Memory

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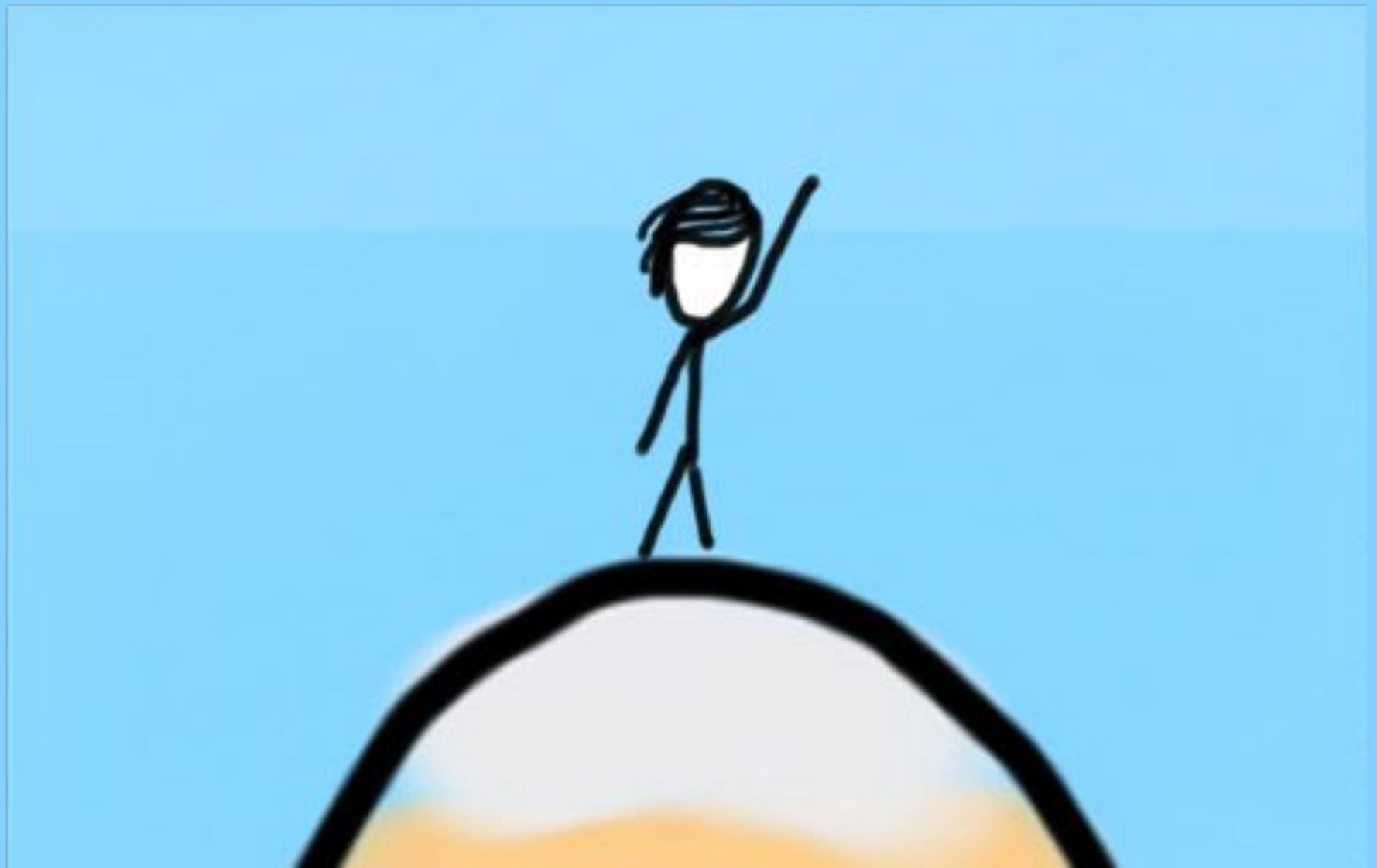
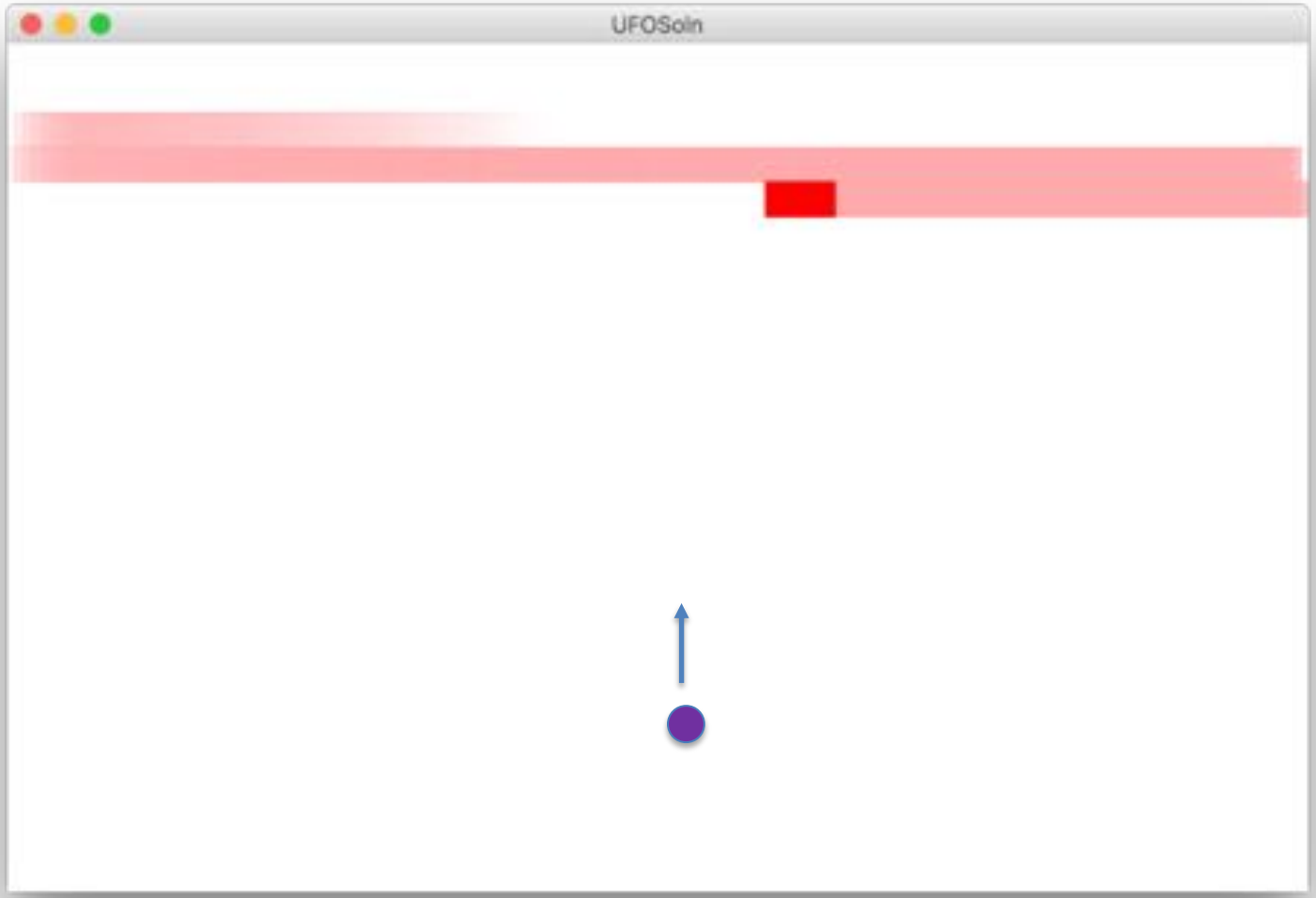
CS106A, Stanford University

Learning Goals

1. Be able to trace memory with references



Write this program



Who thinks this prints **`true`**?

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


Who thinks this prints **`true`**?

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


Who thinks this prints **`true`**?

```
private GRect first = new GRect(20, 30);
public void run() {
    first.setFilled(true);
    add(first, 0, 0);
    GObject second = getElementAt(1, 1);
    println(first == second);
}
```


Class of the 10 keys

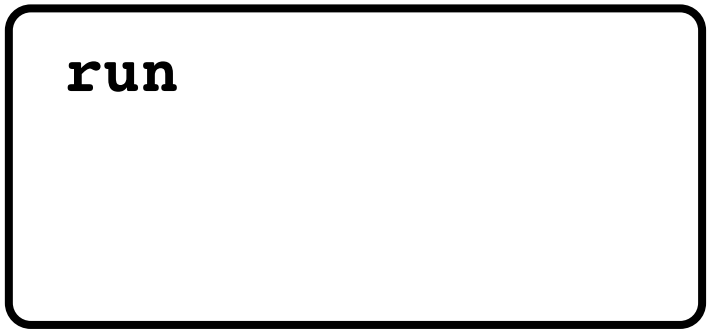
Advanced memory model

Core memory model

Stack Diagrams

```
public void run() {
    println(toInches(5));
}

private int toInches(int feet){
    int result = feet * 12;
    return result;
}
```



Stack Diagrams

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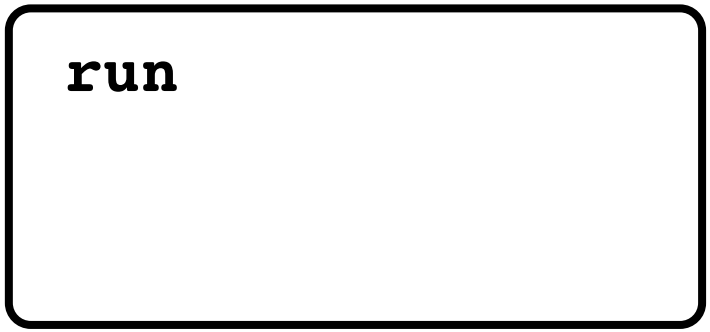

Stack Diagrams

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private int toInches(int feet){
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f
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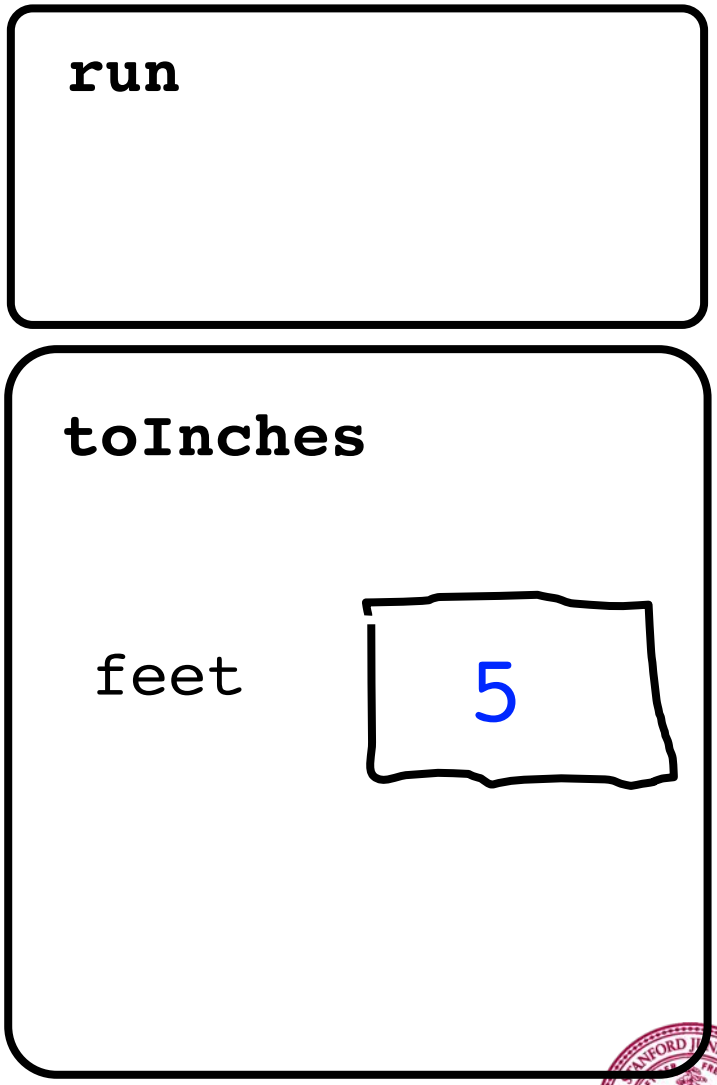

Stack Diagrams

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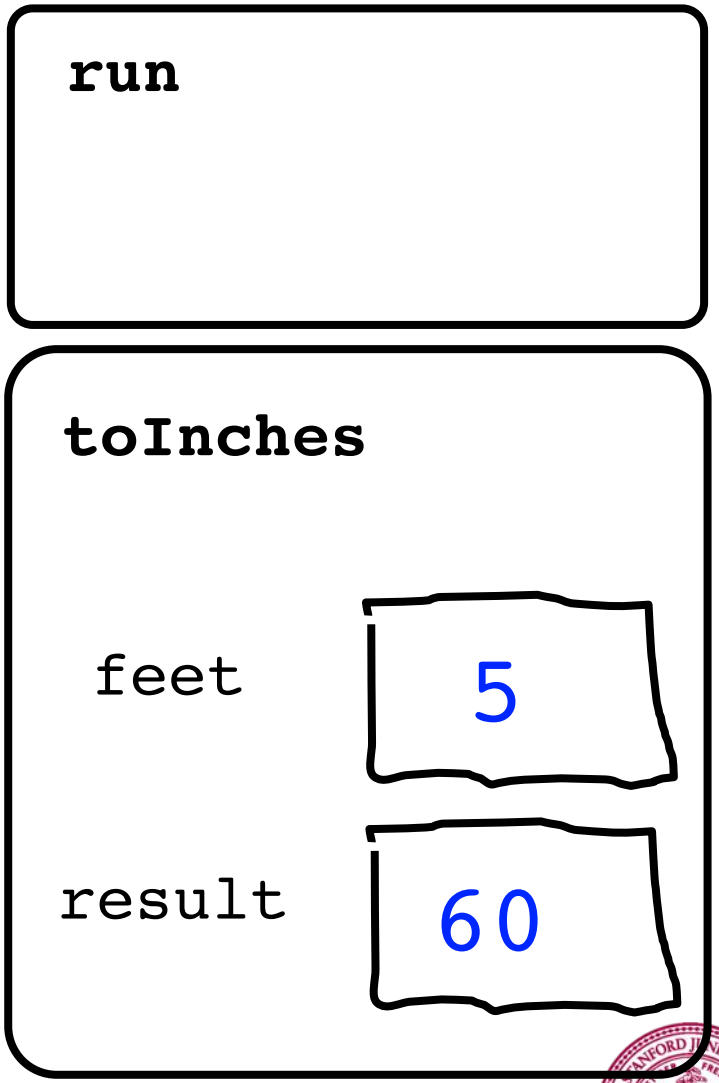

