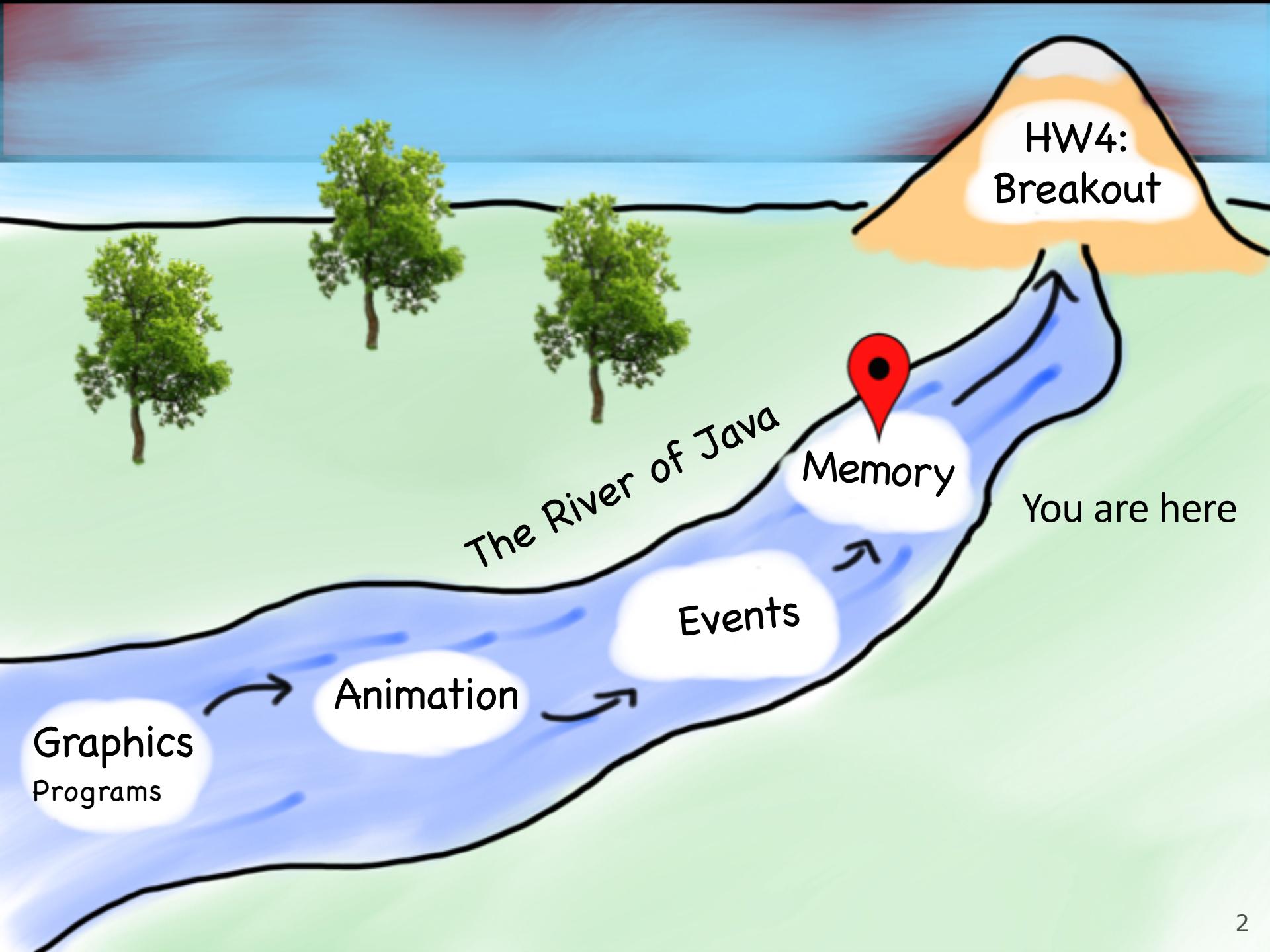


CS 106A, Lecture 15

Events and Memory



Plan for Today

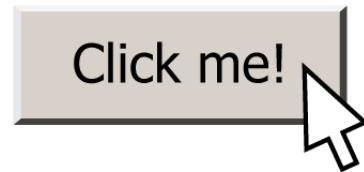
- Review: events and instance variables
- A Boolean Aside
- Memory
- Revisiting Whack-A-Mole
- Midterm tips

Plan for Today

- Review: events and instance variables
- A Boolean Aside
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Events

- **event:** Some external stimulus that your program can respond to.



- **event-driven programming:** A coding style (common in graphical programs) where your code is executed in response to user events.

Events

```
public void run() {  
    // Java runs this when program launches  
}  
  
public void mouseClicked(MouseEvent event) {  
    // Java runs this when mouse is clicked  
}  
  
public void mouseMoved(MouseEvent event) {  
    // Java runs this when mouse is moved  
}
```

Types of Mouse Events

- There are many different types of mouse events.

- Each takes the form:

```
public void eventMethodName(MouseEvent event) { ... }
```

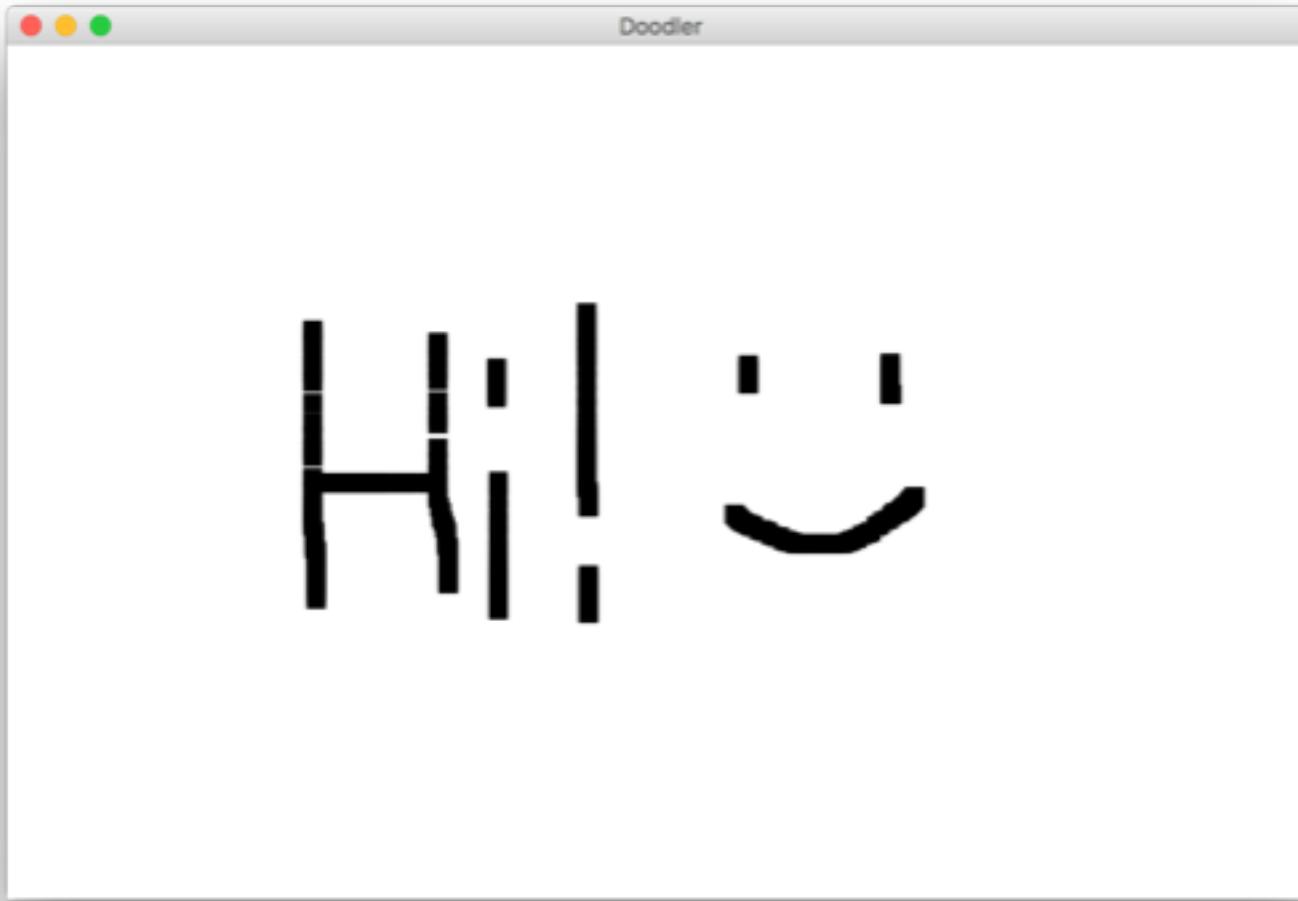
Method	Description
mouseMoved	mouse cursor moves
mouseDragged	mouse cursor moves while button is held down
mousePressed	mouse button is pressed down
mouseReleased	mouse button is lifted up
mouseClicked	mouse button is pressed and then released
mouseEntered	mouse cursor enters your program's window
mouseExited	mouse cursor leaves your program's window

MouseEvent Objects

- A MouseEvent contains information about the event that just occurred:

Method	Description
<code>e.getX()</code>	the x-coordinate of mouse cursor in the window
<code>e.getY()</code>	the y-coordinate of mouse cursor in the window

Example: Doodler



Doodler

```
public void mouseDragged(MouseEvent event) {  
    double mouseX = event.getX();  
    double mouseY = event.getY();  
    double rectX = mouseX - SIZE / 2.0;  
    double rectY = mouseY - SIZE / 2.0;  
    GRect rect = new GRect(rectX, rectY, SIZE, SIZE);  
    rect.setFilled(true);  
    add(rect);  
}
```

What if we wanted the *same* GRect to track the mouse, instead of making a new one each time?

Instance Variables

```
private type name; // declared outside of any method
```

- **Instance variable:** A variable that lives outside of any method.
 - The *scope* of an instance variable is throughout an entire file (class).
 - Useful for data that must persist throughout the program, or that cannot be stored as local variables or parameters (event handlers).
 - *It is bad style to overuse instance variables*

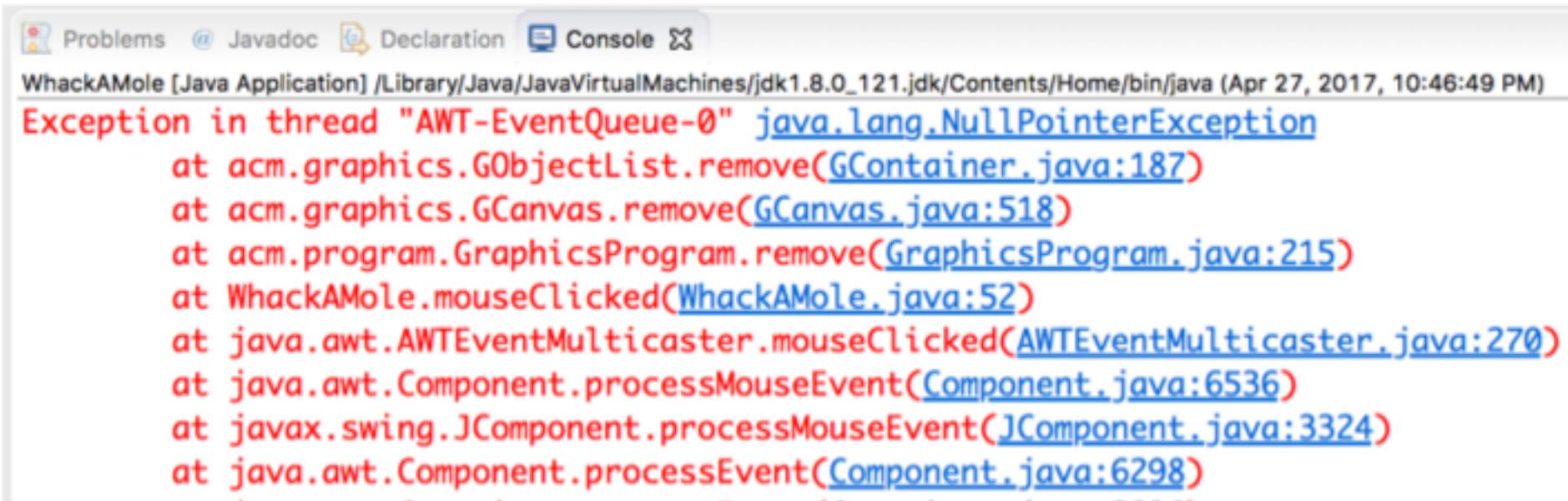
Whack-A-Mole

We used instance variables and events to make Whack-A-Mole!



