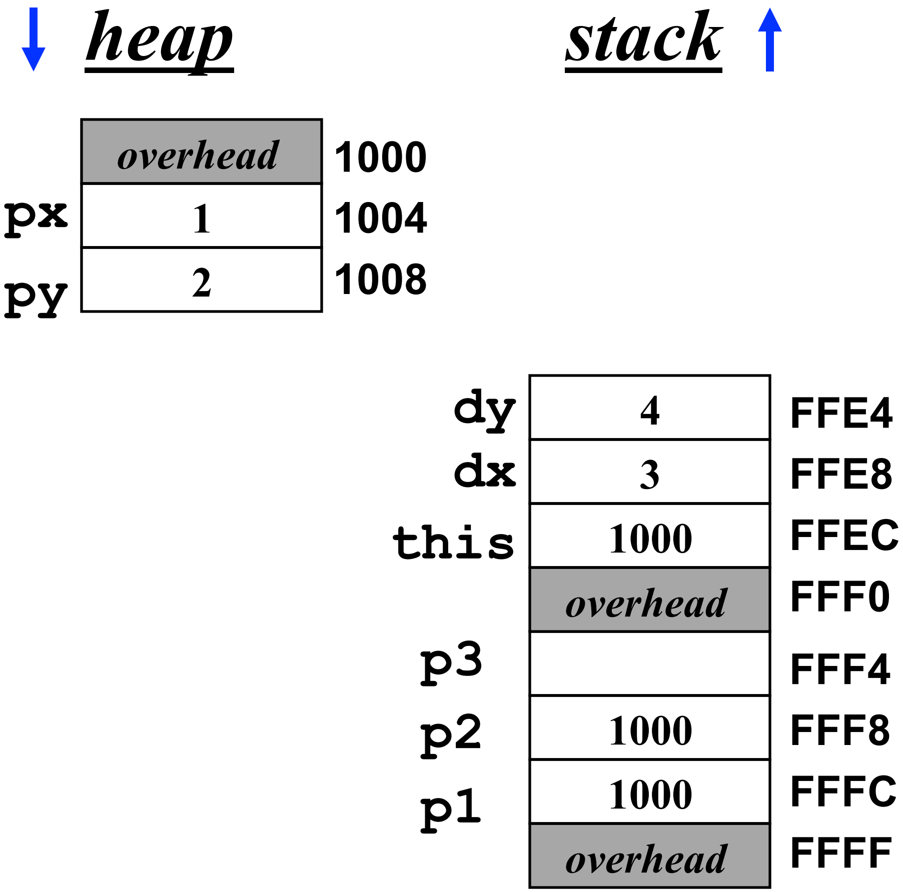
```
public class MyProgram
       extends ConsoleProgram {

  public void run() {
    Point p1 = new Point(1, 2);
    Point p2 = p1;
    p2.move(3, 4);

    Point p3;
    p3.move(1, 1);
  }

}
```

Another Example



↓ ***heap***

	overhead	1000
px	1	1004
py	2	1008

stack ↑

dy	4	FFE4
dx	3	FFE8
this	1000	FFEC
	overhead	FFF0
p3		FFF4
p2	1000	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
            extends ConsoleProgram {