Stack Diagrams

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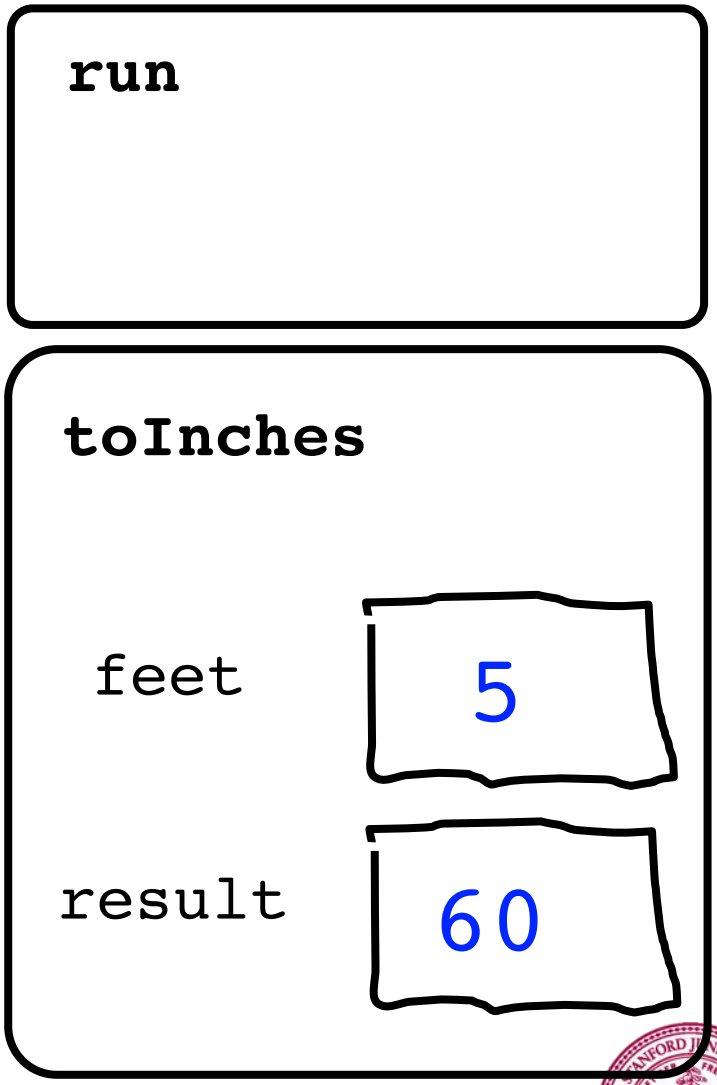

Stack Diagrams

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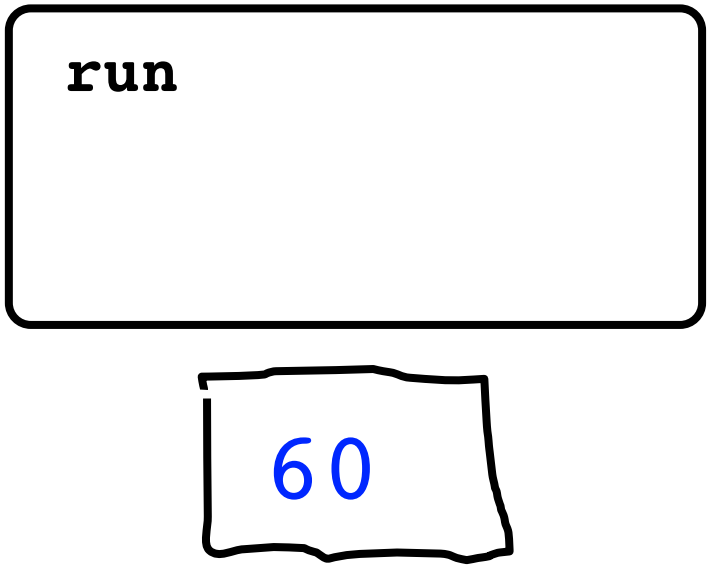
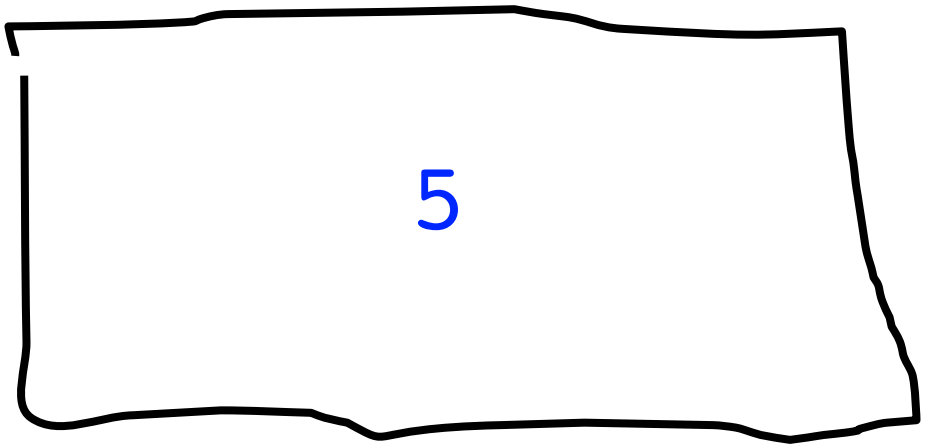


Aside: Actual Memory

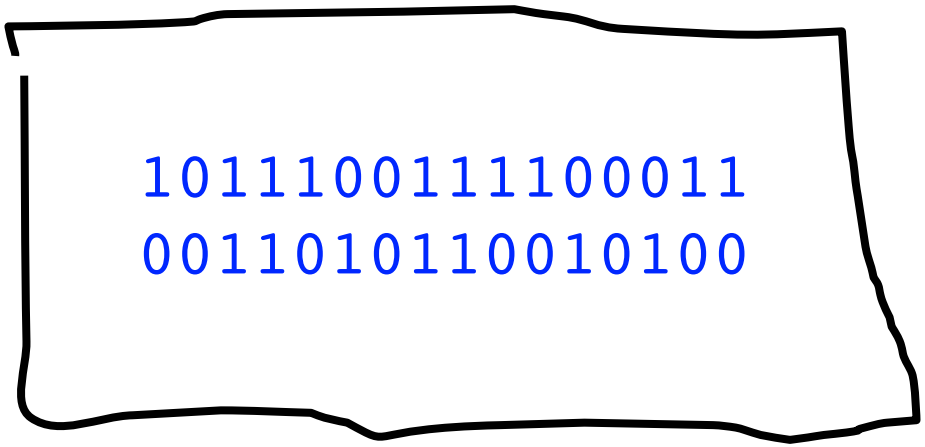
What is a bucket

feet



What is a bucket

feet



* Each bucket or “word” holds 64 bits

** don’t think on the binary level (yet)

#0: variables have fixed size buckets to store values

End aside

Primitives vs Classes

Primitive Variable Types

```
int
double
char
boolean
```

Class Variable Types

```
GRect
GOval
Gline
Color
```

Class variables (aka objects)

1. Have upper camel case types
2. You can call methods on them
3. Are constructed using `new`
4. Are stored in a special way

Primitives vs Classes

Primitive Variable Types

```
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double
char
boolean
```

Class Variable Types

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GOval
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Color
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aka Objects

Class variables (aka objects)

1. Have upper camel case types
2. You can call methods on them
3. Are constructed using `new`
4. Are stored in a special way

How do you share wikipedia articles?

Antelope Canyon Article

Antelope Canyon is a slot canyon in the American Southwest. It is located on Navajo land east of Page, Arizona. Antelope Canyon includes two separate, photogenic slot canyon sections, referred to individually as *Upper Antelope Canyon* or *The Crack*; and *Antelope Canyon* or *The Corkscrew*.[2]

The Navajo name for Upper Antelope Canyon is Tsé bighánílíní, which means "the place where water runs through rocks." Lower Antelope Canyon is Hazdistazí (advertised as *"Hasdestwazi"* by the Navajo Parks and Recreation Department), or "spiral rock arches." Both are located within the LeChee Chapter of the Navajo Nation.[4]

Contents [hide]

1 Geology
2 Tourism and photography
2.1 Upper Antelope Canyon

Antelope Canyon

Tsé bighánílíní dóó Hazdistazí (Navajo)

A beam of light in Upper Antelope Canyon

https://en.wikipedia.org/wiki/Antelope_Canyon

All of todays class:

Objects store addresses
(which are like URLs)

What does an object store?

Objects store addresses
(which are like URLs)

A Variable love story

By Chris Piech

A Variable origin ~~love~~ story

Nick Troccoli

By ~~Chris Piech~~

Once upon a time…

...a variable x was born!

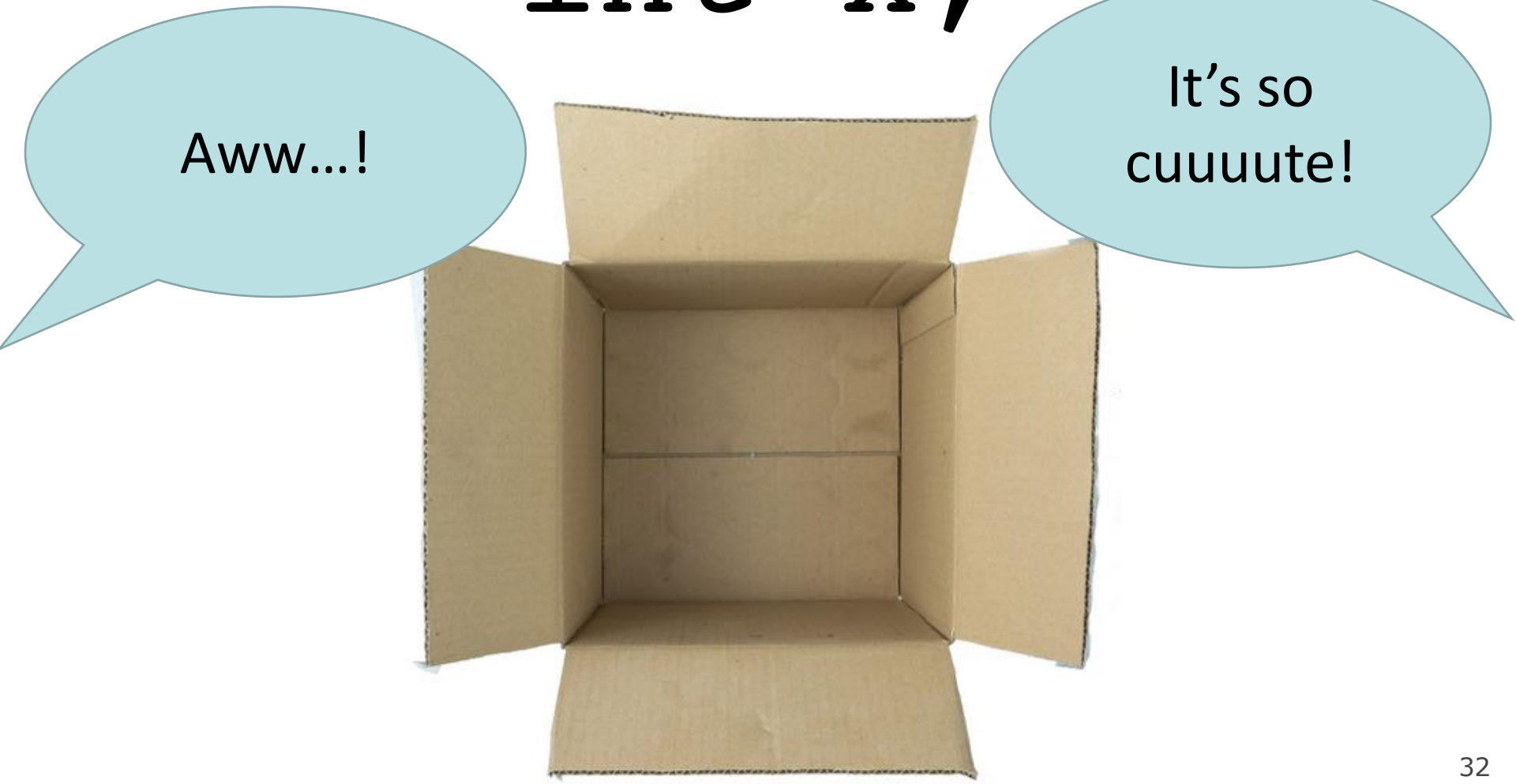
```
int x;
```

...a variable x was born!

```
int x;
```

x was a primitive variable...

```
int x;
```



…and its parents loved it very much.

```
int x;
```

We should give it…. value 27!

...and its parents loved it very much.

```
x = 27;
```

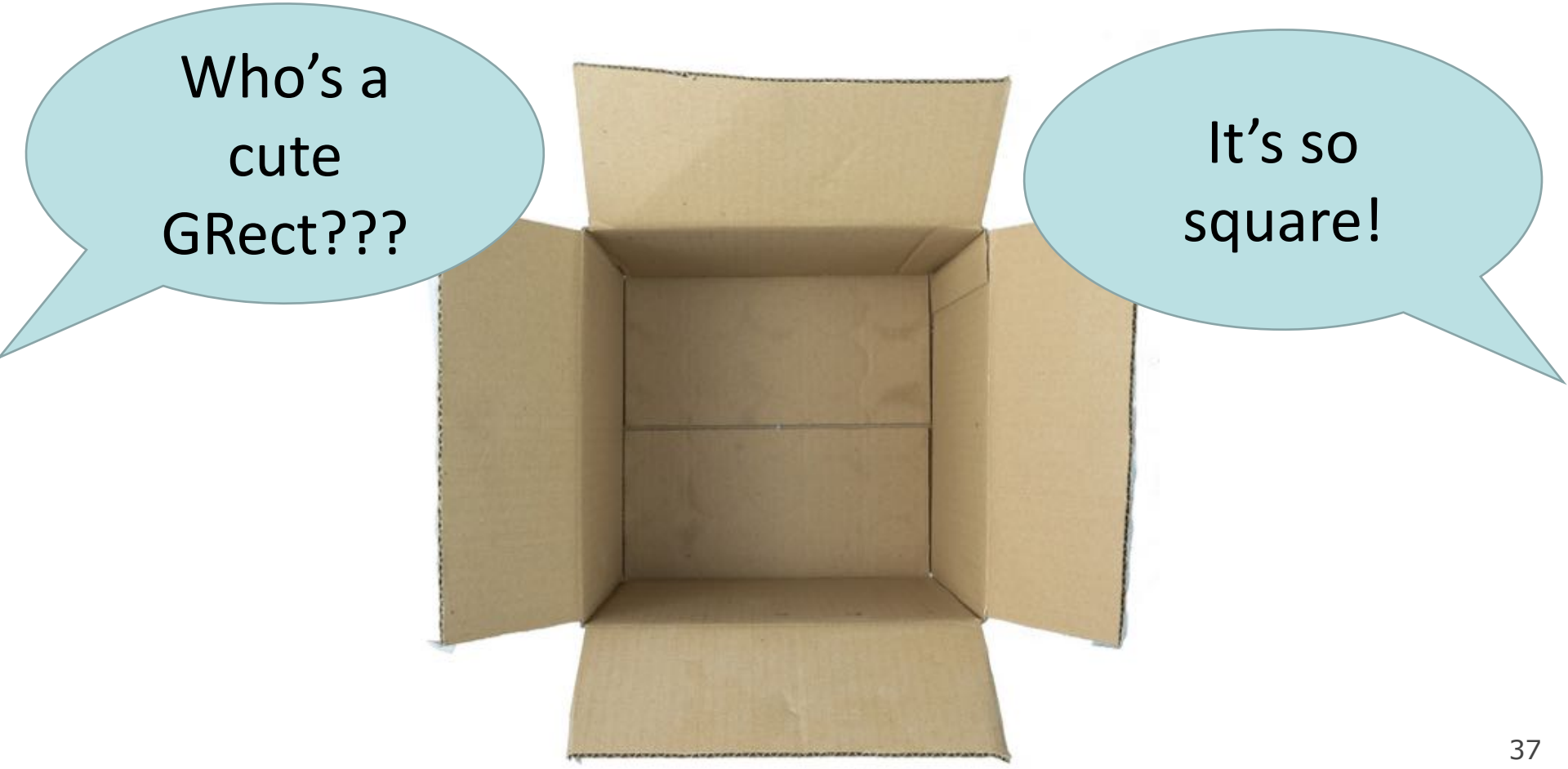
A few years later, the parents decided to have another variable.