Exception

- If the user clicks an area with no mole, the program crashes.
 - A program crash in Java is called an **exception**.
 - When you get an exception, Eclipse shows red error text.
 - The error text shows the line number where the error occurred.
 - Why did this error happen?
 - How can we avoid this?



The screenshot shows the Eclipse IDE interface with the 'Console' tab selected. The console window displays a stack trace for a `java.lang.NullPointerException`. The text is color-coded in red, indicating it is an error message. The stack trace lists the following frames:

```
WhackAMole [Java Application] /Library/Java/JavaVirtualMachines/jdk1.8.0_121.jdk/Contents/Home/bin/java (Apr 27, 2017, 10:46:49 PM)
Exception in thread "AWT-EventQueue-0" java.lang.NullPointerException
    at acm.graphics.GObjectList.remove(GContainer.java:187)
    at acm.graphics.GCanvas.remove(GCanvas.java:518)
    at acm.program.GraphicsProgram.remove(GraphicsProgram.java:215)
    at WhackAMole.mouseClicked(WhackAMole.java:52)
    at java.awt.AWTEventMulticaster.mouseClicked(AWTEventMulticaster.java:270)
    at java.awt.Component.processMouseEvent(Component.java:6536)
    at javax.swing.JComponent.processMouseEvent(JComponent.java:3324)
    at java.awt.Component.processEvent(Component.java:6298)
```

Whack-A-Null?

```
public void mouseClicked(MouseEvent event) {  
    double mouseX = event.getX();  
    double mouseY = event.getY();  
    GObject mole = getElementAt(mouseX, mouseY);  
  
    remove(mole);  
    score++;  
    scoreLabel.setText("Score: " + score);  
}
```

Whack-A-Null?

```
public void mouseClicked(MouseEvent event) {  
    double mouseX = event.getX();  
    double mouseY = event.getY();  
    GObject mole = getElementAt(mouseX, mouseY);  
  
    remove(mole);  
    score++;  
    scoreLabel.setText("Score: " + score);  
}
```

Problem: **mole** may be null if the user doesn't click on a mole! Removing null will crash ☹

Whack-A-Mole!

```
public void mouseClicked(MouseEvent event) {  
    double mouseX = event.getX();  
    double mouseY = event.getY();  
    GObject mole = getElementAt(mouseX, mouseY);  
  
    if (mole != null) {  
        remove(mole);  
        score++;  
        scoreLabel.setText("Score: " + score);  
    }  
}
```

Plan for Today

- Review: events and instance variables
- A Boolean Aside
- Memory
- Revisiting Whack-A-Mole
- Midterm tips

A Boolean Aside

There is one helpful property of how Java evaluates boolean expressions, called **short-circuit evaluation**.

When evaluating boolean expressions, Java only evaluates *as much of the expression as it needs to* in order to evaluate it to be true or false.

A Boolean Aside

```
String str = readLine("? ");

if (str.length() > 0 && str.charAt(0) == 'A') {

    ...

}
```

A Boolean Aside

```
String str = readLine("? "); // what about ""!  
  
if (str.length() > 0 && str.charAt(0) == 'A') {  
    ...  
}
```

A Boolean Aside

```
String str = readLine("? "); // what about ""!  
  
if (str.length() > 0 && str.charAt(0) == 'A') {  
    ...  
}
```

A Boolean Aside

```
String str = readLine("? "); // what about ""!  
  
if (str.length() > 0 && str.charAt(0) == 'A') {  
    ...  
}
```

&& : true if both parts are true

Java only executes the second
part if the first part is **true!**
This means it never crashes.

A Boolean Aside

```
GObject obj = getElementAt(x, y);  
  
if (obj == null || obj.getX() == 0) {  
    ...  
}
```

A Boolean Aside

```
GObject obj = getElementAt(x, y); // what about null!  
  
if (obj == null || obj.getX() == 0) {  
    ...  
}
```

A Boolean Aside

```
GObject obj = getElementAt(x, y); // what about null!  
  
if (obj == null || obj.getX() == 0) {  
    ...  
}
```

A Boolean Aside

```
GObject obj = getElementAt(x, y); // what about null!  
  
if (obj == null || obj.getX() == 0) {  
    ...  
}
```

|| : true if either side is true

Java only executes second part if the first part is **false**!
This means it never crashes.

Plan for Today

- Review: events and instance variables
- A Boolean Aside
- **Memory**
- Revisiting Whack-A-Mole
- Midterm tips

A Variable love story

By Chris Piech

A Variable origin ~~love~~ story

Nick Troccoli

By ~~Chris Piech~~

Chapter 1: Birth

Once upon a time...

...a variable x was born!

```
int x;
```

...a variable x was born!

```
int x;
```



x was a primitive variable...

```
int x;
```

Aww...!

It's so
cuuuute!



...and its parents loved it very much.

```
int x;
```

We should
give it...
value 27!



...and its parents loved it very much.

$$x = 27;$$

We should
give it...
value 27!



A few years later, the parents decided to have another variable.

...and a variable rect was born!

GRect rect;

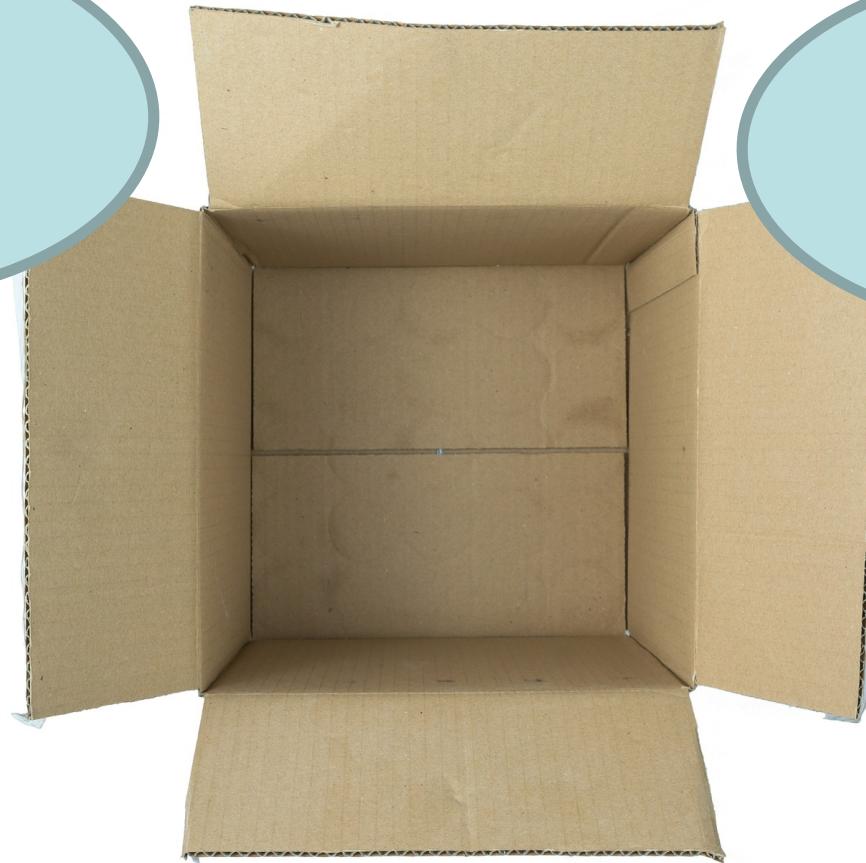


rect was an object variable...

```
GRect rect;
```

Who's a
cute
GRect???

It's so
square!



...and its parents loved it very much.

GRect rect;

We should
make it... a big,
strong GRect!



...and its parents loved it very much.

```
GRect rect = new GRect(0, 0, 50, 50);
```

We should
make it... a big,
strong GRect!



...but rect's box was not big enough for an object!

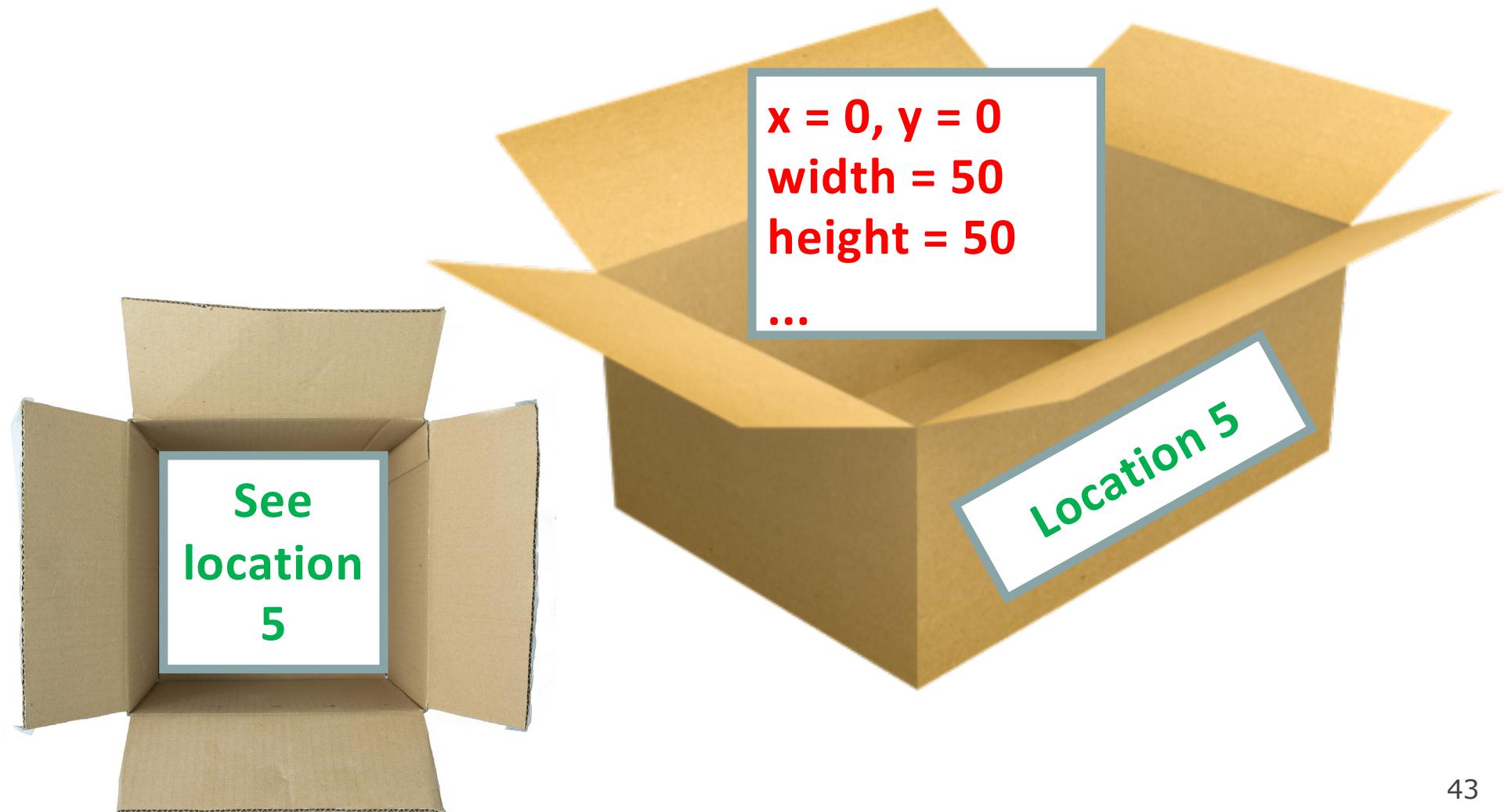
```
GRect rect = new GRect(0, 0, 50, 50);
```

That box isn't
big enough to
store
everything
about a GRect!