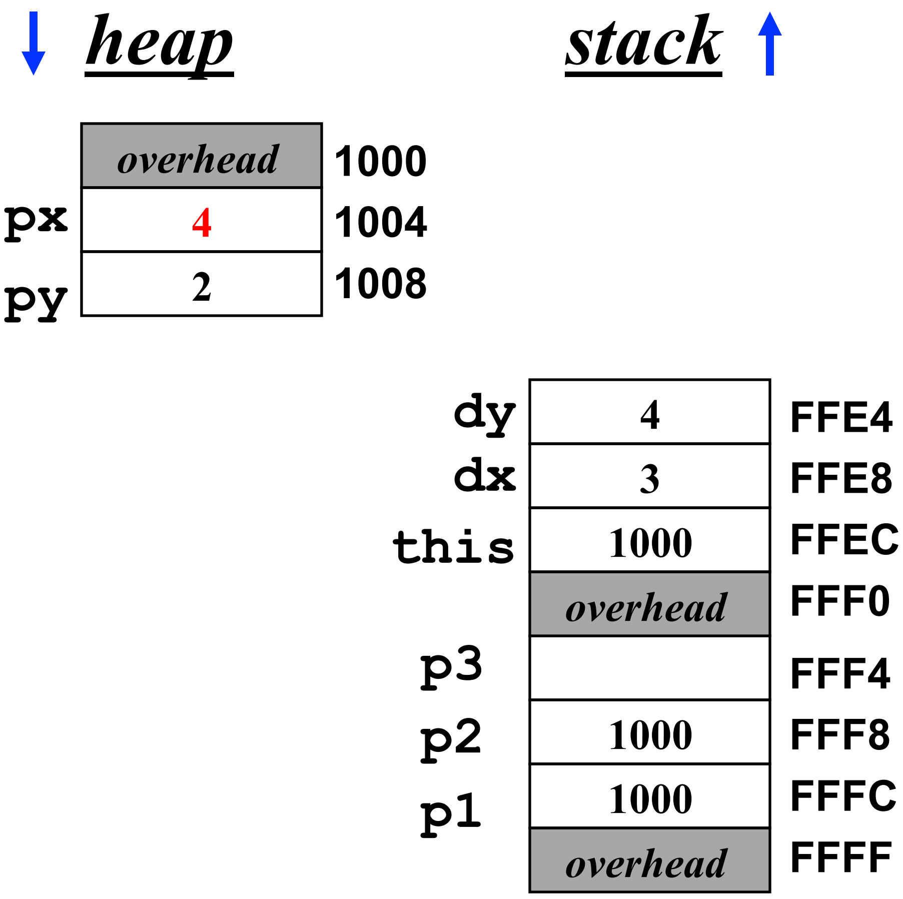
    public void run() {
        Point p1 = new Point(1, 2);
        Point p2 = p1;
        p2.move(3, 4);

        Point p3;
        p3.move(1, 1);
    }

}
```

```
    public void move(int dx,
                     int dy) {
        px += dx;
        py += dy;
    }
```

Another Example



↓ ***heap***

	overhead	1000
px	4	1004
py	2	1008

stack ↑

dy	4	FFE4
dx	3	FFE8
this	1000	FFEC
	overhead	FFF0
p3		FFF4
p2	1000	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
          extends ConsoleProgram {

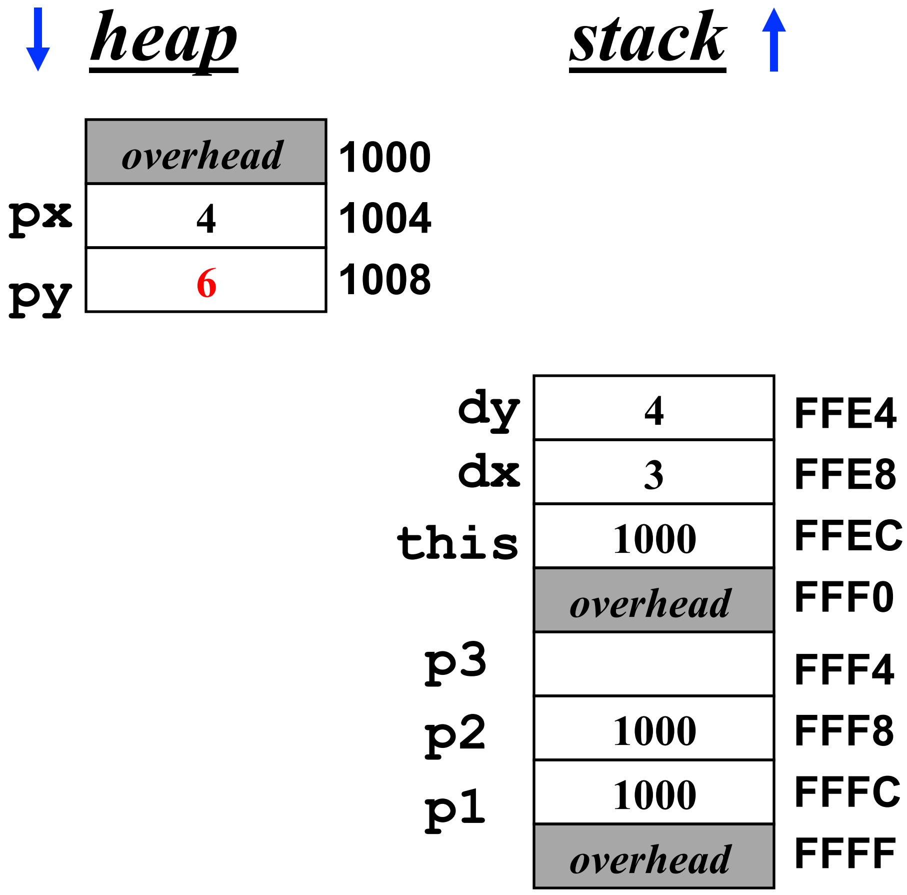
   public void run() {
     Point p1 = new Point(1, 2);
     Point p2 = p1;
     p2.move(3, 4);

     Point p3;
     p3.move(1, 1);
   }

}
```

```
   public void move(int dx,
                    int dy) {
     px += dx;
     py += dy;
   }
```