...and a variable rect was born!

```
GRect rect;
```

rect was an object variable…

```
GRect rect;
```



…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);
```

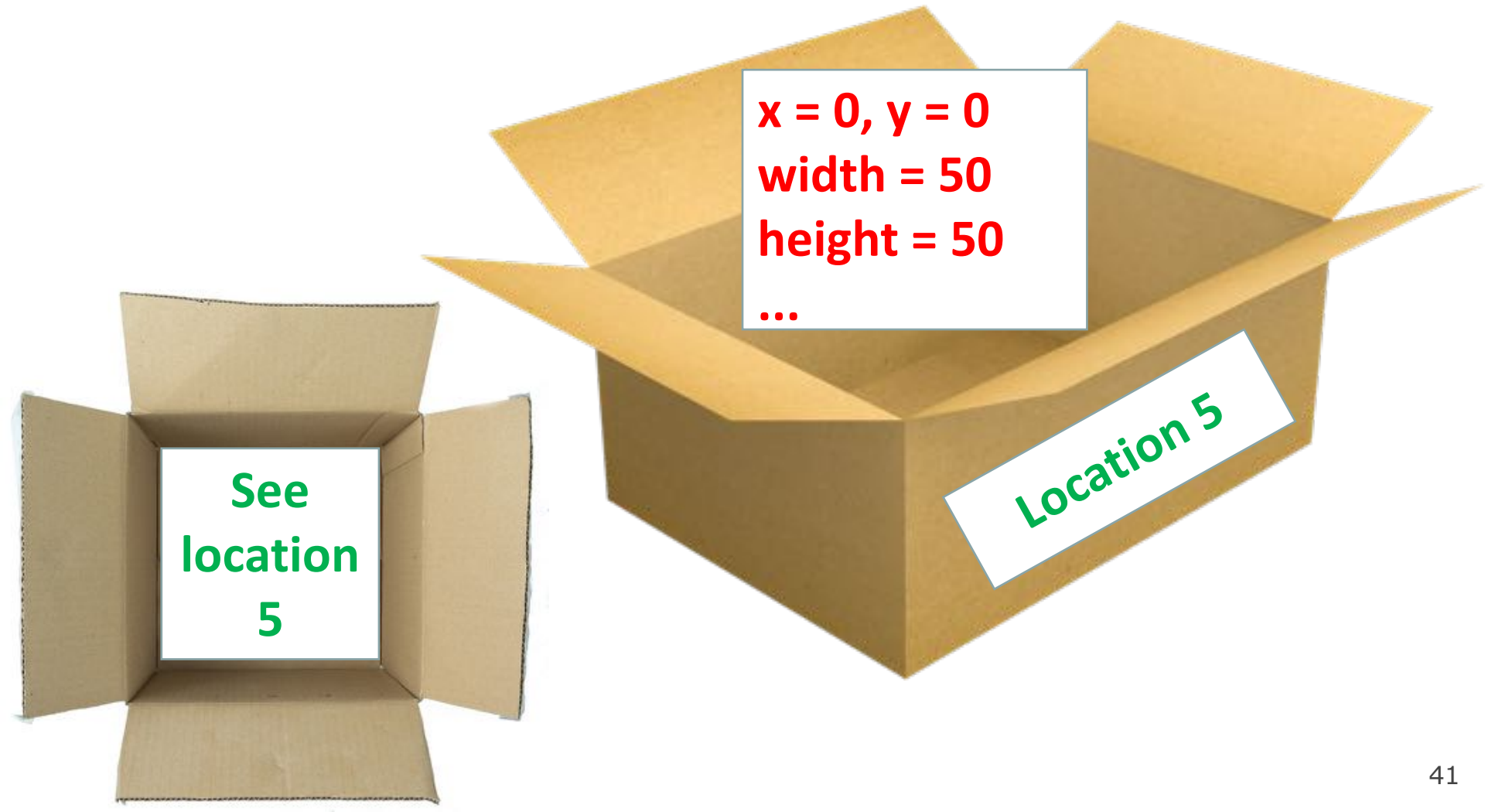
…but rect's box was not big enough for an object!

```
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);
```



In practice

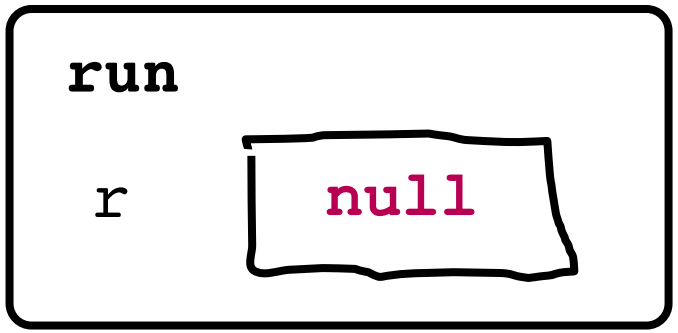
```
public void run() {
    GRect r = null;
}
```

Method memory

Object memory

```
public void run() {
   GRect r = null;
}
```

Method memory



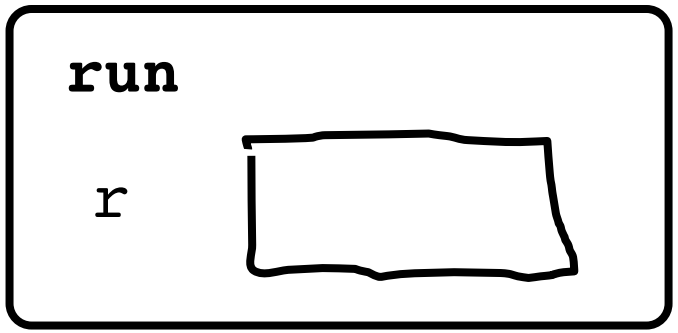
Object memory

Wahoo!

```
public void run() {
    GRect r = new GRect(50, 50);
}
```

Method memory

Object memory



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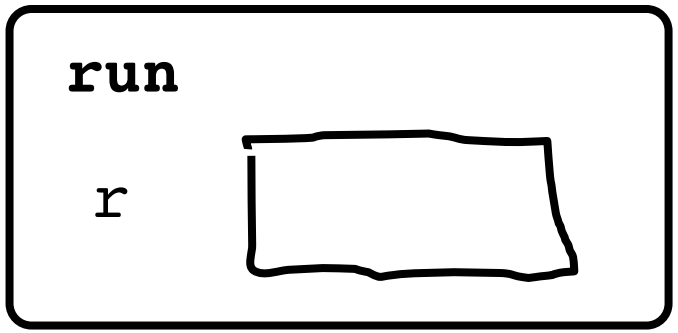
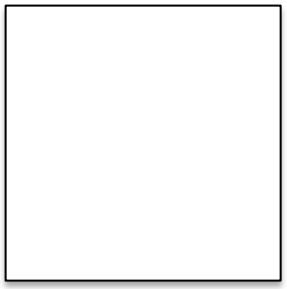
Method memory



Object memory

memory.com/18



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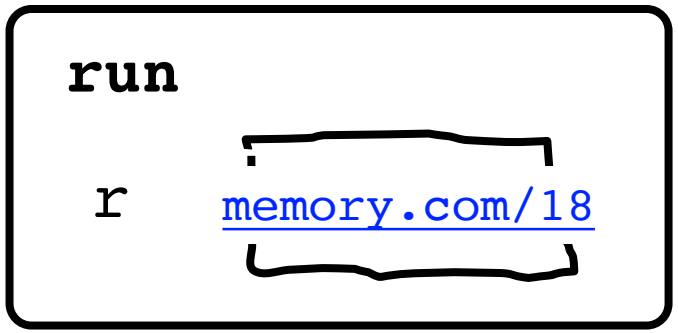
Method memory



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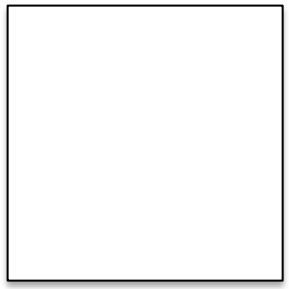

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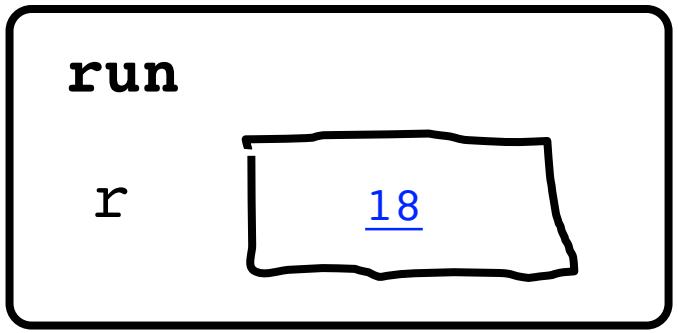

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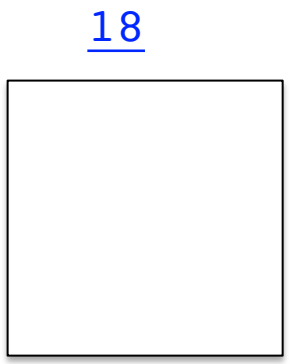

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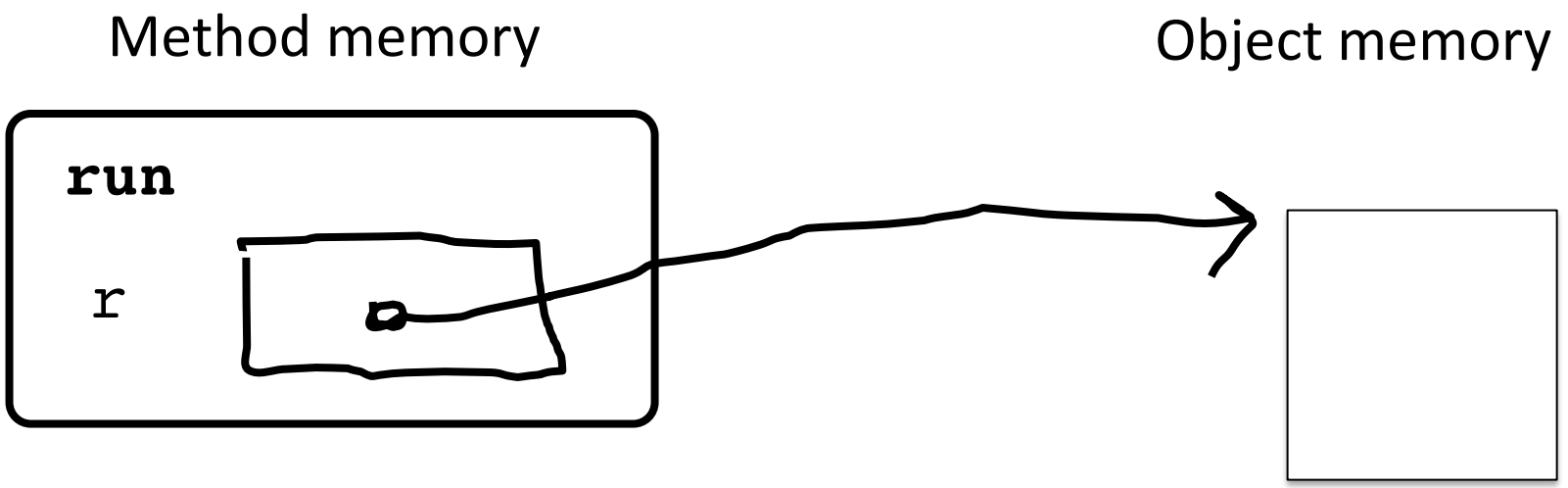
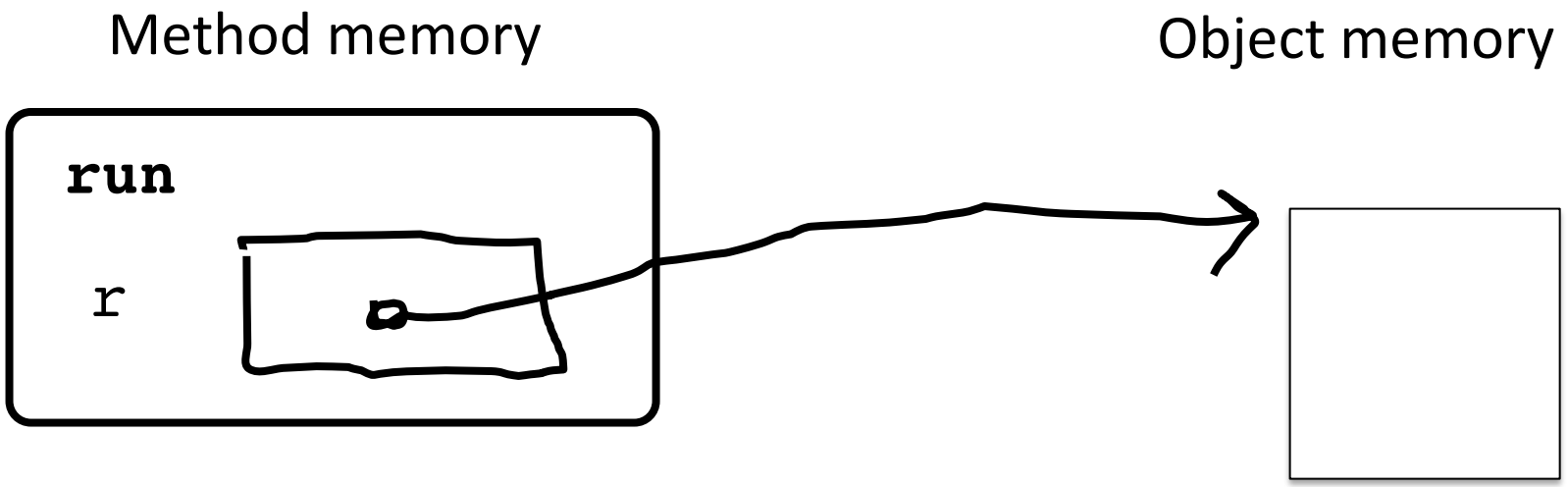