...so they stored the information in a bigger box somewhere else.

```
GRect rect = new GRect(0, 0, 50, 50);
```



Chapter 2: Friends

...x makes a new friend!

```
int y = 27;
```



...x makes a new friend!

```
int y = 27;
```

Hi! I'm y.



...x makes a new friend!

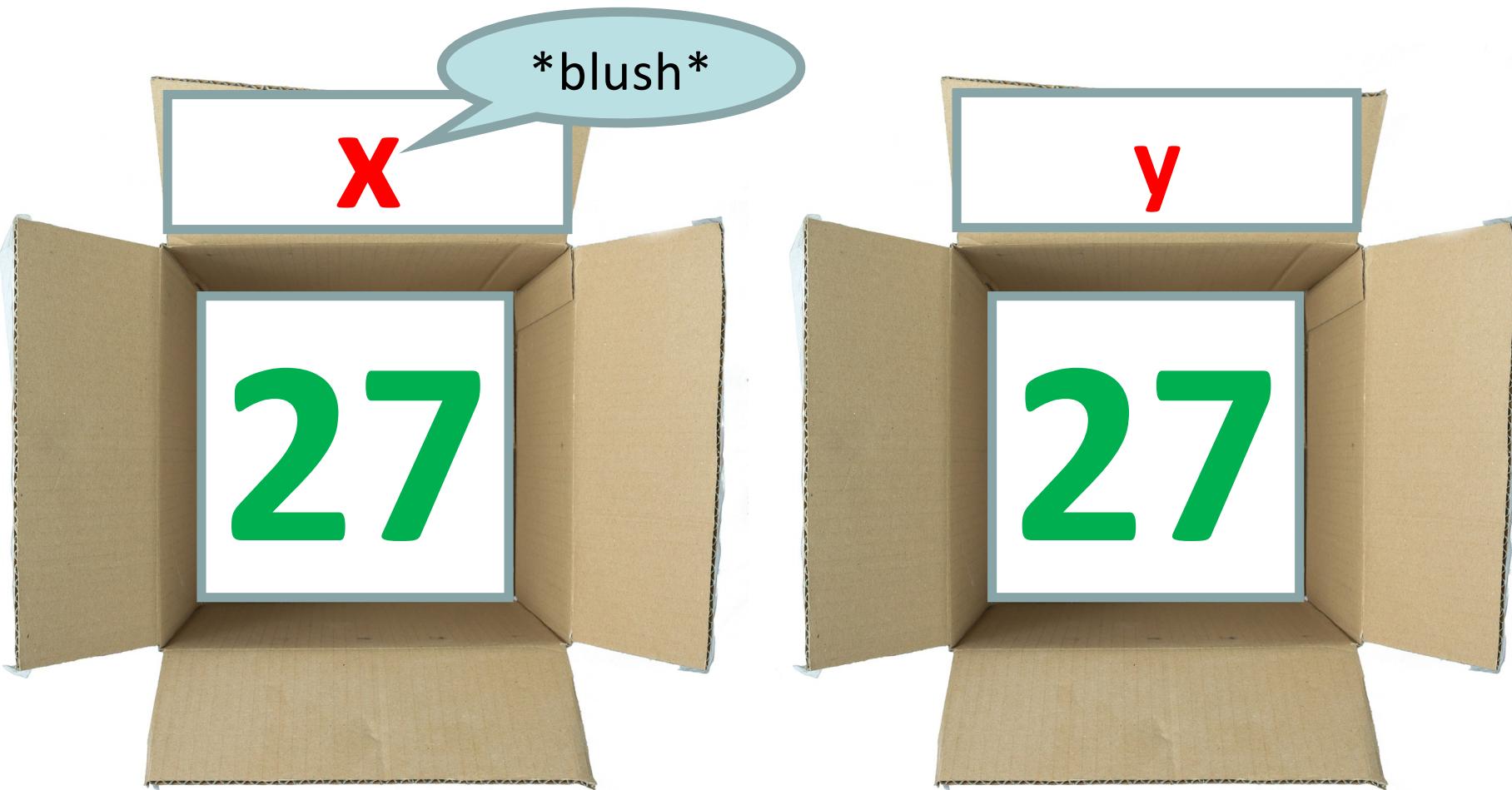
```
int y = 27;
```



We have
the same
value!

...x makes a new friend!

```
int y = 27;
```



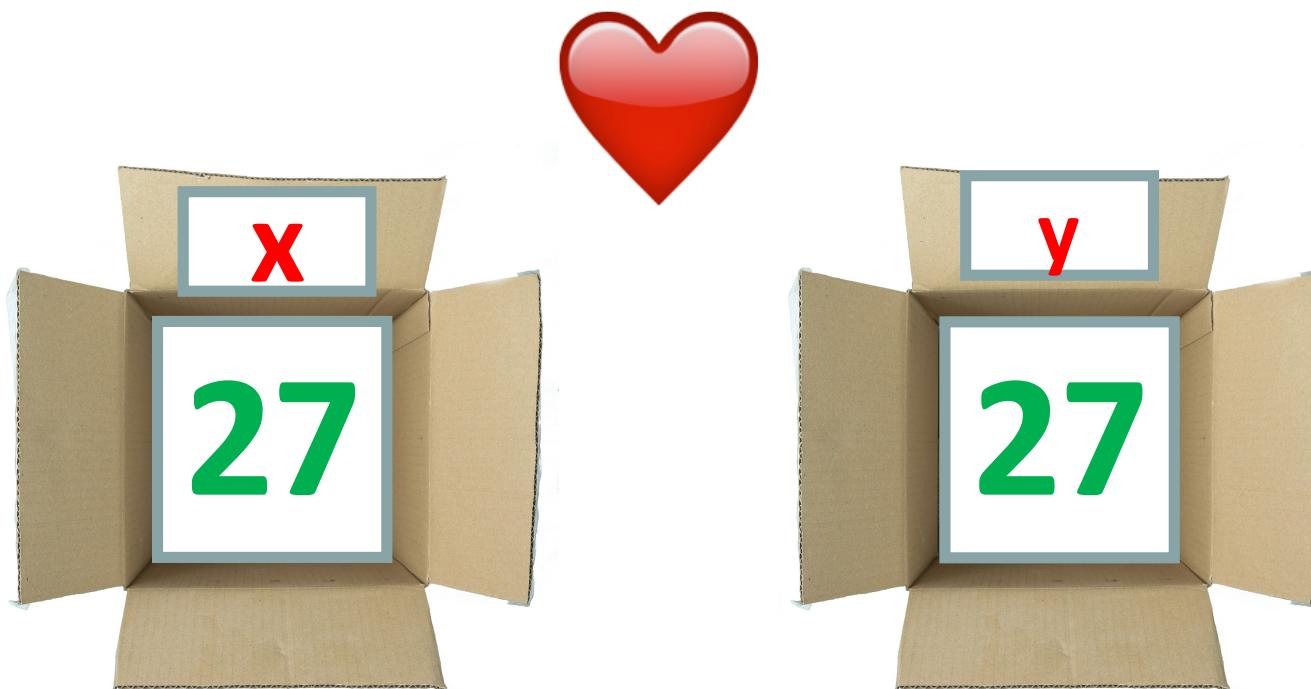
They can use == to compare values.

```
if (x == y) { // true!  
...  
}
```



They can use == to compare values.

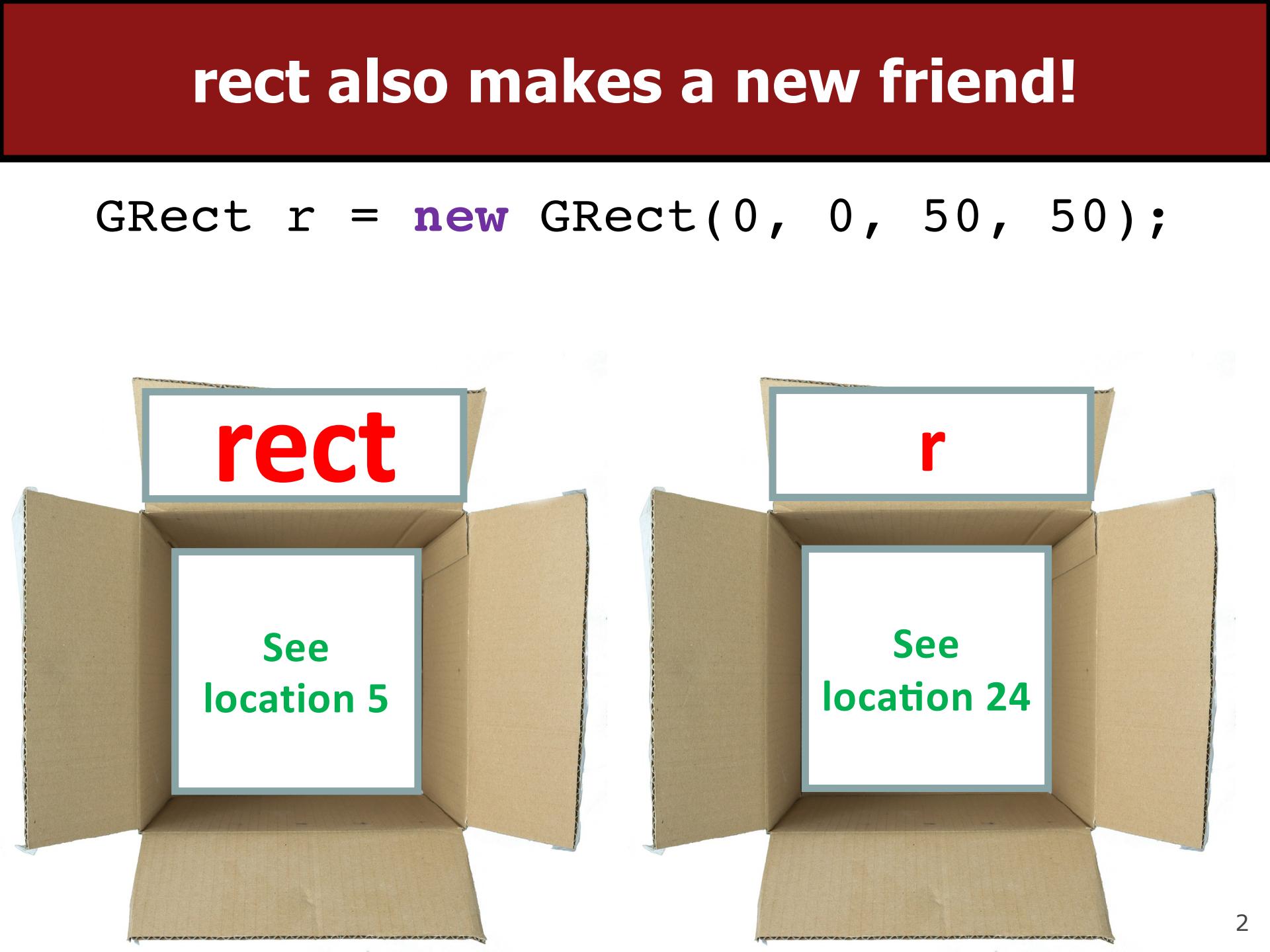
```
if (x == y) { // true!  
...  
}
```