Another Example



heap

	overhead	1000
px	4	1004
py	6	1008

stack

dy	4	FFE4
dx	3	FFE8
this	1000	FFEC
	overhead	FFF0
p3		FFF4
p2	1000	FFF8
p1	1000	FFFC
	overhead	FFFF

```
public class MyProgram
        extends ConsoleProgram {

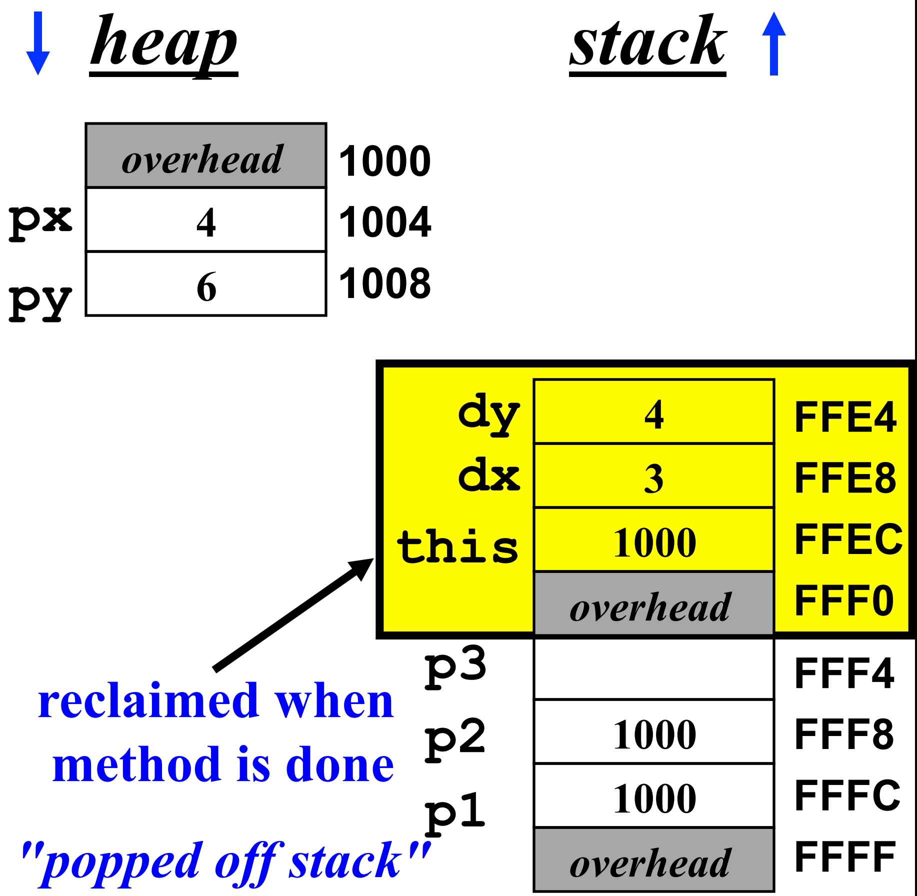
   public void run() {
     Point p1 = new Point(1, 2);
     Point p2 = p1;
     p2.move(3, 4);

     Point p3;
     p3.move(1, 1);
   }

}
```

```
   public void move(int dx,
                    int dy) {
     px += dx;
     py += dy;
   }
```