```
public void run() {
   GRect r = new GRect(50, 50);
   r.setColor(Color.BLUE);
   r.setFilled(true);
}
```



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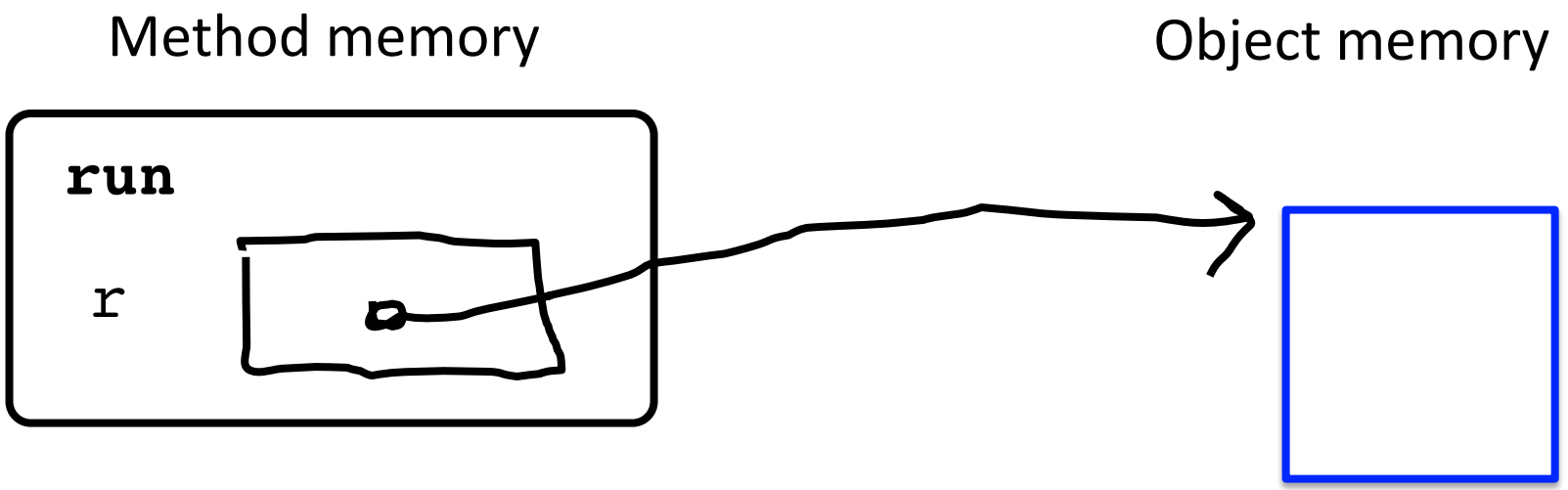

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Method memory

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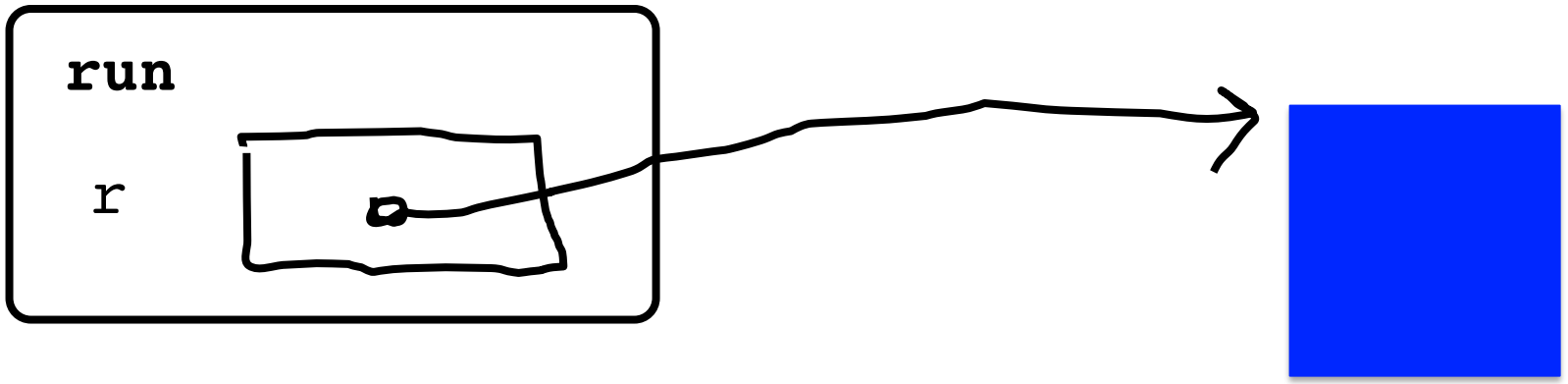


#1: `new` allocates memory for objects

* The data for an object can't always fit inside a fixed size bucket

#2: object variables store addresses

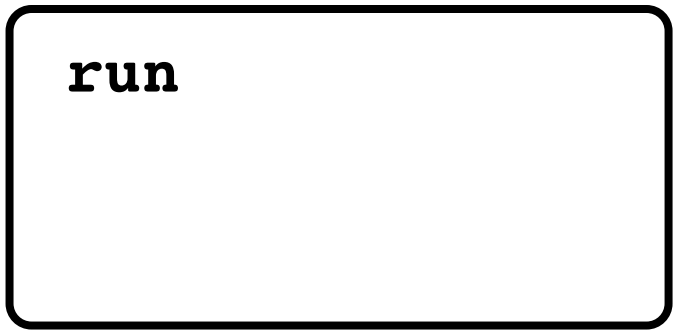
#ultimatekey

```
public void run() {
    GImage img = new GImage("mountain.jpg");
    add(img, 0, 0);
}
```

---

stack

heap



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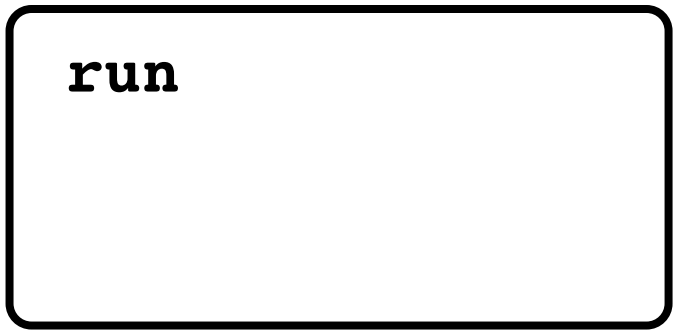

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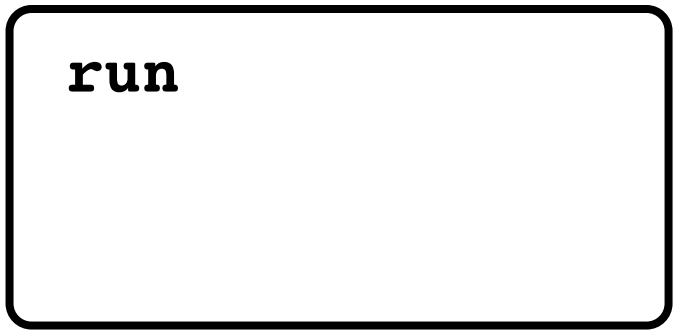

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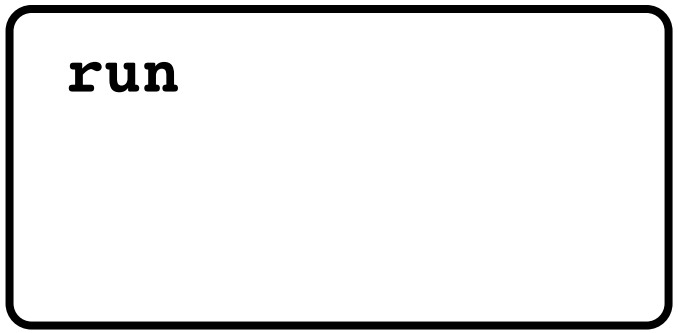

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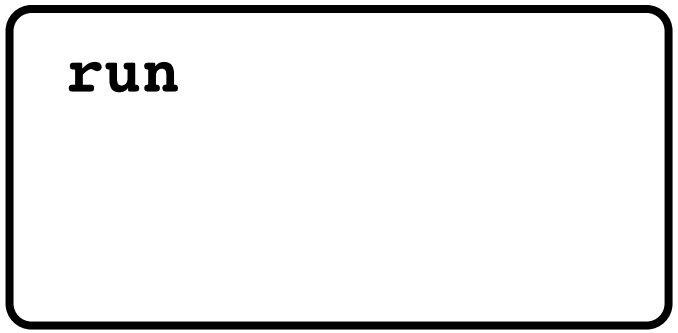

heap

42

```
public void run() {
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    add(img, 0, 0);
}
```
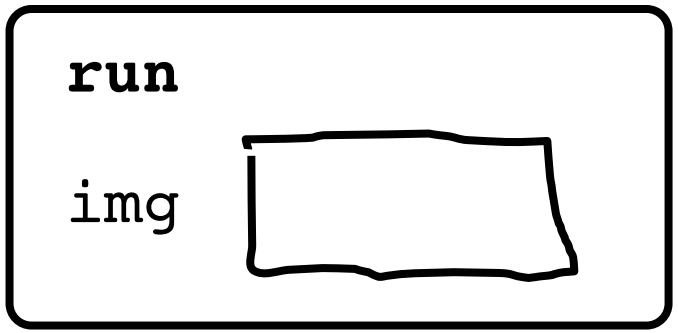

---

stack



heap

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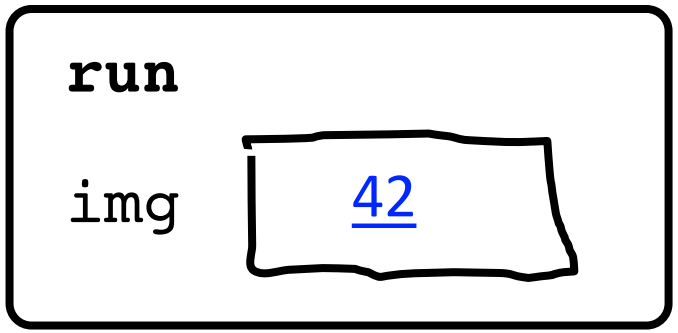

heap

42

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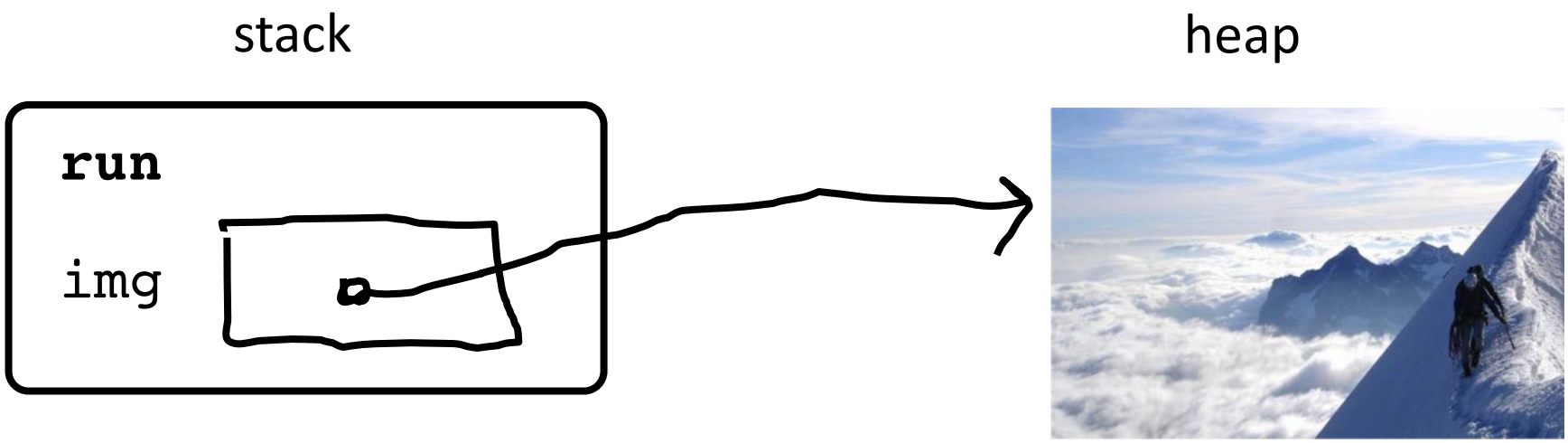

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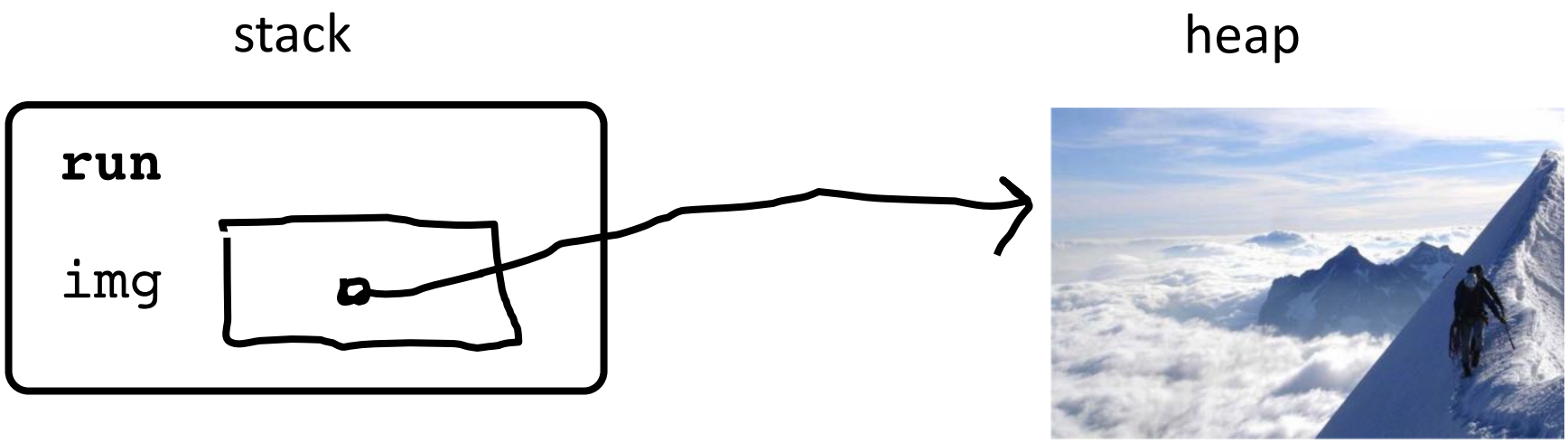
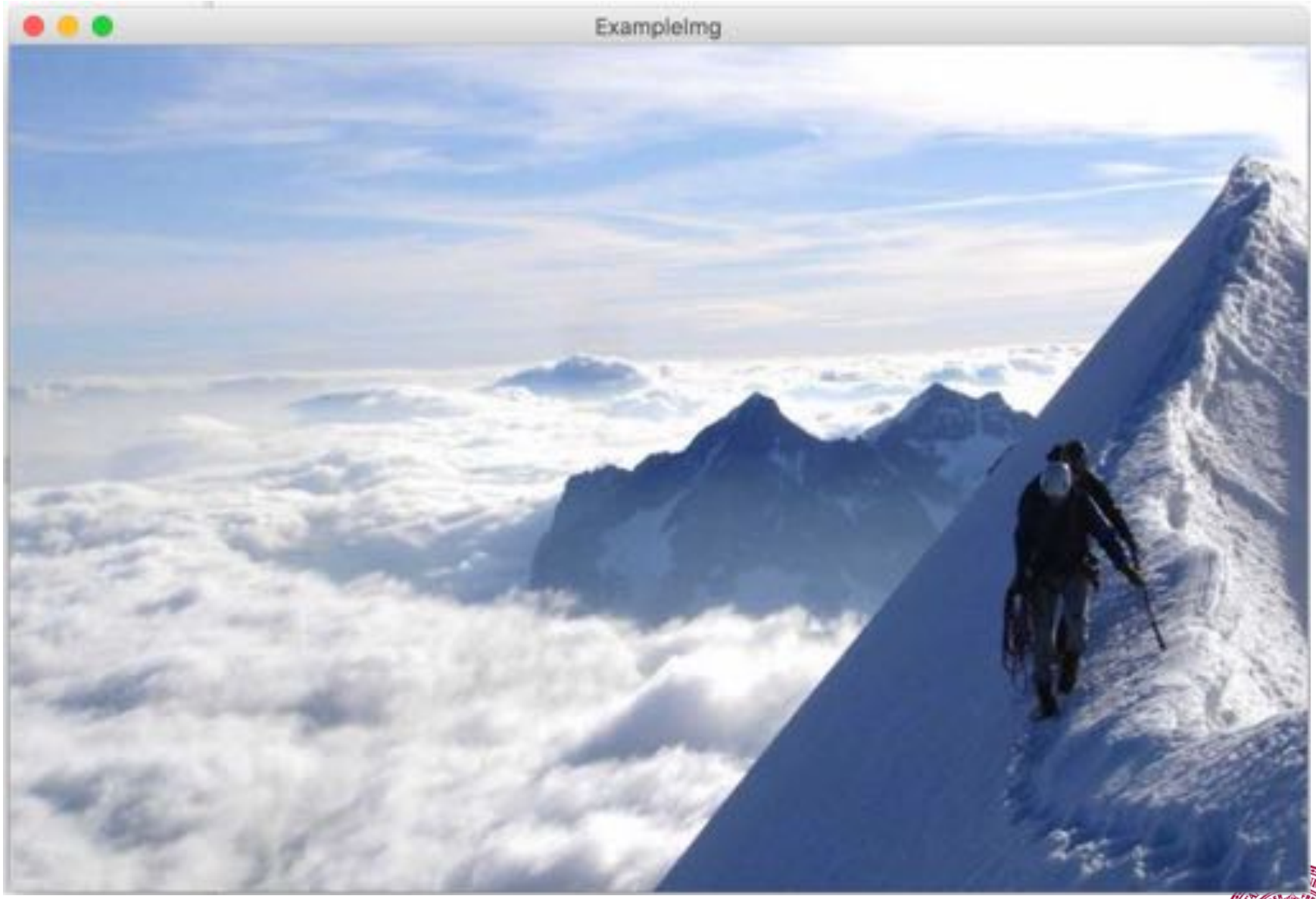



ExampleImg

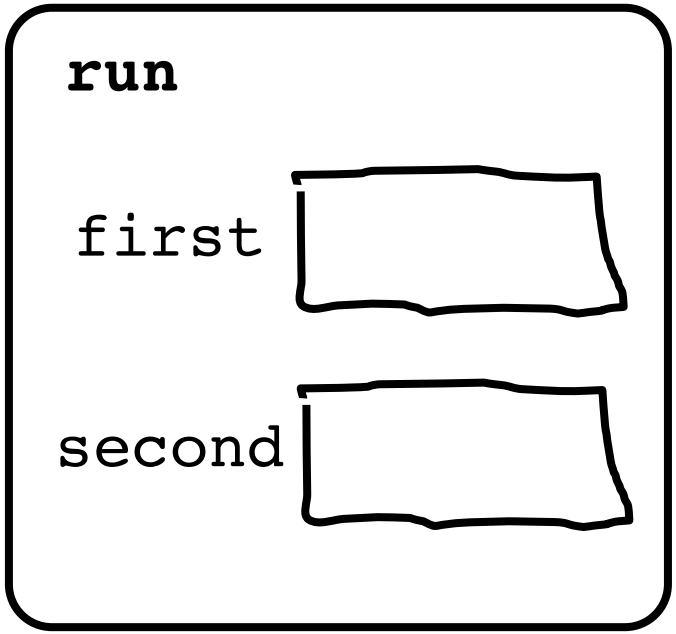
#3: **`GImage`**s look impressive but don't take much extra work