See “A Variable Love Story” for
more...

rect also makes a new friend!

```
GRect r = new GRect(0, 0, 50, 50);
```



rect

See
location 5

r

See
location 24

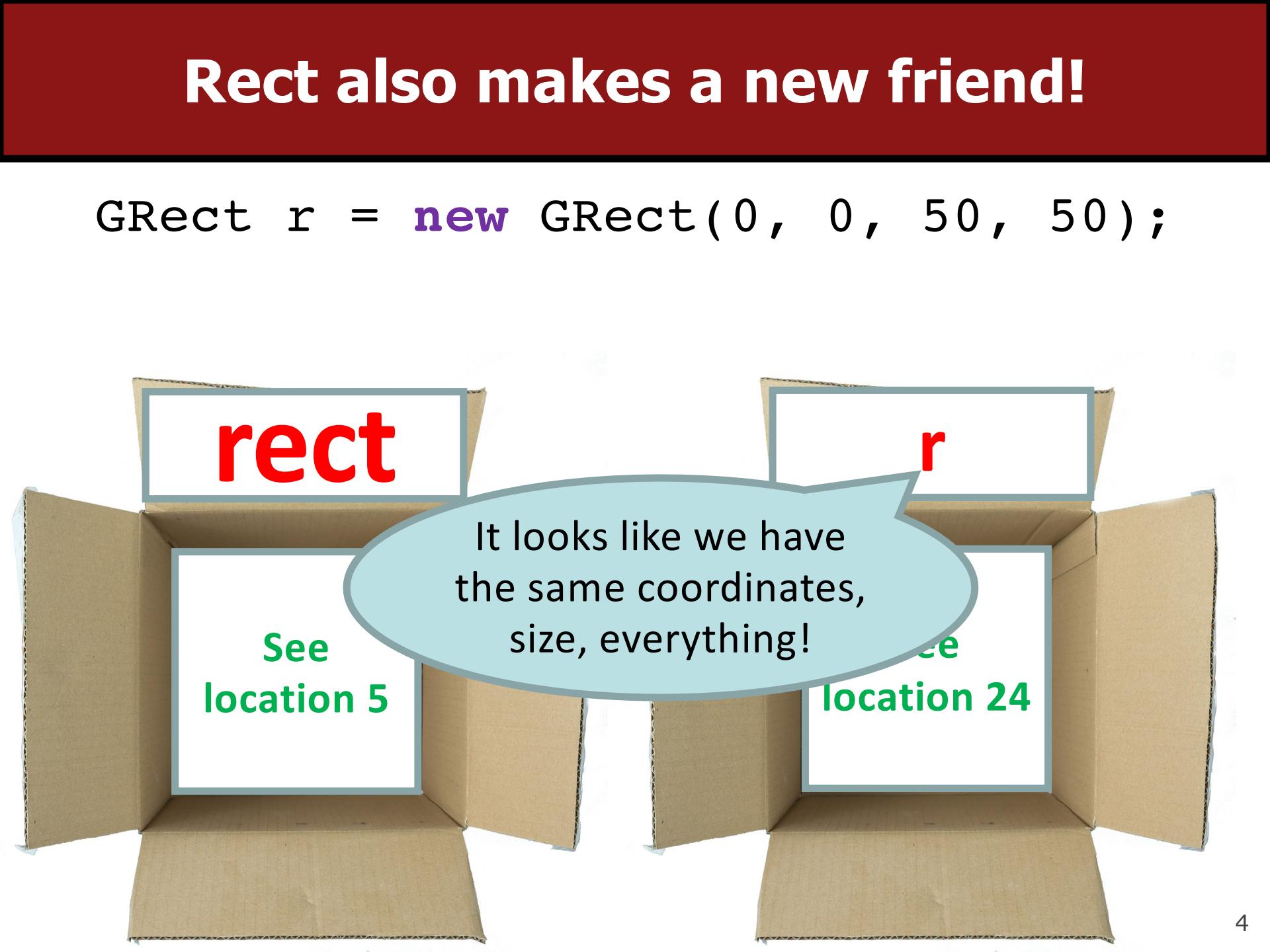
Rect also makes a new friend!

```
GRect r = new GRect(0, 0, 50, 50);
```



Rect also makes a new friend!

```
GRect r = new GRect(0, 0, 50, 50);
```



rect

See
location 5

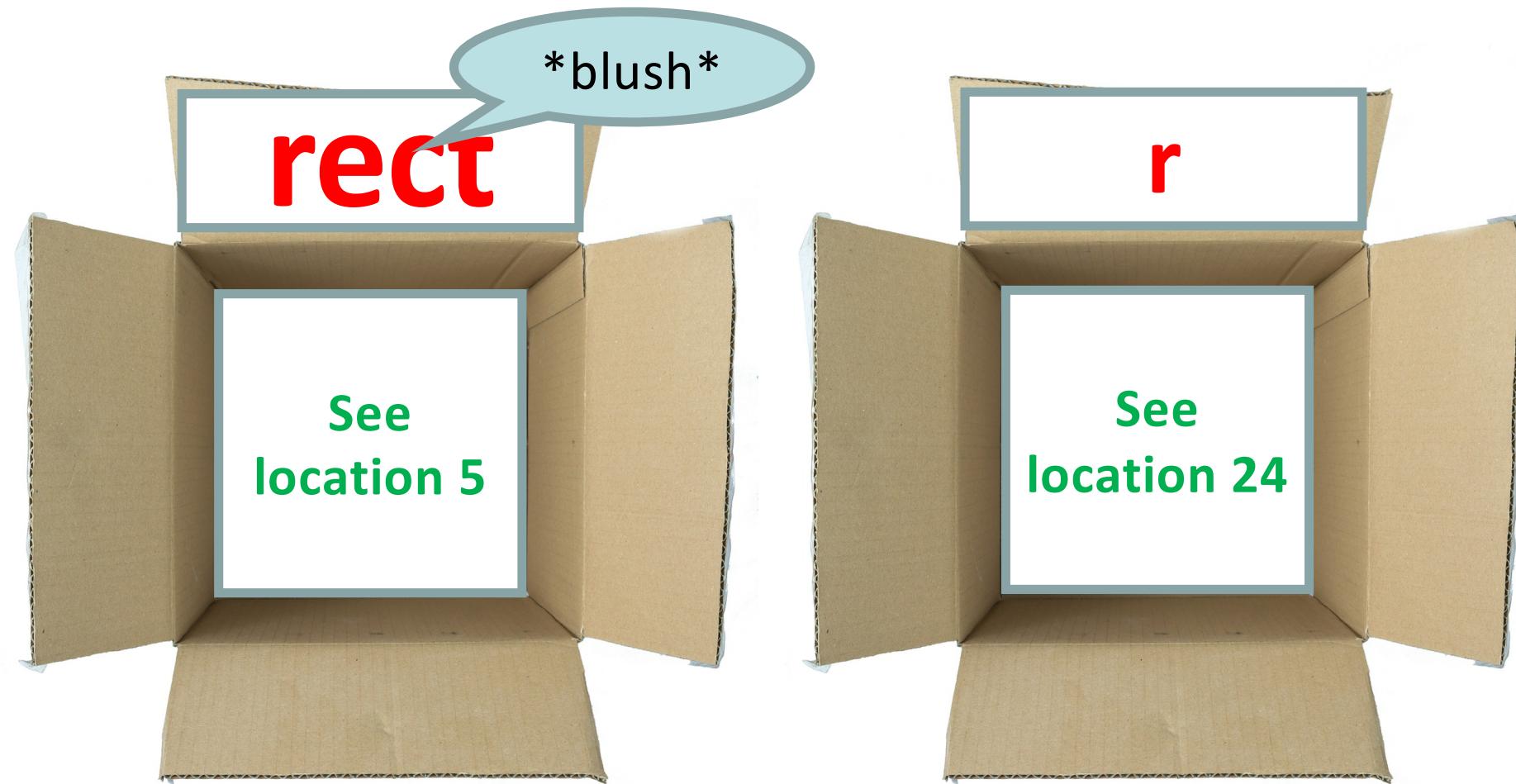
r

See
location 24

It looks like we have
the same coordinates,
size, everything!

Rect also makes a new friend!

```
GRect r = new GRect(0, 0, 50, 50);
```



But when they use == to compare
values...

...something goes wrong.

```
if (rect == r) { // false!  
    ...  
}
```



...something goes wrong.

```
if (rect == r) { // false!
```

• • •

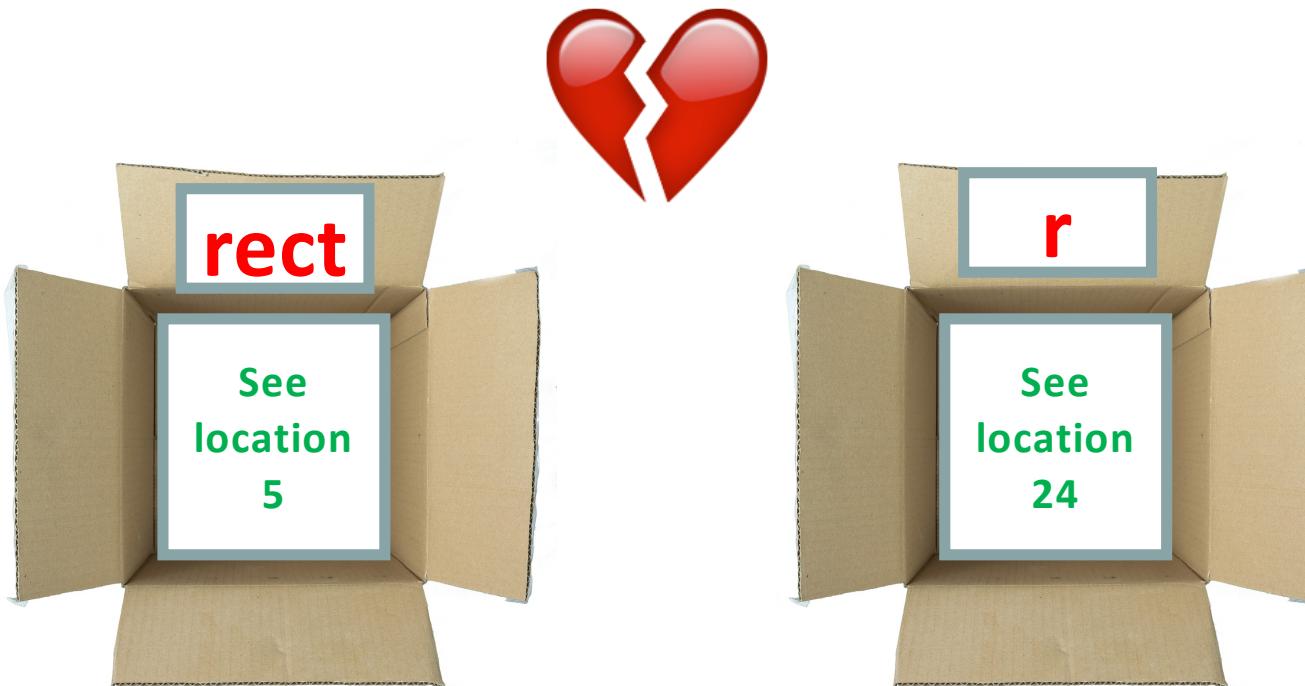
}

...but... but I thought
we had so much in
common!