Another Example



	overhead	1000
px	4	1004
py	6	1008

dy	4	FFE4
dx	3	FFE8
this	1000	FFEC
	overhead	FFF0
p3		FFF4
p2	1000	FFF8
p1	1000	FFFC
	overhead	FFFF

reclaimed when method is done

"popped off stack"

```
public class MyProgram
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   public void run() {
     Point p1 = new Point(1, 2);
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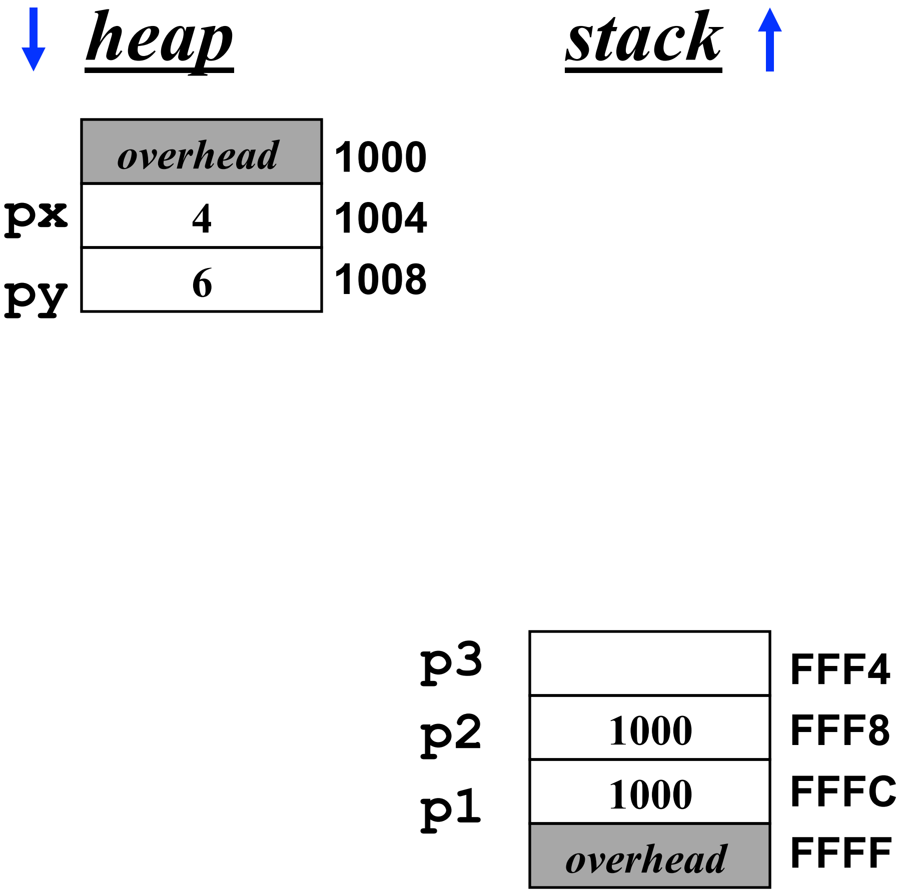
     p2.move(3, 4);

     Point p3;
     p3.move(1, 1);
   }

}
```

```
   public void move(int dx,
                    int dy) {
     px += dx;
     py += dy;
   }
```