```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```

---

stack

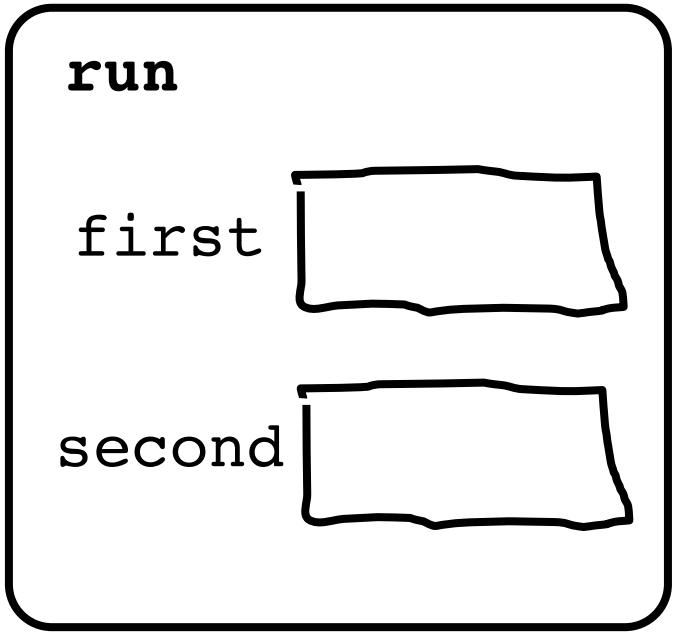
heap



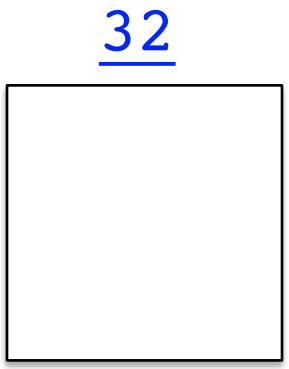
```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```

---

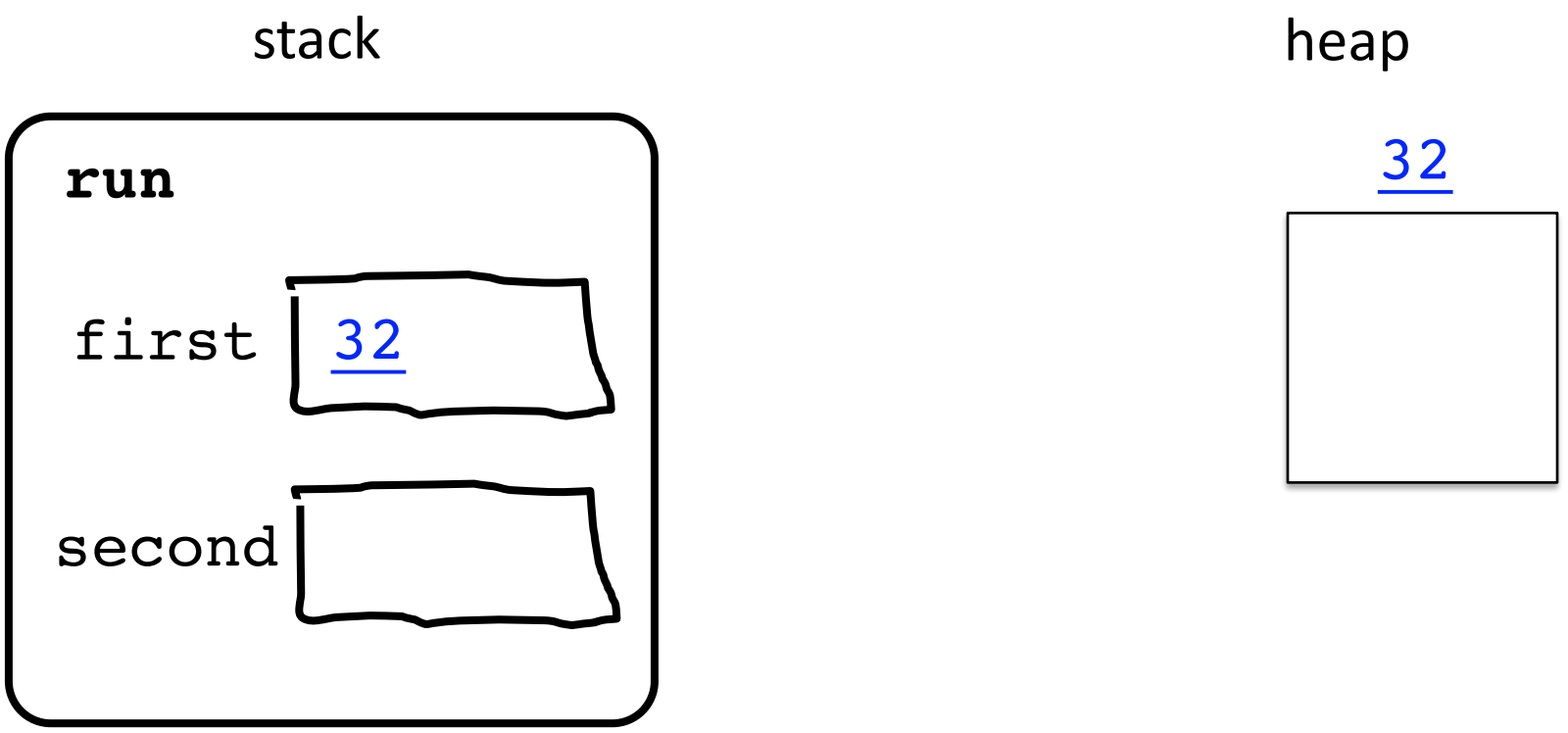
stack



heap