...something goes wrong.

```
if (rect == r) { // false!  
    ...  
}
```



...something goes wrong.

```
if (rect == r) { // false!  
    ...  
}
```

You see, `==` compares what is in *each variable's box*.



...something goes wrong.

```
if (rect == r) { // false!  
    ...  
}
```

Primitives store their
actual value in their box.



...something goes wrong.

```
if (rect == r) { // false!  
    ...  
}
```

But objects store the *location* where all their information lives.



...something goes wrong.

```
if (rect == r) { // false!
```

A diagram consisting of three black dots arranged horizontally at the top, and a large black brace symbol { located below them.

This means == on objects compares their *locations*, which is not what we want here!



Chapter 3: Twins

One day, they wanted a twin.

Wow, what an awesome int! Let's make another one.



One day, they wanted a twin.

Wow, what an awesome int! Let's make another one.

```
int x2 = x;
```



...so x2 was born!

Wow, what an awesome int! Let's make another one.

```
int x2 = x;
```



...so x2 was born!

But let's increment
this one by 2.

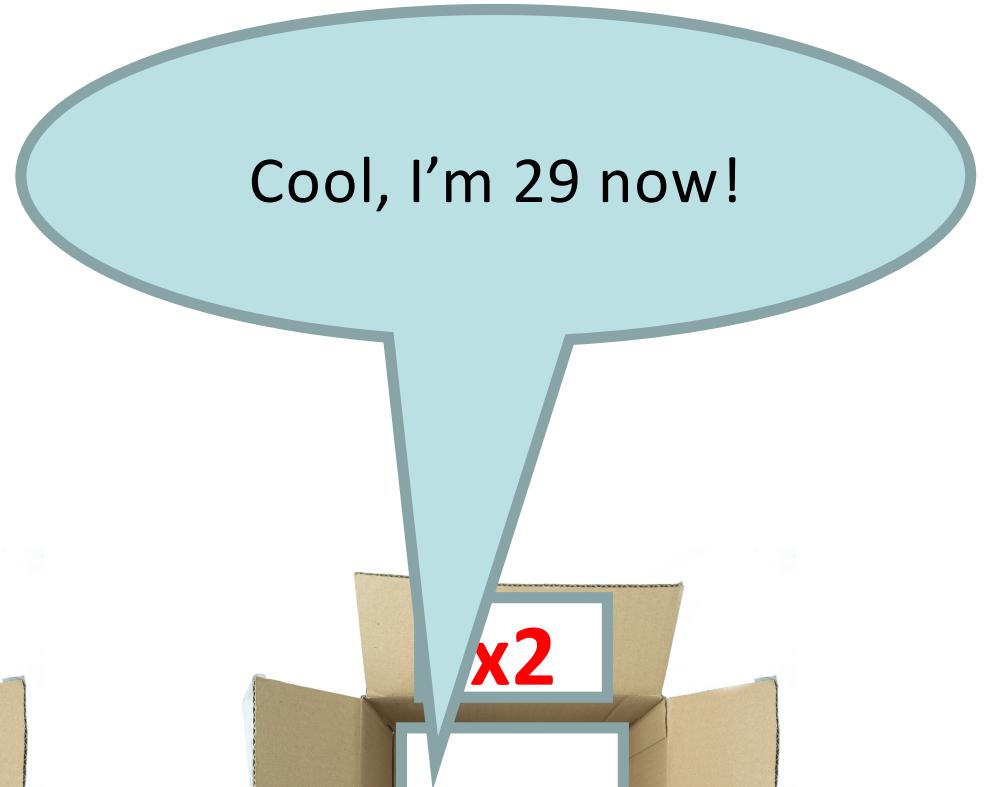
```
int x2 = x;
```

```
x2 += 2;
```



...so x2 was born!

```
int x2 = x;  
x2 += 2;
```



Cool, I'm 29 now!

...so x2 was born!

```
int x2 = x;  
x2 += 2;
```



Then, they wanted a twin for rect, too.

Wow, what an awesome GRect! Let's make another one.



...so rect2 was born!

Wow, what an awesome GRect! Let's make another one.

```
GRect rect2 = rect;
```



...so rect2 was born!

Wow, what an awesome GRect! Let's make another one.

```
GRect rect2 = rect;
```



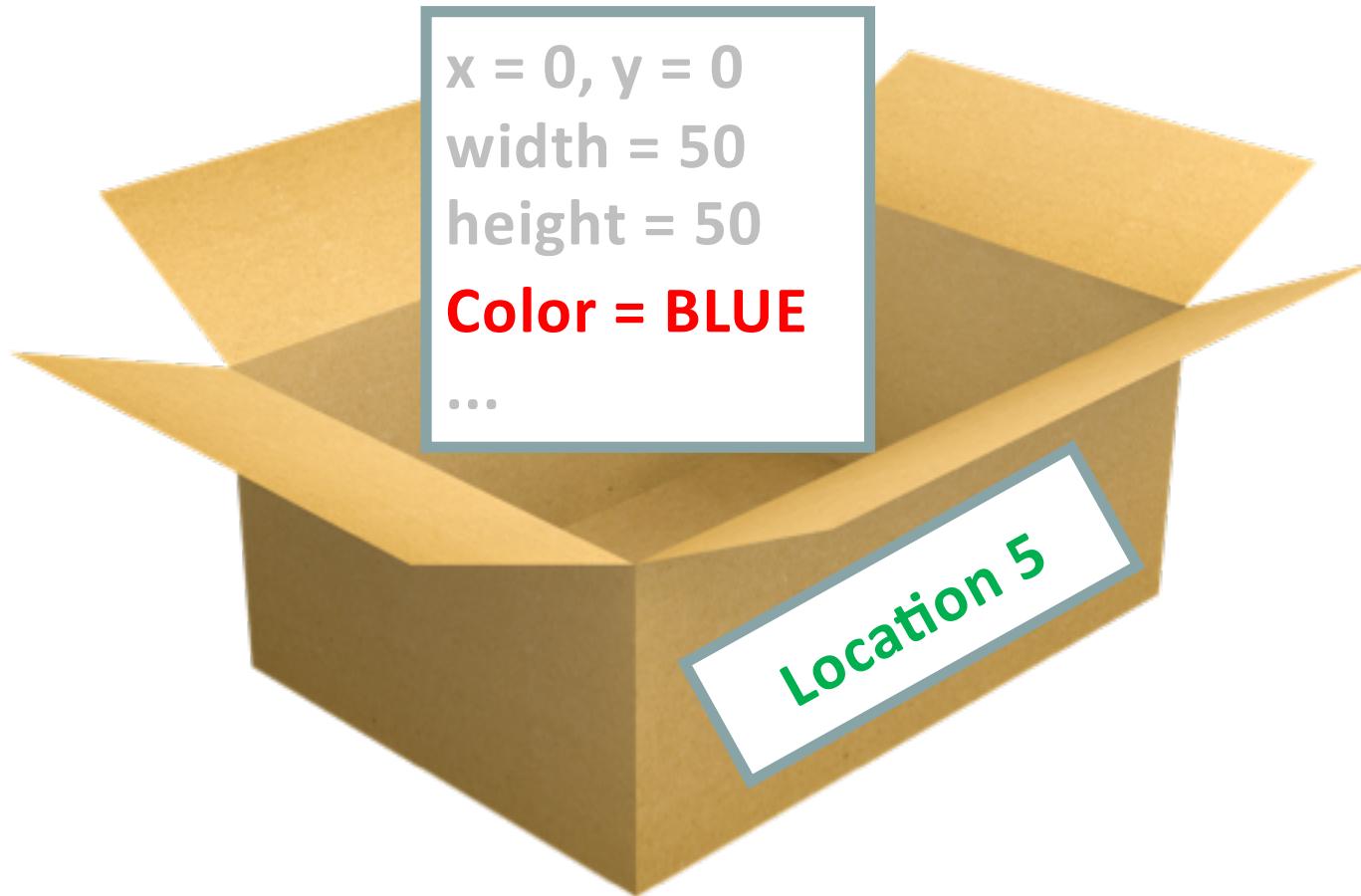
...so rect2 was born!

But let's make this
one BLUE.

```
GRect rect2 = rect;  
rect2.setColor(Color.BLUE);
```



...so they went to location 5 and changed the color to blue.



But something went wrong...

Cool, I'm blue!

```
GRect rect2 = rect  
rect2.setColor(Color.BLUE);
```



But something went wrong...

```
GRect rect = new GRect();
rect2.setColor(Color.BLUE);
```



But something went wrong...

You see, when you set one variable equal to another, the value *in its box* is copied over.

```
GRect rect2 = rect;  
rect2.setColor(Color.BLUE);
```



But something went wrong...

For primitive variables, this just means we copy their value.

```
GRect rect2 = rect;  
rect2.setColor(Color.BLUE);
```



But something went wrong...

But for objects, we copy its
location instead.

```
GRect rect2 = rect;  
rect2.setColor(Color.BLUE);
```



But something went wrong...

Therefore, both rect and rect2 think their information is at location 5.

```
GRect rect2 = rect;  
rect2.setColor(Color.BLUE);
```



But something went wrong...

When you change information for an object,
you go to its location first, and then update
the information.

```
GRect rect2 = rect;  
rect2.setColor(Color.BLUE);
```



But something went wrong...

Since rect and rect2 reference the same location, when you change information for one of them, it changes for both!

```
GRect rect2 = rect;  
rect2.setColor(Color.BLUE);
```



Chapter 4: Leaving the Nest

X grew up, and went to college.

college(x);

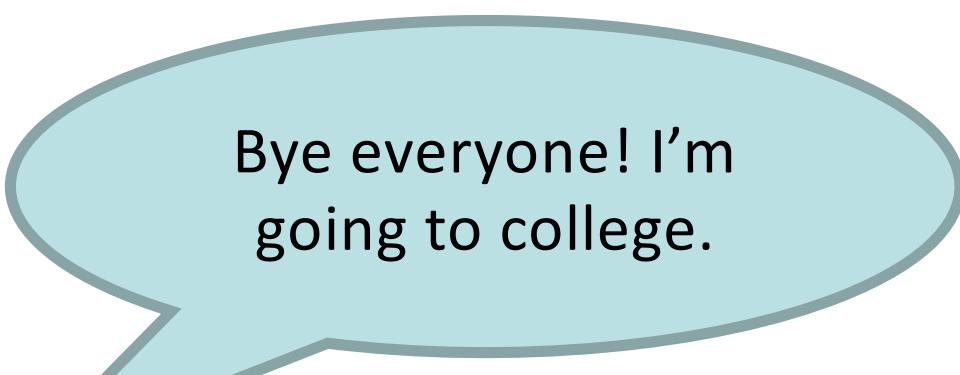


X grew up, and went to college.

college(x);



We'll miss you,
honey! Don't forget to
call! Don't stay up too
late! Watch out for
rogue bicyclists!



Bye everyone! I'm
going to college.