Another Example



↓ ***heap***

	overhead	1000
px	4	1004
py	6	1008

stack ↑

p3		FFF4
p2	1000	FFF8
p1	1000	FFFC
	overhead	FFFF

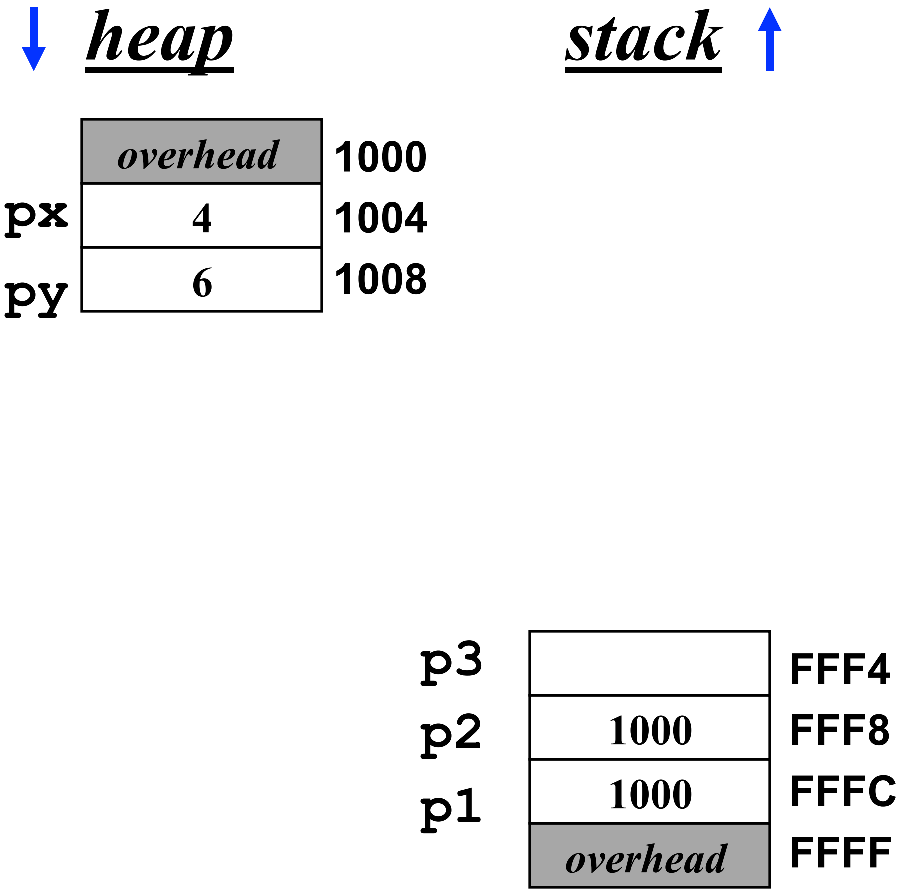
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(1, 2);
      Point p2 = p1;
      p2.move(3, 4);

      Point p3;
      p3.move(1, 1);
   }

}
```

Another Example



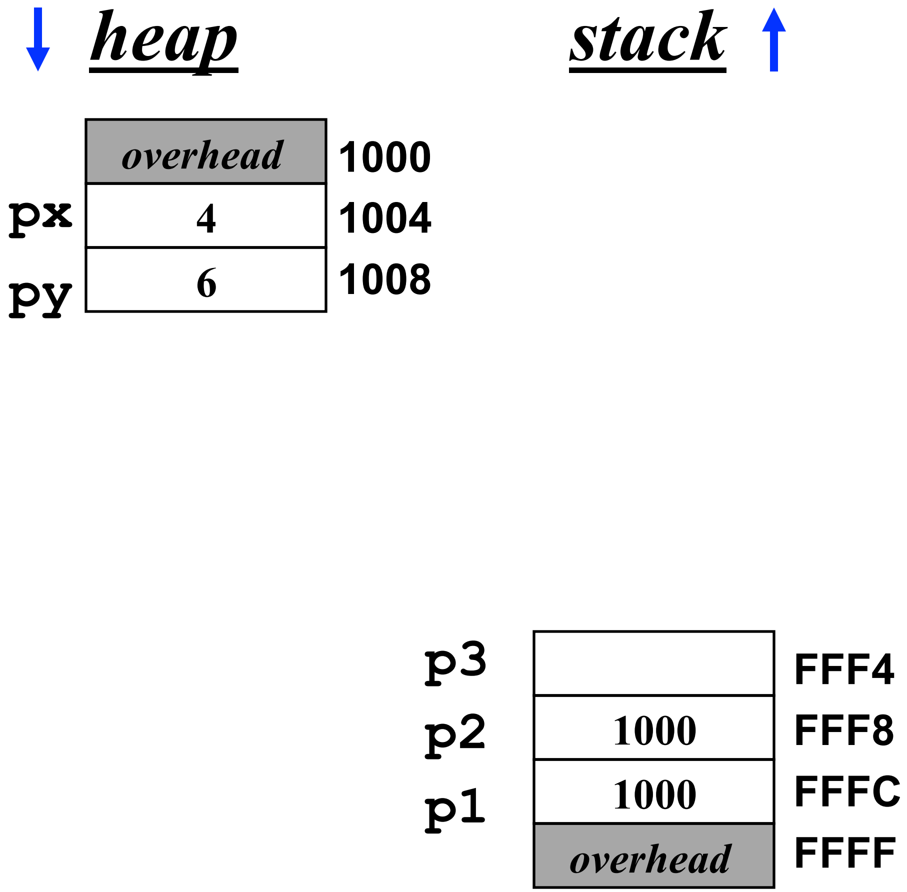
```
public class MyProgram
        extends ConsoleProgram {