```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```



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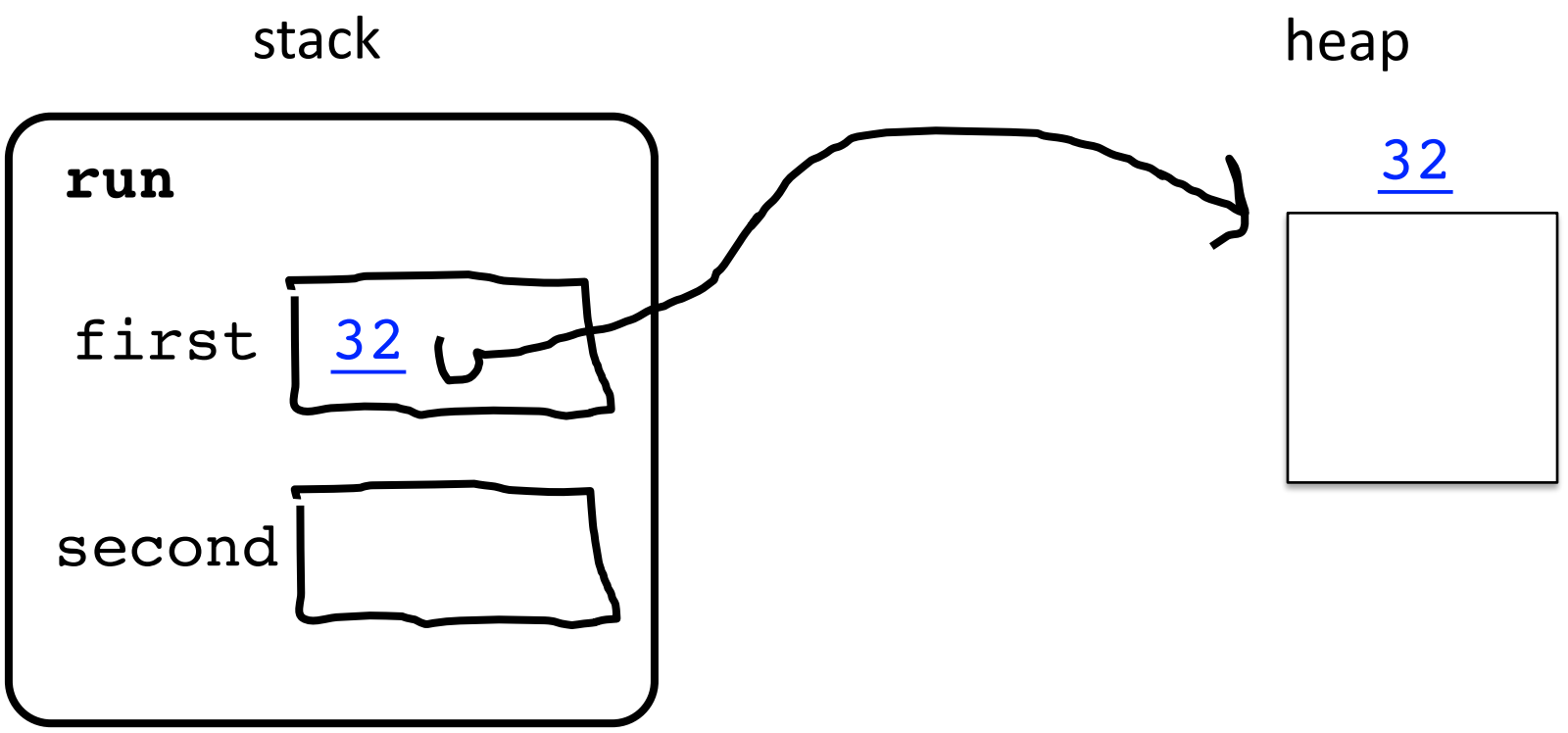
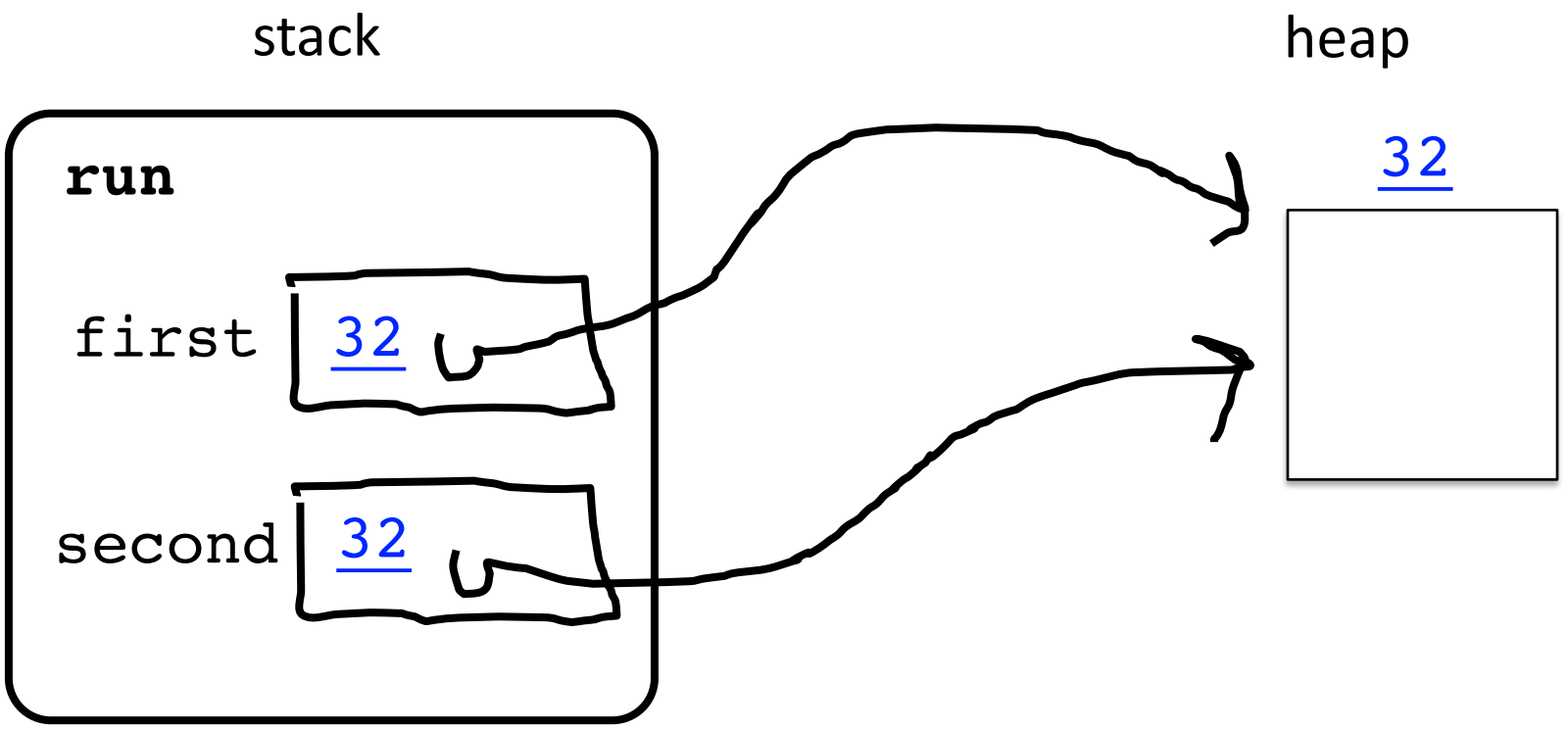
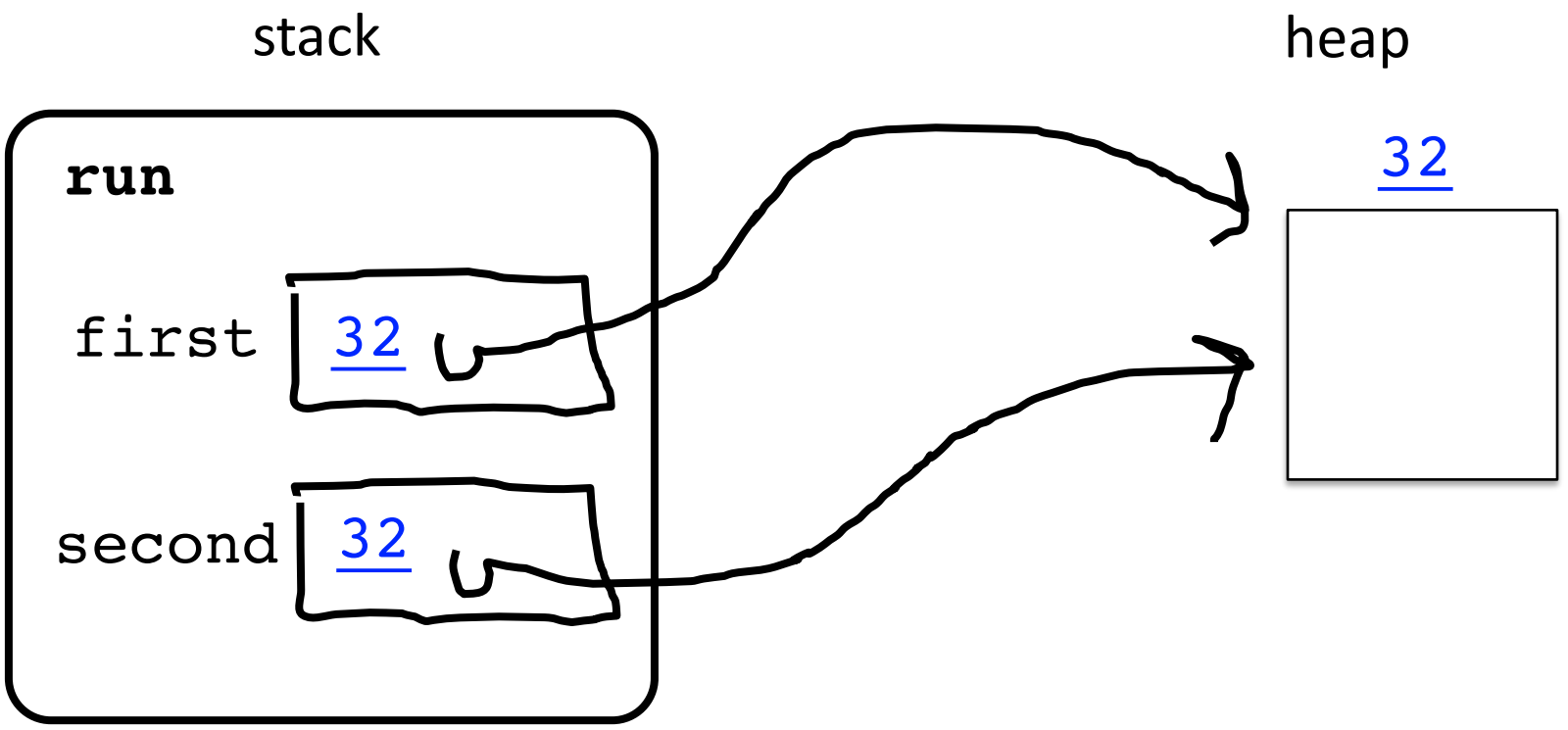
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```



```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```



```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```



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    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```
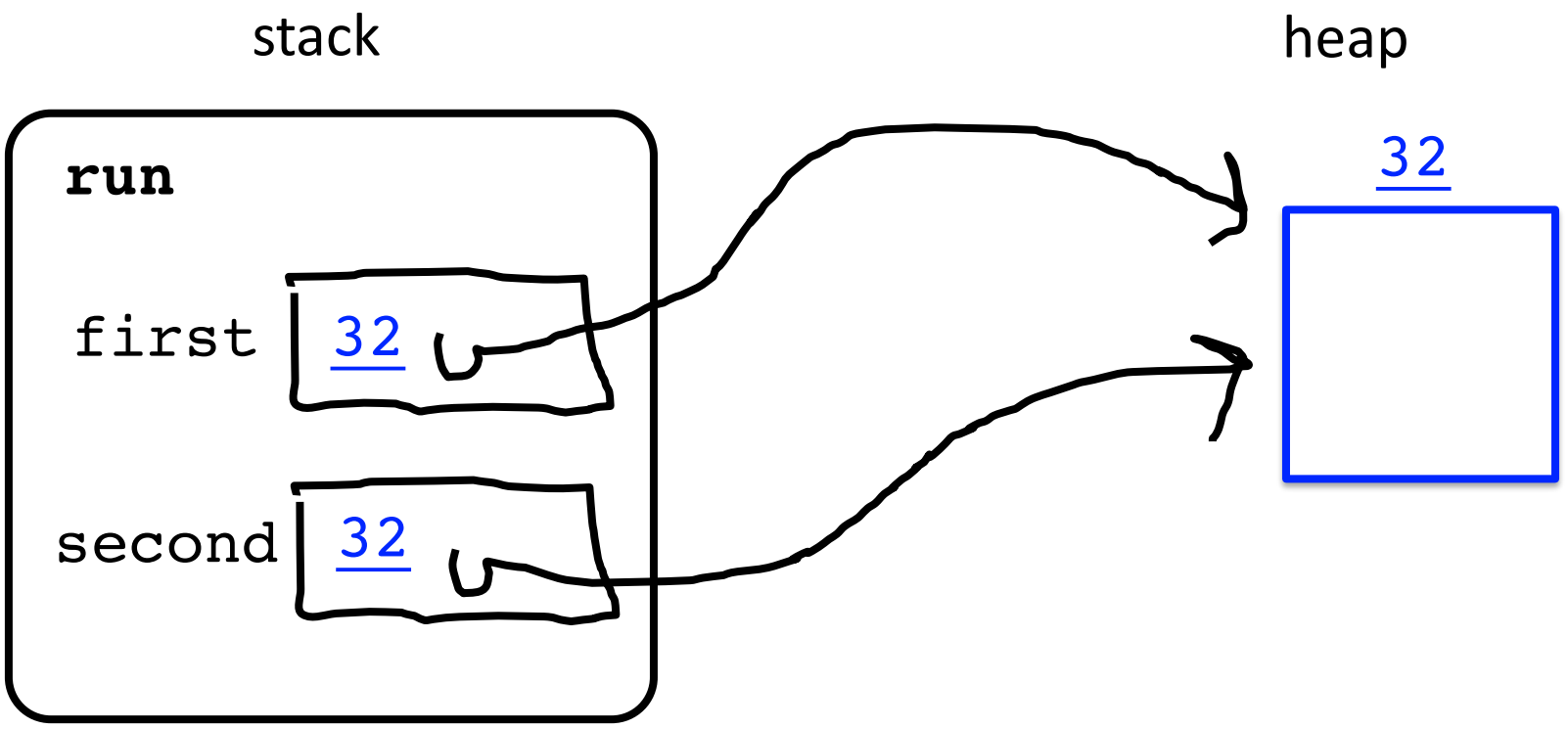
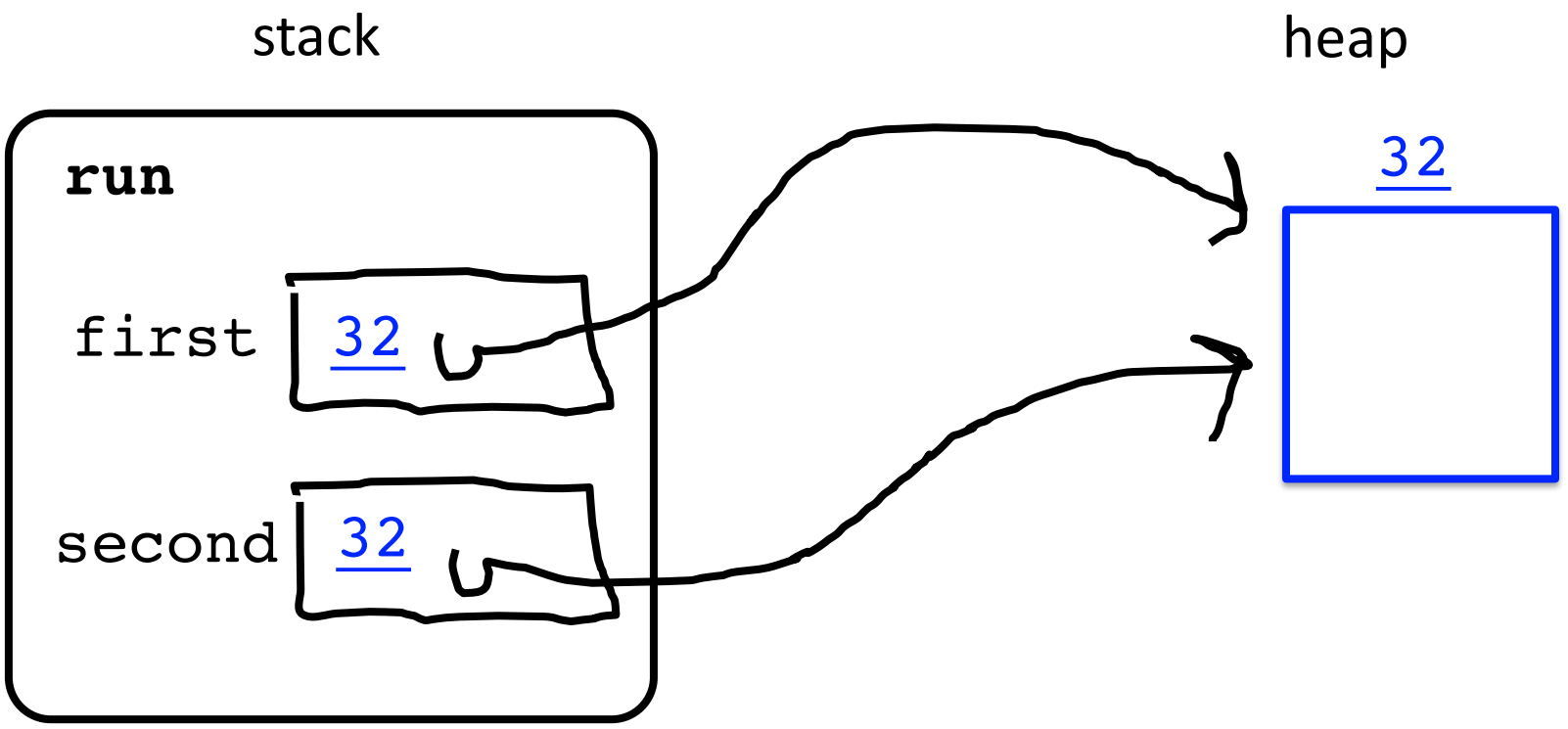
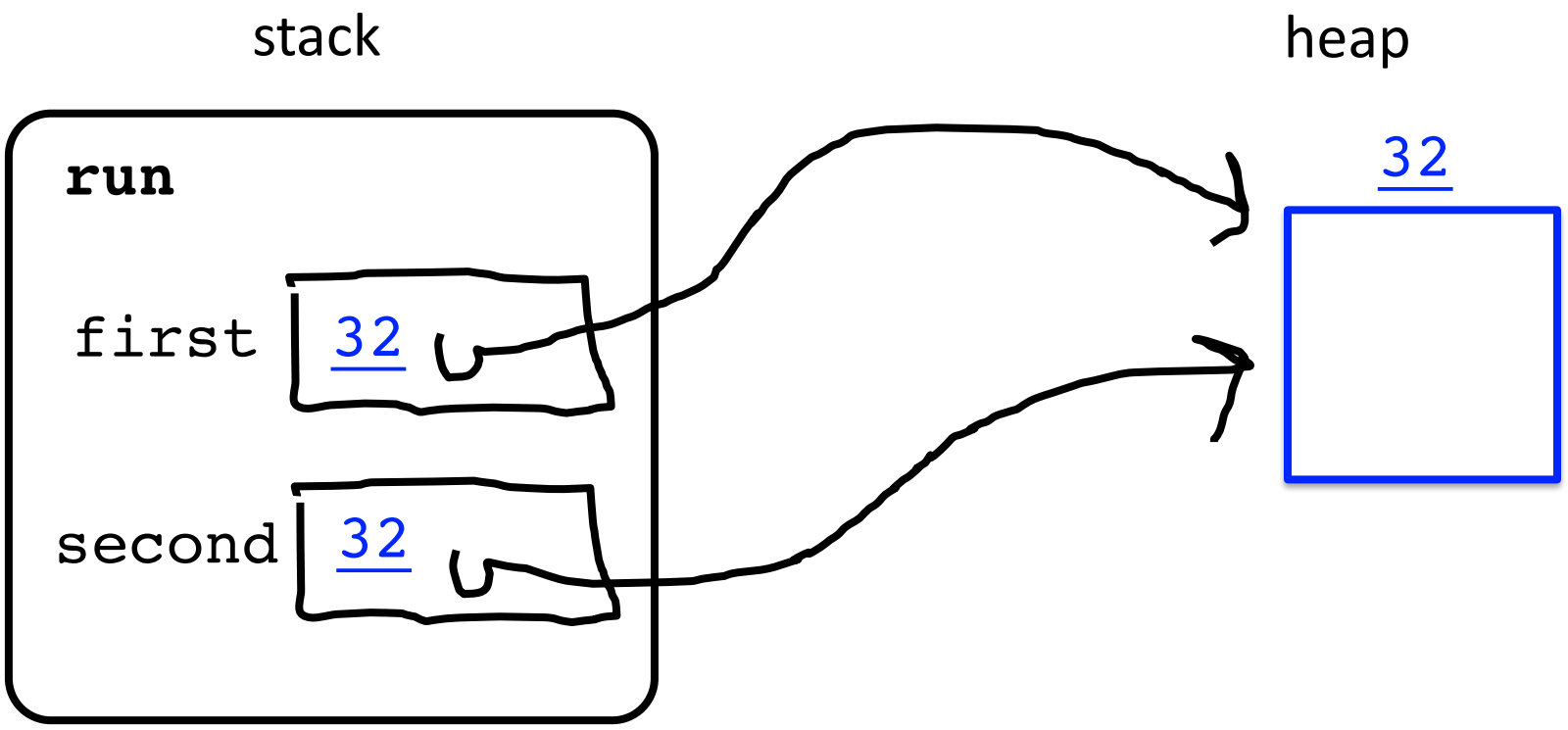