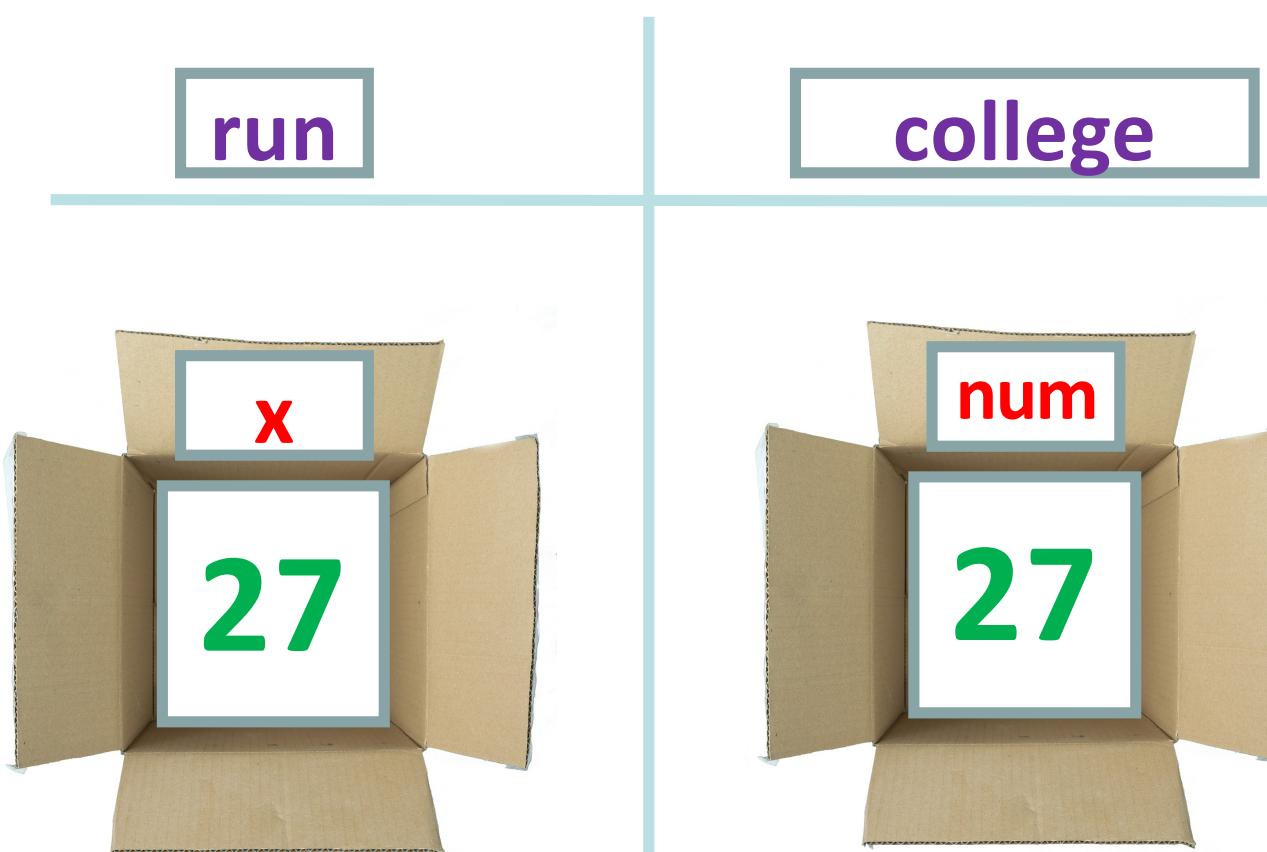


X grew up, and went to college.

```
private void college(int num) {
```

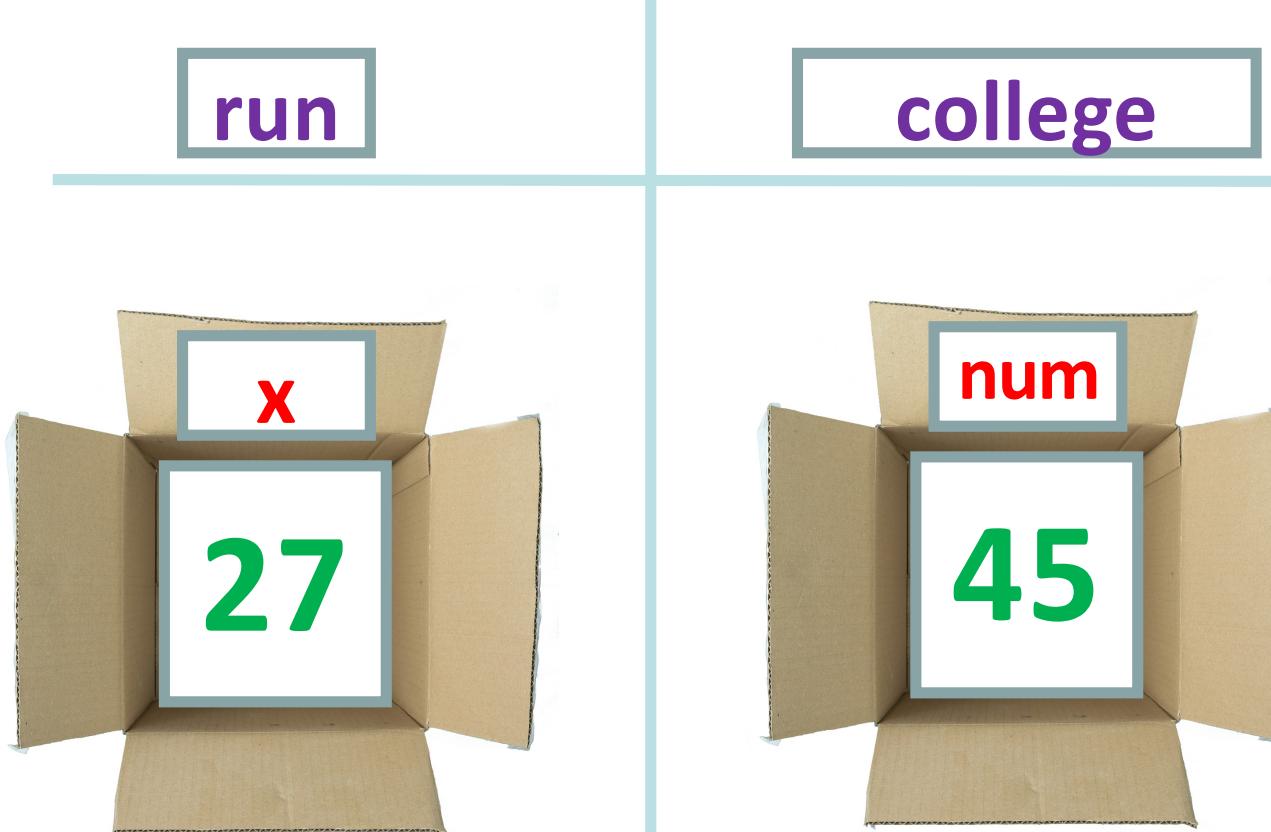
```
    ...
```

```
}
```



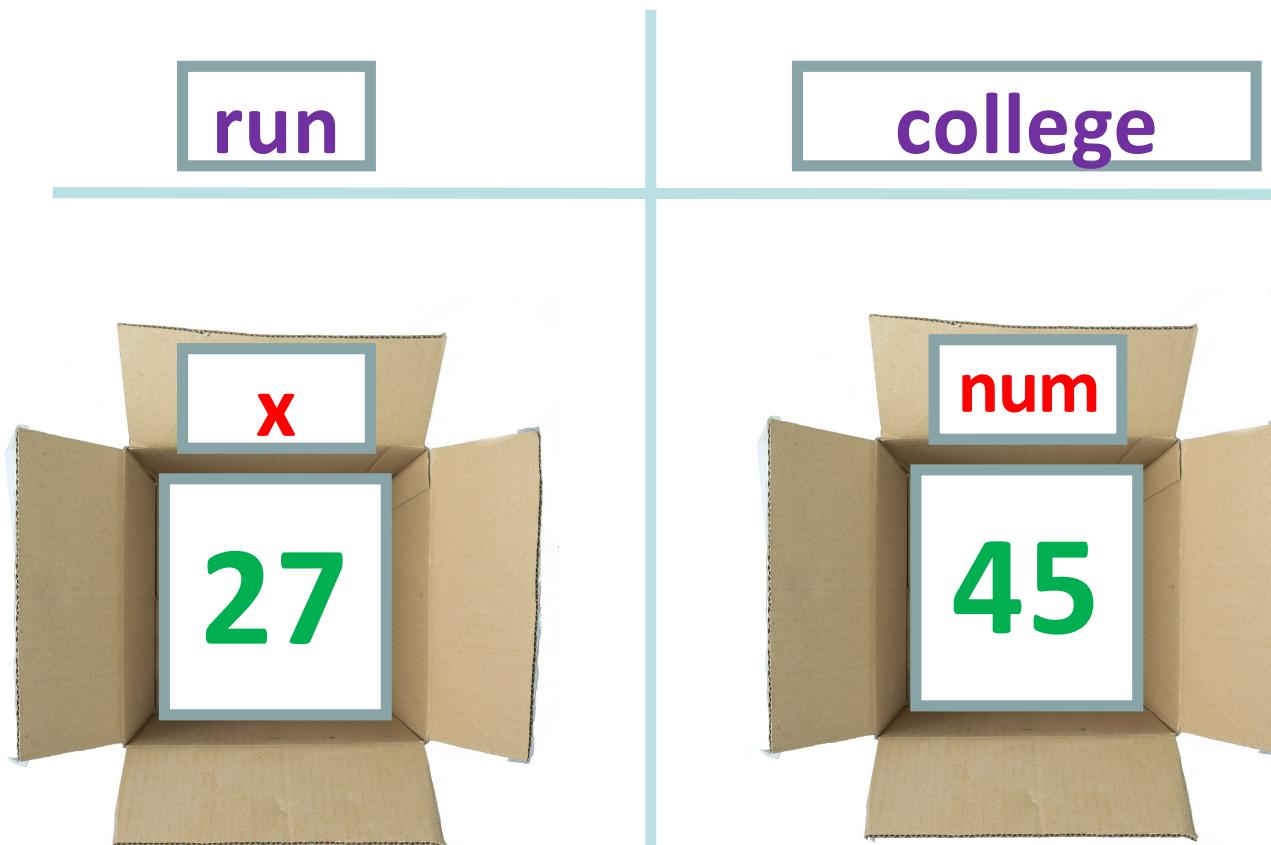
x had an amazing college experience...

```
private void college(int num) {  
    num = 45;  
}
```



...but ultimately returned home the same.

```
private void college(int num) {  
    num = 45;  
}
```



...but ultimately returned home the same.

```
college(x);  
println(x);
```



...but ultimately returned home the same.

```
college(x);  
println(x);
```

Ohhhh honey! You'll
always be our little
27.

I'm baaaaack! And I'm
still 27.



rect grew up too, and also went to college.

college2(rect);

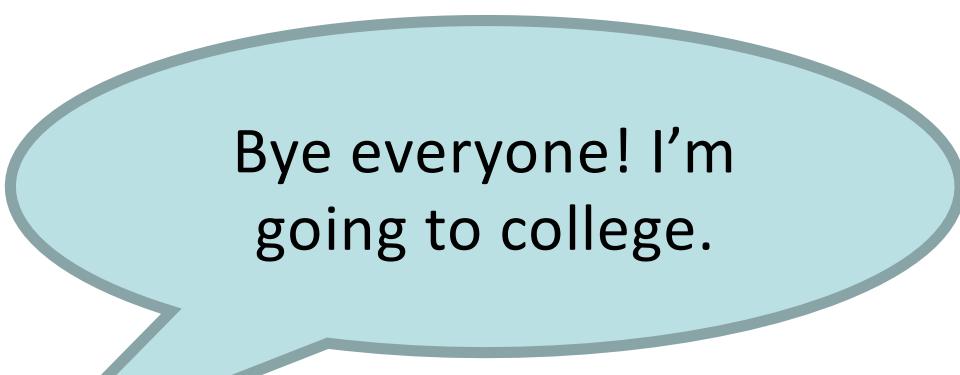


rect grew up too, and also went to college.

college2(rect);



Not you too, rect! We are empty nesters now...