   public void run() {
      Point p1 = new Point(1, 2);
      Point p2 = p1;
      p2.move(3, 4);

      Point p3;
      p3.move(1, 1);
   }

}
```

Another Example



heap

	overhead	1000
px	4	1004
py	6	1008

stack

p3		FFF4
p2	1000	FFF8
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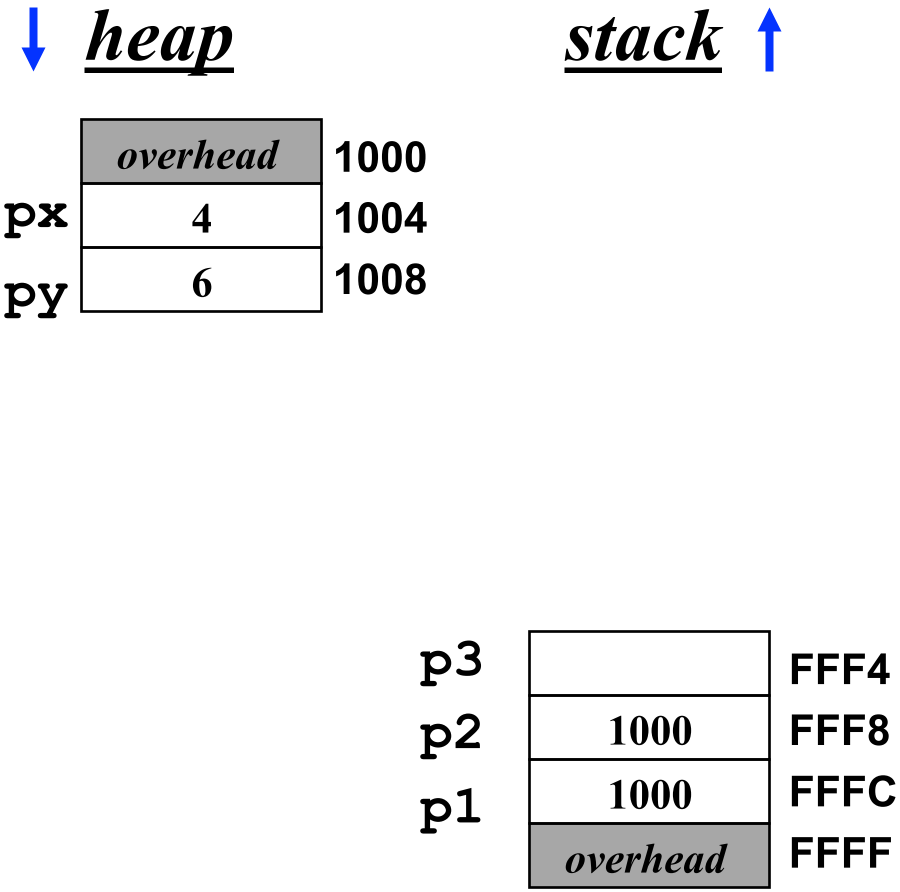
    p3.move(1, 1);
  }

}
```

Another Example



heap

	overhead	1000
px	4	1004
py	6	1008

stack

p3		FFF4
p2	1000	FFF8
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```
public class MyProgram
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  public void run() {
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    Point p2 = p1;
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    Point p3;
    p3.move(1, 1);
  }

}
```

ERROR!

p3 is not pointing to a valid object!