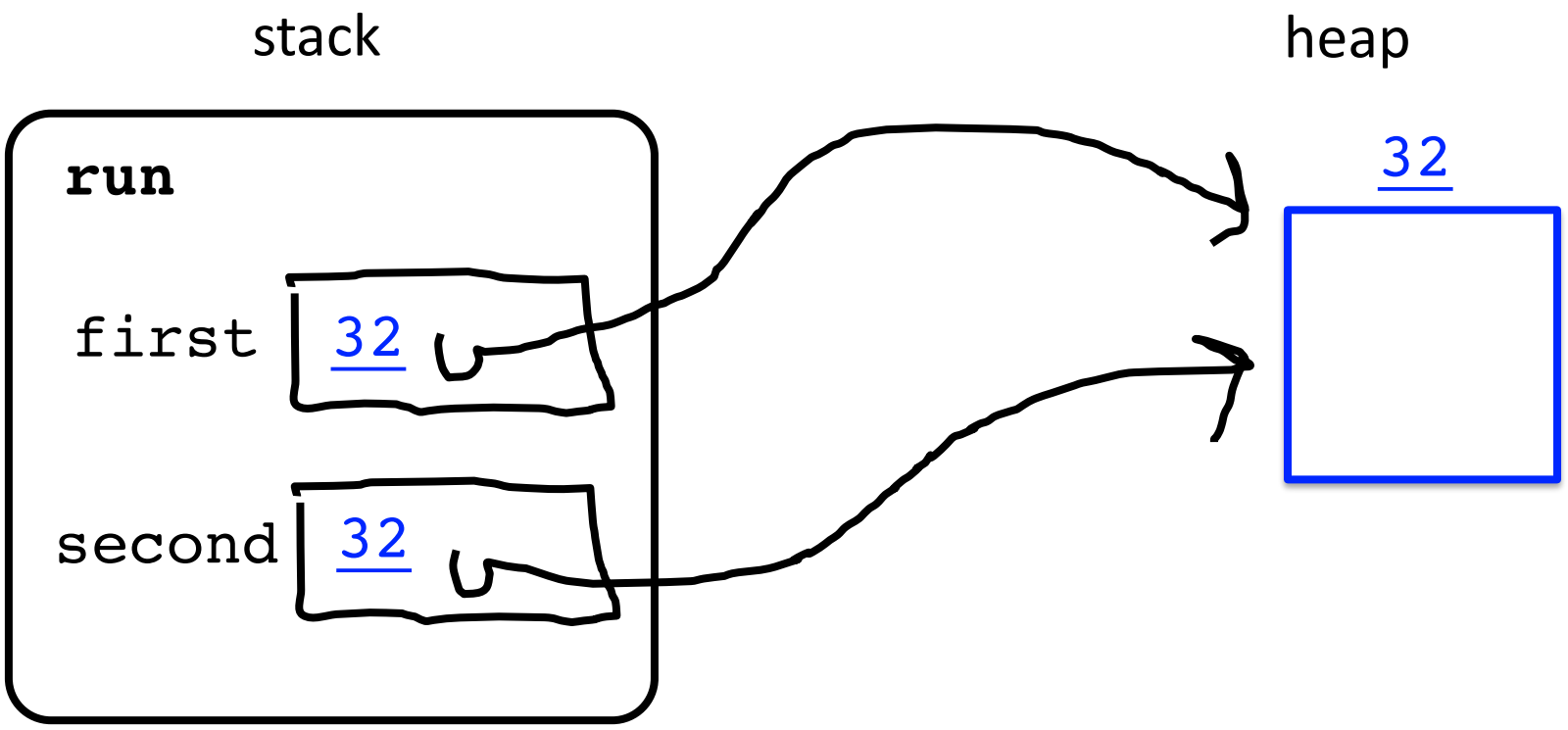
```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
}
```



```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
    add(second, 10, 10);
}
```



```
public void run() {
    GRect first = new GRect(20, 20);
    GRect second = first;
    second.setColor(Color.BLUE);
    add(first, 0, 0);
    add(second, 10, 10);
}
```



#4: when you use the = operator with objects, it copies the *address*

What does an object store?

Objects store addresses
(which are like URLs)

Passing by “Reference”

Primitives pass by value

```
// NOTE: This program is buggy!!

public void run() {
   int x = 3;
   addFive(x);
   println("x = " + x);
}

private void addFive(int x) {
   x += 5;
}
```

* This is probably the single more important example to understand in CS106A

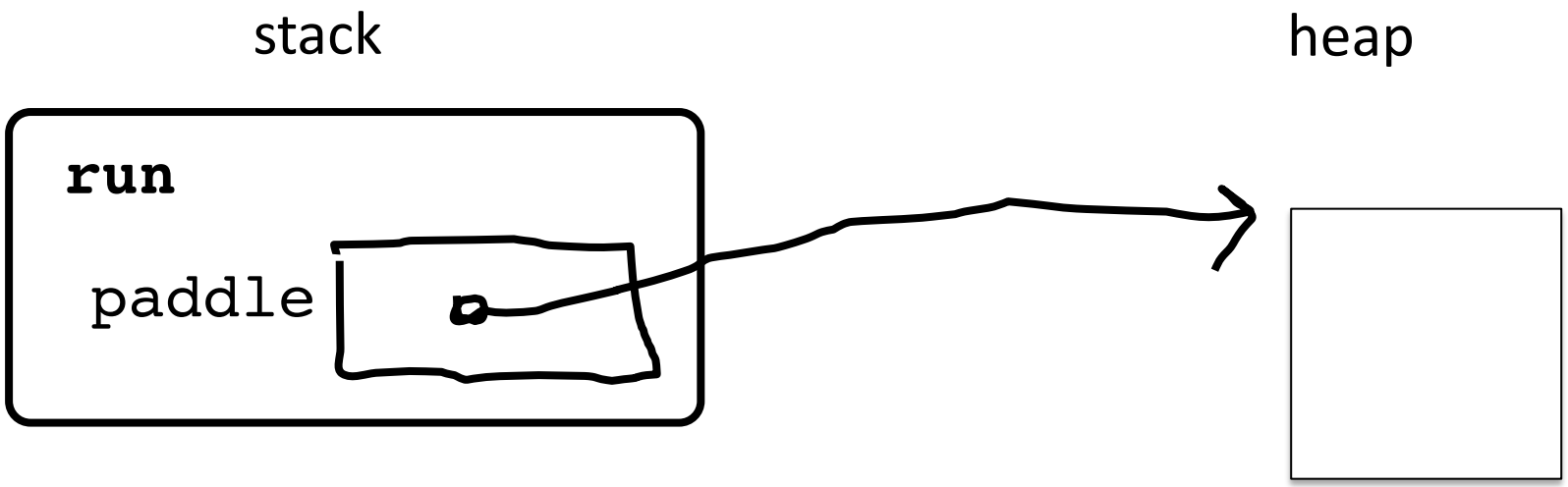
Objects pass by reference

```
// NOTE: This program is awesome!!

public void run() {
  GRect paddle = new GRect(50, 50);
  makeBlue(paddle);
  add(paddle, 0, 0);
}

private void makeBlue(GRect object) {
   object.setColor(Color.BLUE);
   object.setFilled(true);
}
```

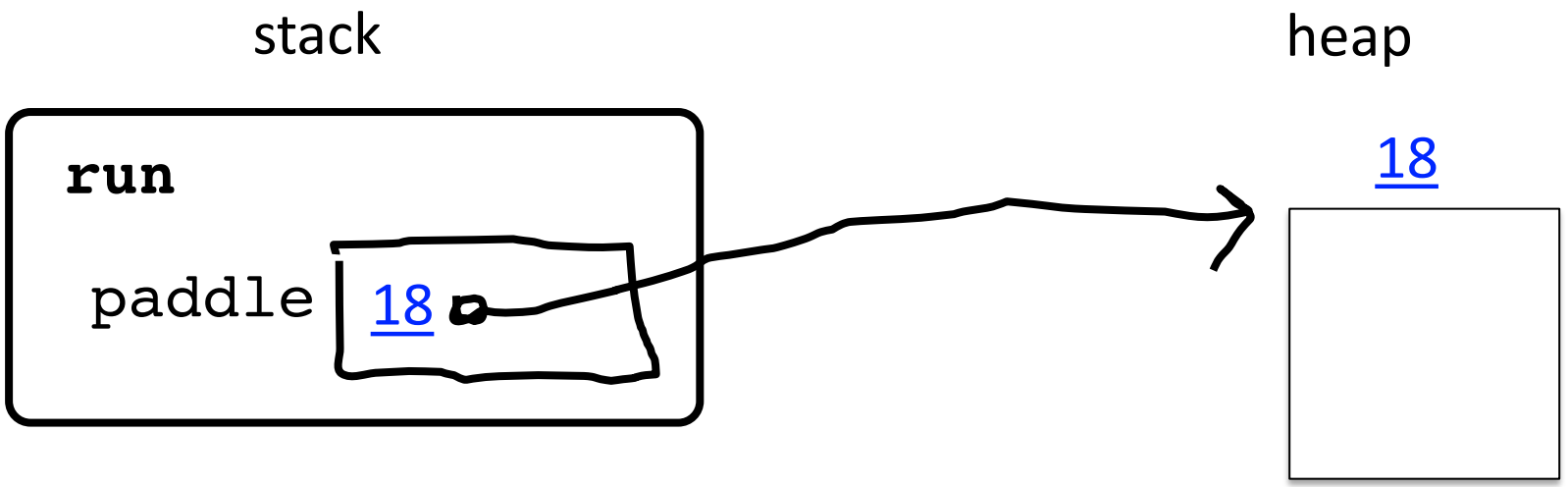
* This is probably the single more important example to understand in CS106A

```
public void run() {
    GRect paddle = new GRect(50, 50);
    makeBlue(paddle);
    add(paddle, 0, 0);
}
private void makeBlue(GRect object) {
    object.setColor(Color.BLUE);
    object.setFilled(true);
}
```


```
public void run() {
    GRect paddle = new GRect(50, 50);
    makeBlue(paddle);
    add(paddle, 0, 0);
}
private void makeBlue(GRect object) {
    object.setColor(Color.BLUE);
    object.setFilled(true);
}
```



```
public void run() {
    GRect paddle = new GRect(50, 50);
    makeBlue(paddle);
    add(paddle, 0, 0);
}
private void makeBlue(GRect object) {
    object.setColor(Color.BLUE);
    object.setFilled(true);
}
```