Bye everyone! I'm going to college.

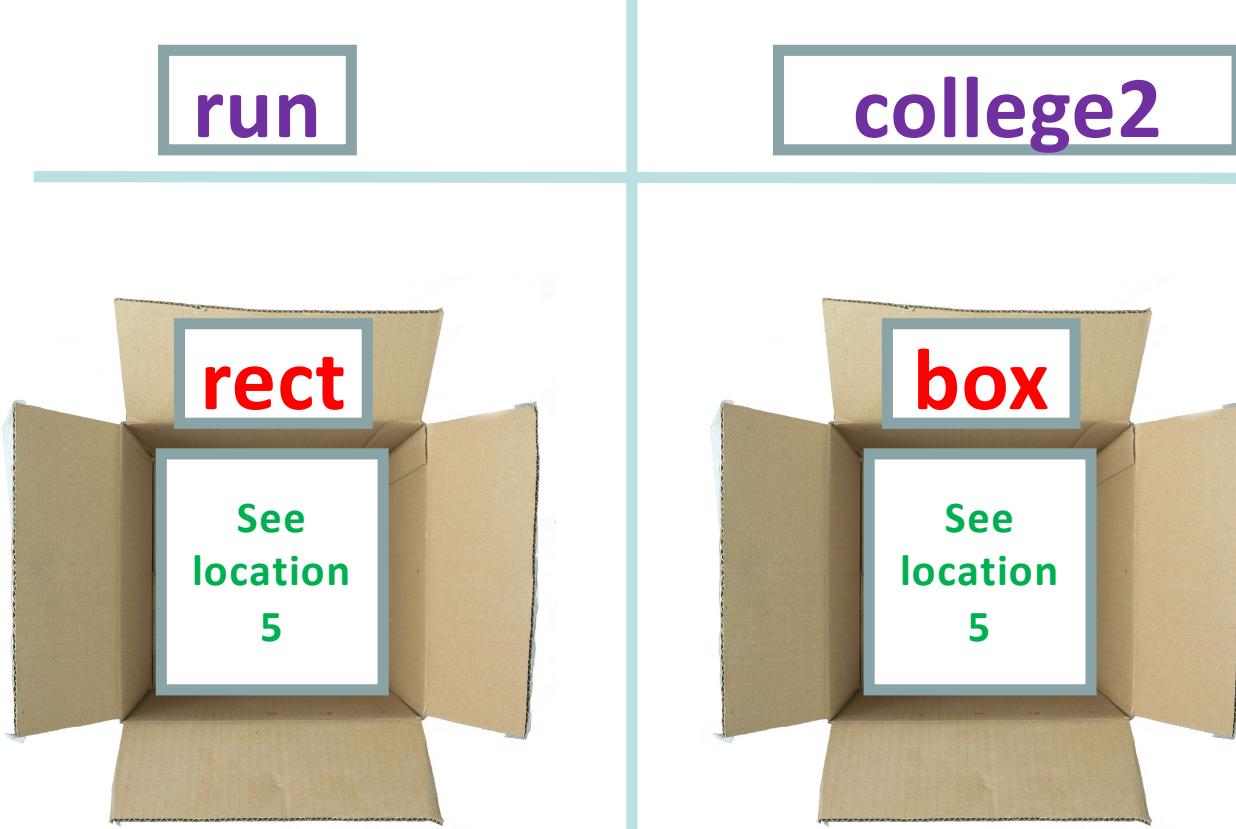


rect grew up too, and also went to college.

```
private void college2(GRect box) {
```

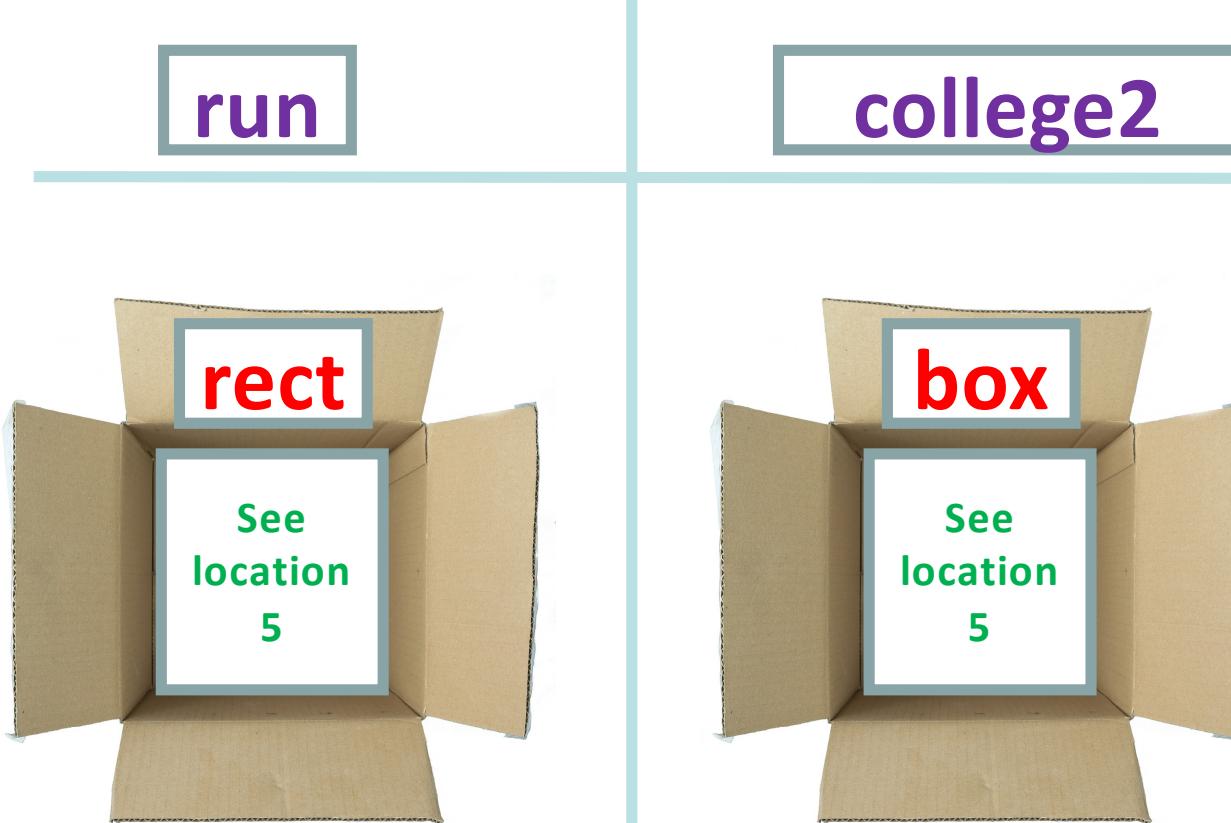
```
    ...
```

```
}
```



rect also had an amazing college experience...

```
private void college2(GRect box) {  
    box.setColor(Color.PINK);  
}
```

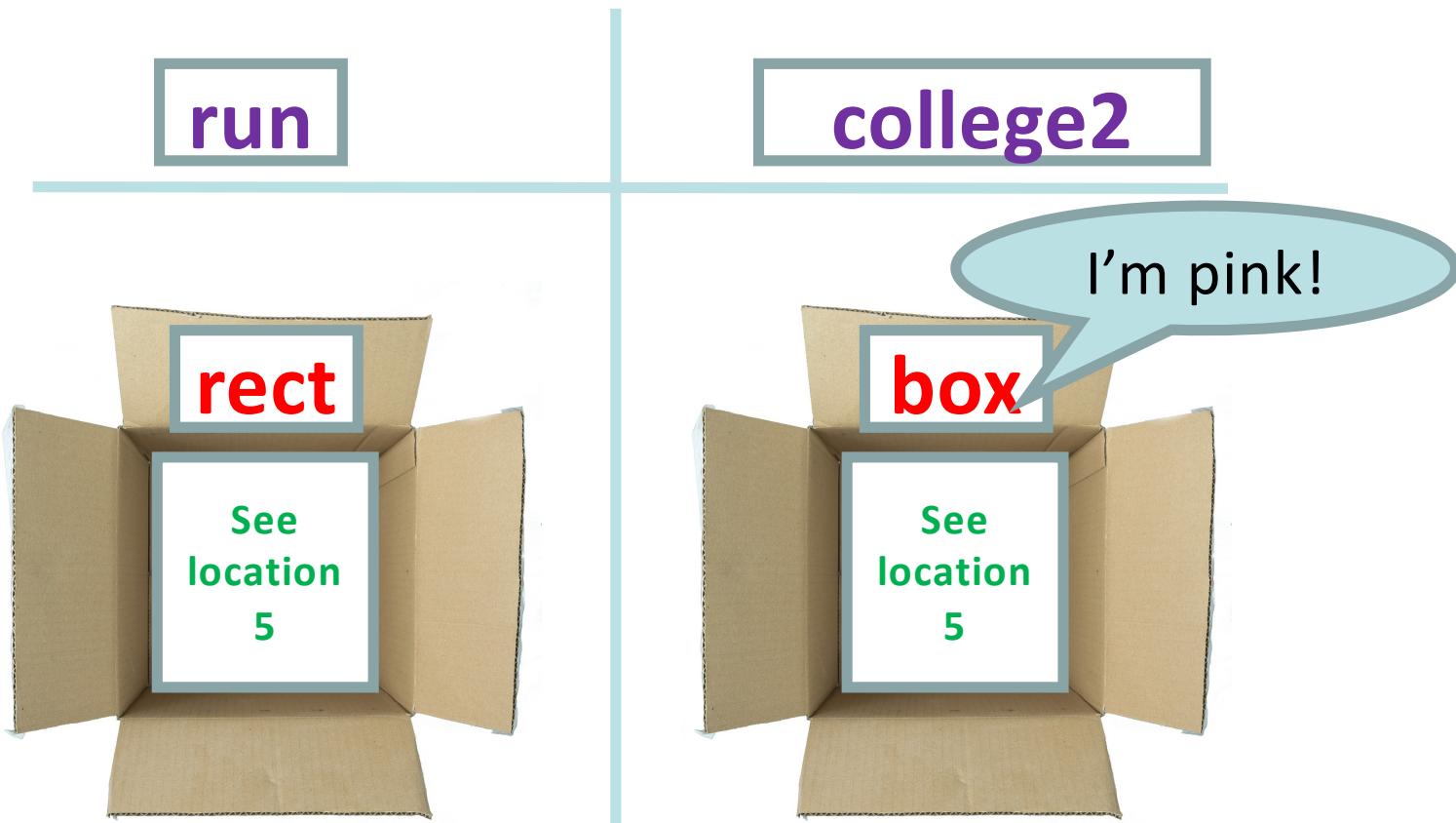


rect also had an amazing college experience...



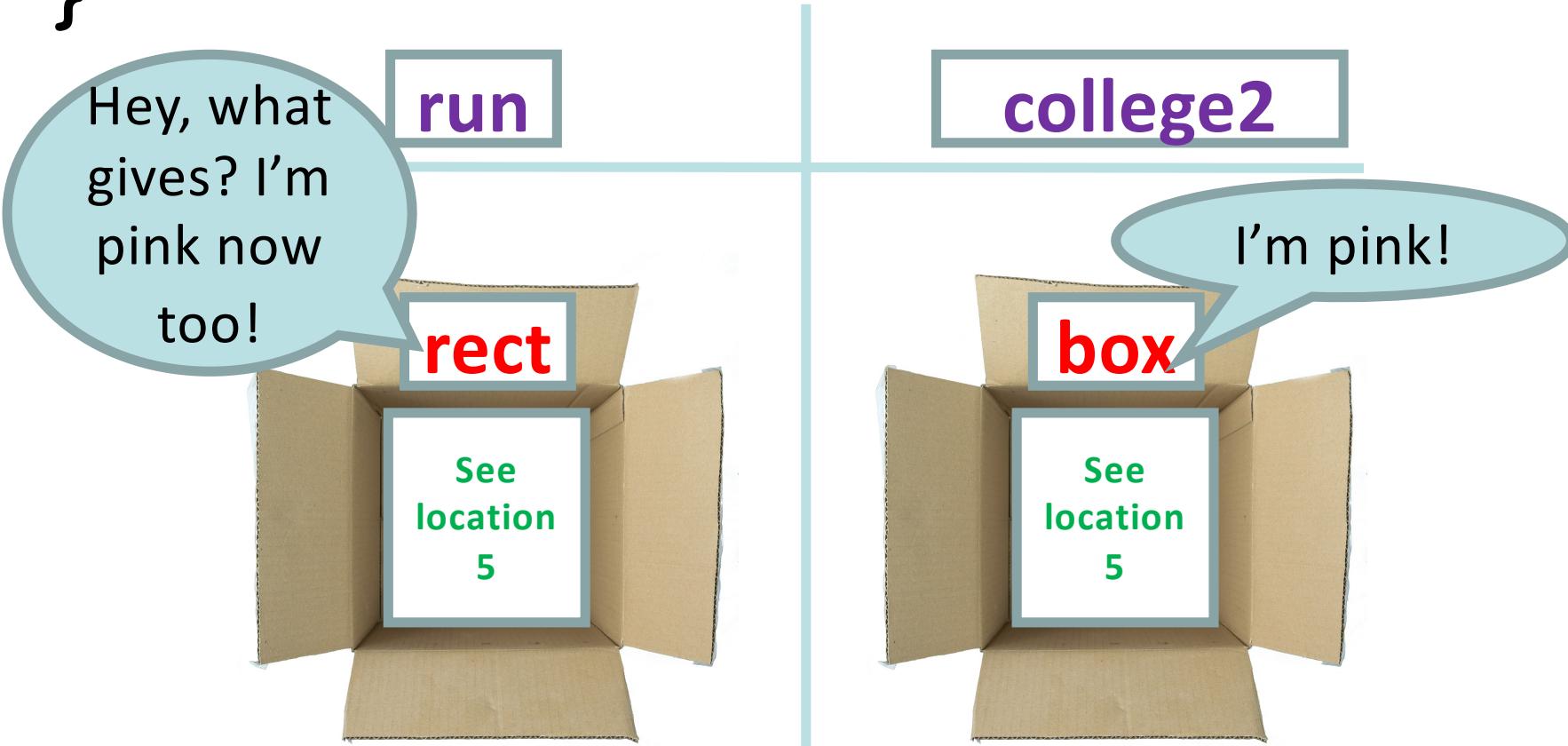
...but it returned home different.

```
private void college2(GRect box) {  
    box.setColor(Color.PINK);  
}
```



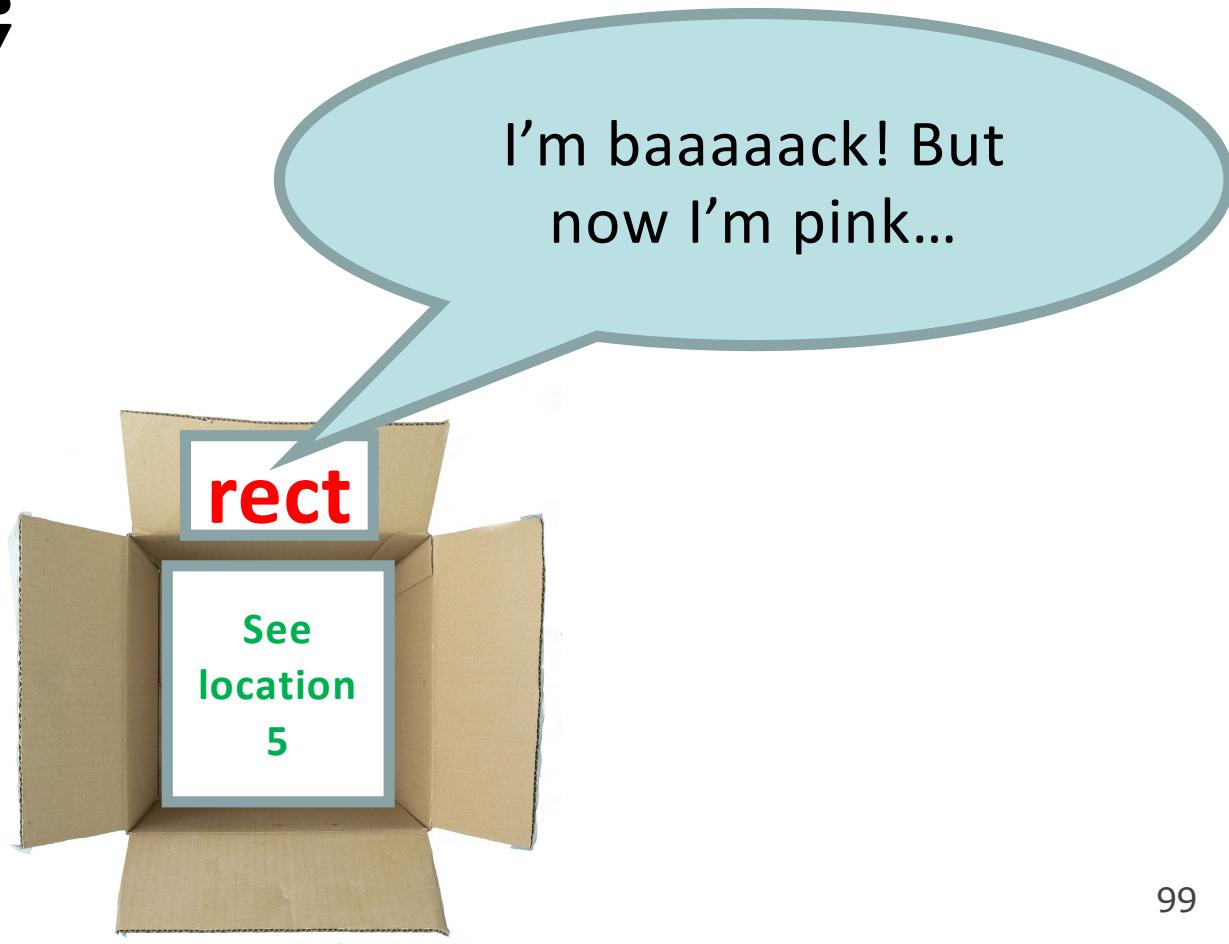
...but it returned home different.

```
private void college2(GRect box) {  
    box.setColor(Color.PINK);  
}
```



...but it returned home different.

```
college(rect);  
add(rect);
```



...but it returned home different.

```
college(rect);  
add(rect);
```

Oh my gosh...what
happened to you??!

I'm baaaaack! But
now I'm pink...



...but it returned home different.

```
college(rect);  
add(rect);
```

You see, when a variable is passed as a parameter, the value *inside its box* is copied and given to the method.



...but it returned home different.

```
college(rect);  
add(rect);
```

For primitives, we make a copy of their *actual value*. Therefore, changes to a parameter do not affect the original.



...but it returned home different.

```
college(rect);
```

```
add(rect);
```

However, for objects we make a copy of their *location*. So changes to the parameter *do affect the original!*



The End

Primitives vs. Objects

- **Primitives** store their *actual value* in their variable box. You can compare values with == and !=, and the original does not change when passed as a parameter and changed.
- **Objects** store their *location* in their variable box. You can't compare properties of an object via ==, and the original *does* change when passed as a parameter and changed.
- **Primitives** are *passed by value*, **Objects** are *passed by reference*

Practice – Chapter 2: Friends

Practice

```
public void run() {  
    int x = 5;  
    int y = 5;  
    println(x == y);  
}
```

Does this print out **true** or
false?

Practice

```
public void run() {  
    GRect first = new GRect(20, 30);  
    GRect second = new GRect(20, 30);  
    println(first == second);  
}
```

Does this print out **true** or
false?

Practice – Chapter 3: Twins

Practice

```
public void run() {  
    int x = 5;  
    int y = x;  
    y += 2;  
    println(y);  
    println(x);  
}
```

What is printed out?

Practice

```
public void run() {  
    GOval oval = new GOval(0, 0, 50, 50);  
    GOval oval2 = oval;  
    oval2.setColor(Color.BLUE);  
    add(oval2);  
    add(oval);  
}
```

What color are oval and
oval2?

Practice – Chapter 4: Leaving the Nest

Practice

```
public void run() {  
    int x = 2;  
    addFive(x);  
    println(x);  
}  
  
private void addFive(int num) {  
    num += 5;  
}
```

What is printed out?

Practice

```
public void run() {  
    GRect rect = new GRect(0, 0, 50, 50);  
    makeBlue(rect);  
    add(rect);  
}  
  
private void makeBlue(GRect box) {  
    box.setColor(Color.BLUE);  
}
```

What color is rect?

Primitives vs. Objects

Primitives store their actual values. **Objects** store their *locations*.

This affects how your code behaves!

getElementAt

getElementAt returns a *reference* to an object.

```
GRect rect = new GRect(0, 0, 50, 50);  
add(rect);
```

...

```
GObject obj = getElementAt(25, 25);  
println(obj == rect);
```



One-Pager: Stack/Heap

```
int x = 27;
```

```
int y = x;
```

```
GRect rect = new GRect(0, 0, 50, 50);
```

```
Grect box = rect;
```

In Java, **new** means create something in heap memory!

*This slide is for curiosity only.
Not required!*

Stack

x
27

y
27

rect

See location 1024

obj

See location 1024

Strings are weird! Their variables store addresses to a special section of the heap.
Detailed explanation on Piazza :)

1024 == 0x400 (base 16!)

Heap

0x400

x = 0
y = 0
width = 50
height = 50

Computer addresses use base 16

Plan for Today

- Review: events and instance variables
- A Boolean Aside
- Memory
- Revisiting Whack-A-Mole
- Midterm tips

Revisiting Whack-A-Mole

Let's revisit our Whack-A-Mole program to add some new functionality using what we just learned.



Plan for Today

- Review: events and instance variables
- A Boolean Aside
- Memory
- Revisiting Whack-A-Mole
- Midterm tips

Midterm

- Study strategies, in order of exam relevance
 - Sleep well for at least two days beforehand!
 - Do the practice exams under timed conditions
 - (Re-)do section problems from all handouts
 - Code up programs we wrote in lecture
 - Review lecture slides
 - Do CodeStepByStep practice problems
 - Read the textbook

Midterm

- Strategies for taking the exam
 - Read over all the problems first
 - Seriously, I always have students who run out of time because they got stuck on one problem
 - If you don't know exactly how to do something, write something approximate
 - If your syntax isn't too far off, we'll allow it
 - More importantly, it gets you unstuck so you can keep writing correct parts of the solution

Midterm

- Methods that *might* be helpful
 - Integer.parseInt: converts String to int
 - Example: `int x = Integer.parseInt("27");`
 - useDelimiter: tells a Scanner to split on a specified String rather than on whitespace
 - Example: `String line = "a,b,c";`
 - `Scanner tokens = new Scanner(line);`
 - `tokens.useDelimiter(",");`
 - `println(tokens.next()); // prints "a"`

Recap

- Review: events and instance variables
- A Boolean Aside
- Memory
- Revisiting Whack-A-Mole
- Midterm tips

Good luck on the midterm!