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

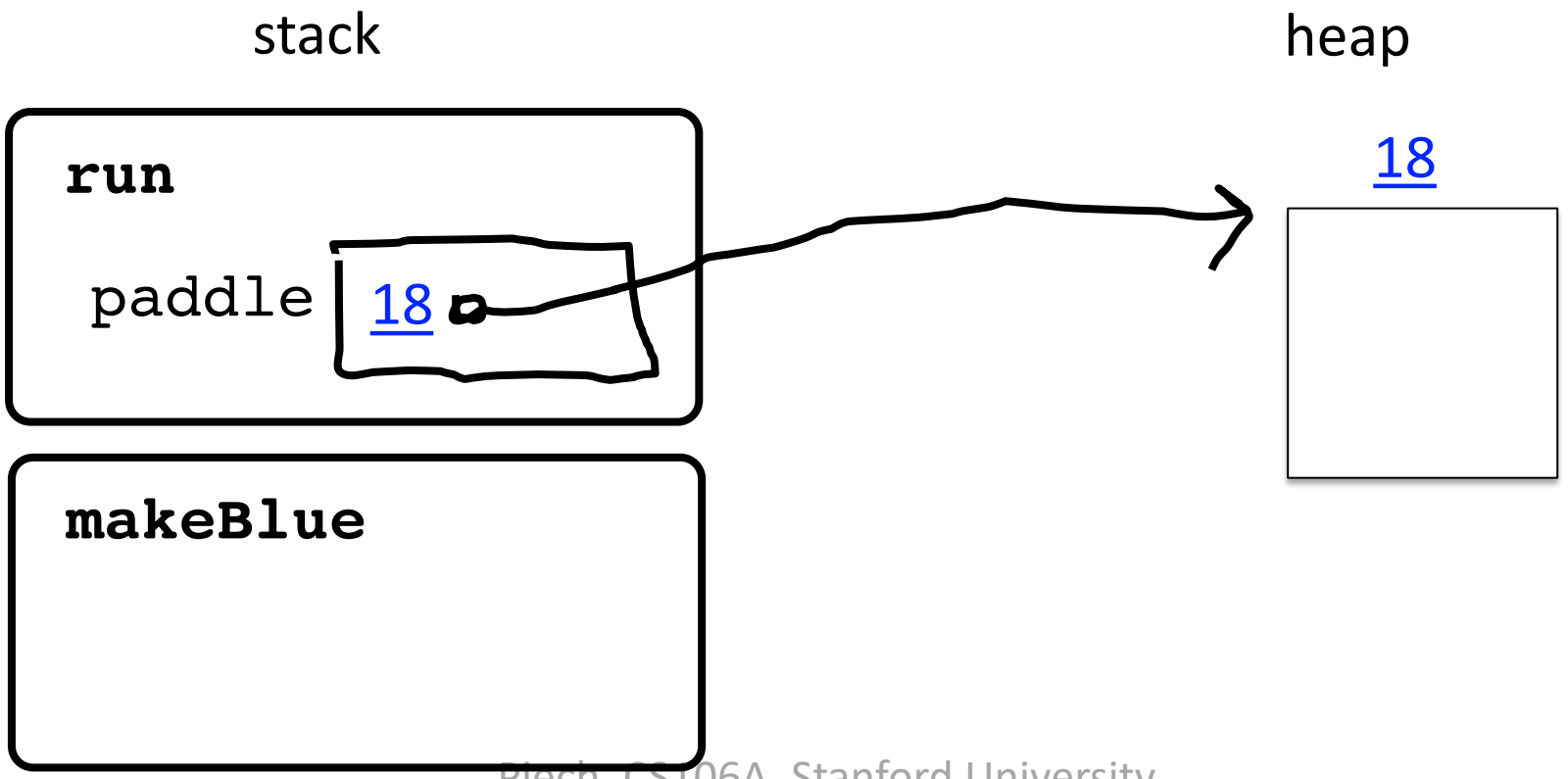

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public void run() {
    GRect paddle = new GRect(50, 50);
    makeBlue(paddle);
    add(paddle, 0, 0);
}
private void makeBlue(GRect object) {
    object.setColor(Color.BLUE);
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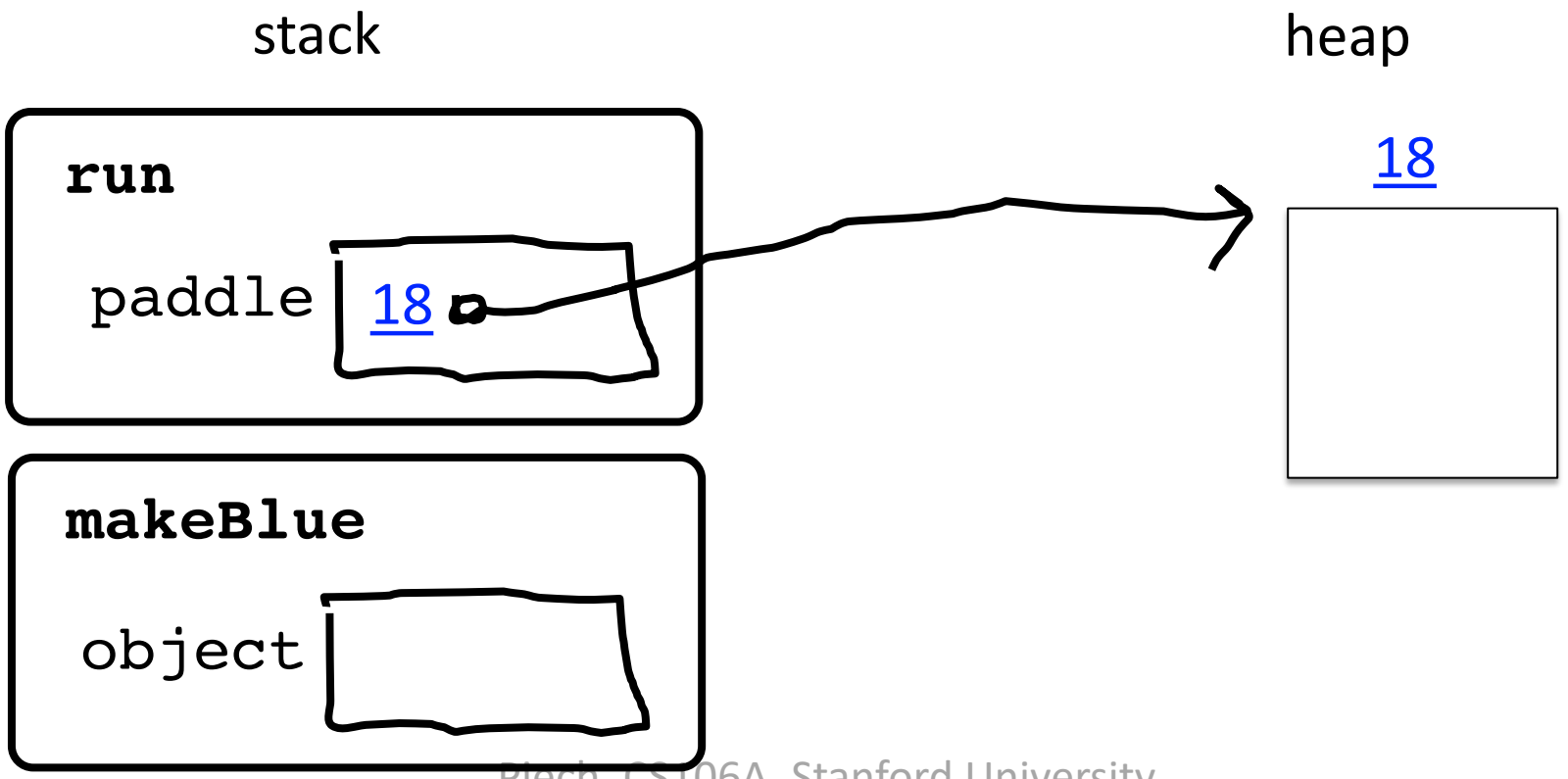
```



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public void run() {
    GRect paddle = new GRect(50, 50);
    makeBlue(paddle);
    add(paddle, 0, 0);
}
private void makeBlue(GRect object) {
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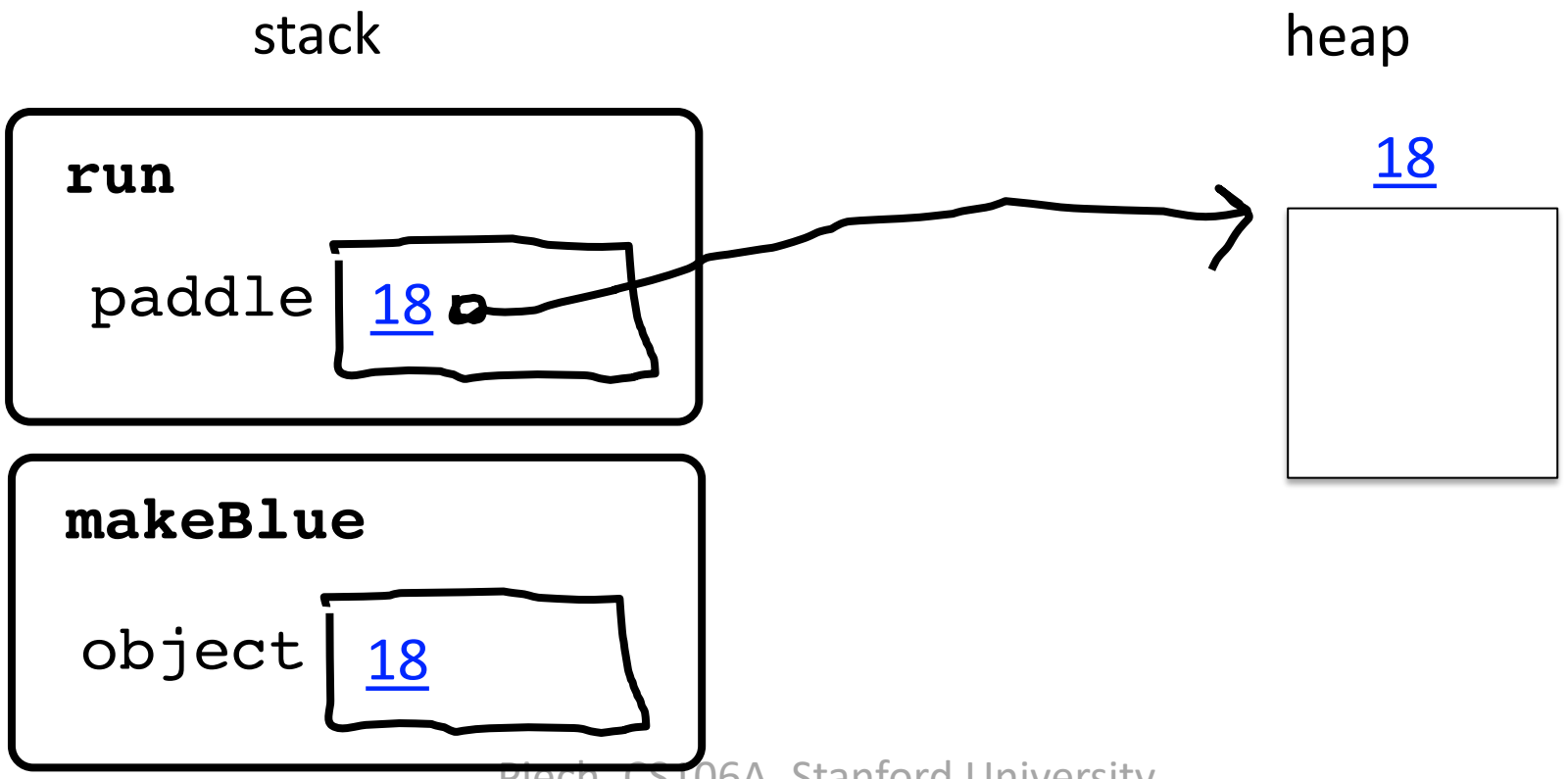

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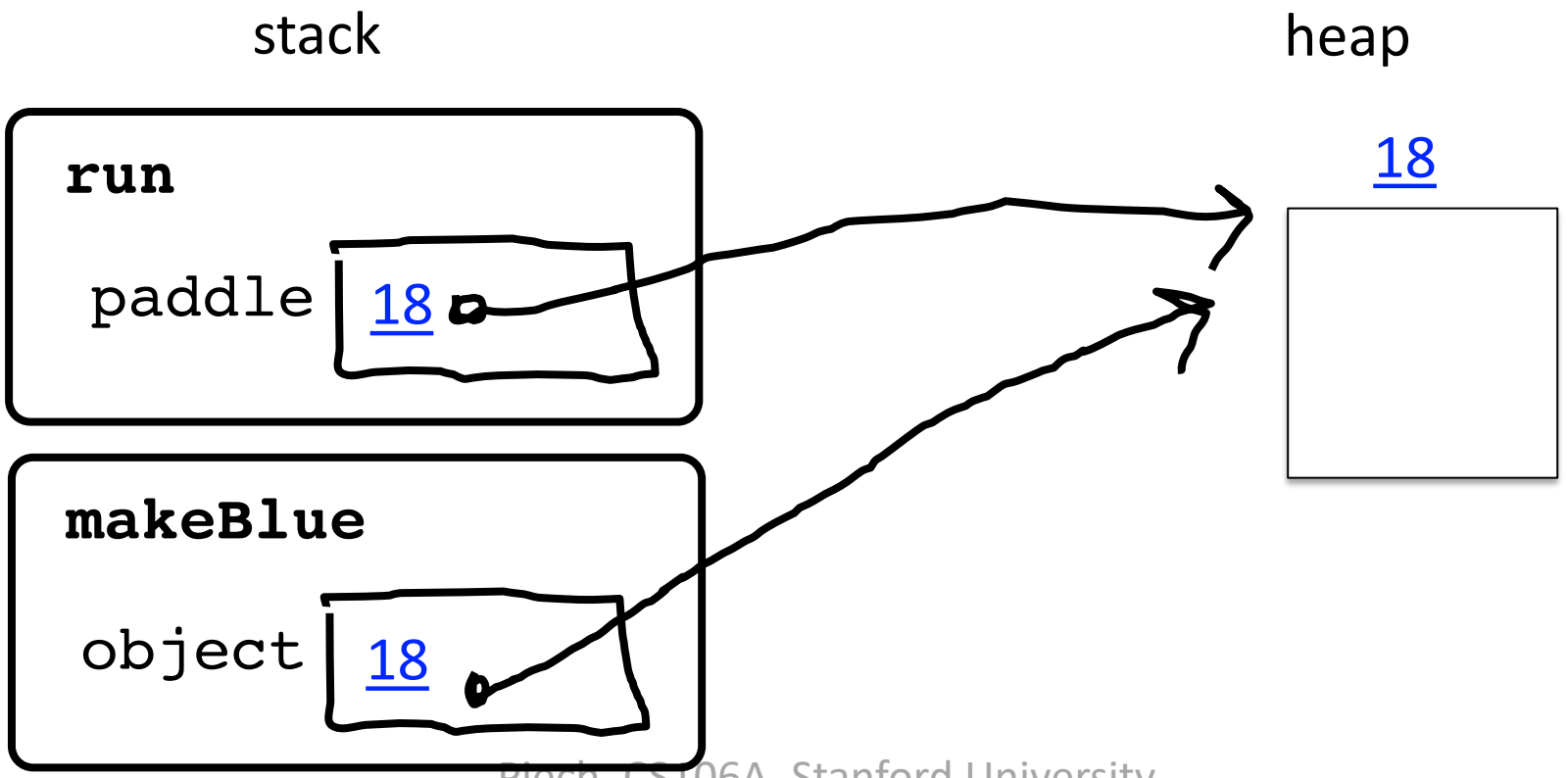

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    GRect paddle = new GRect(50, 50);
    makeBlue(paddle);
    add(paddle, 0, 0);
}
private void makeBlue(GRect object) {
    object.setColor(Color.BLUE);
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}
```

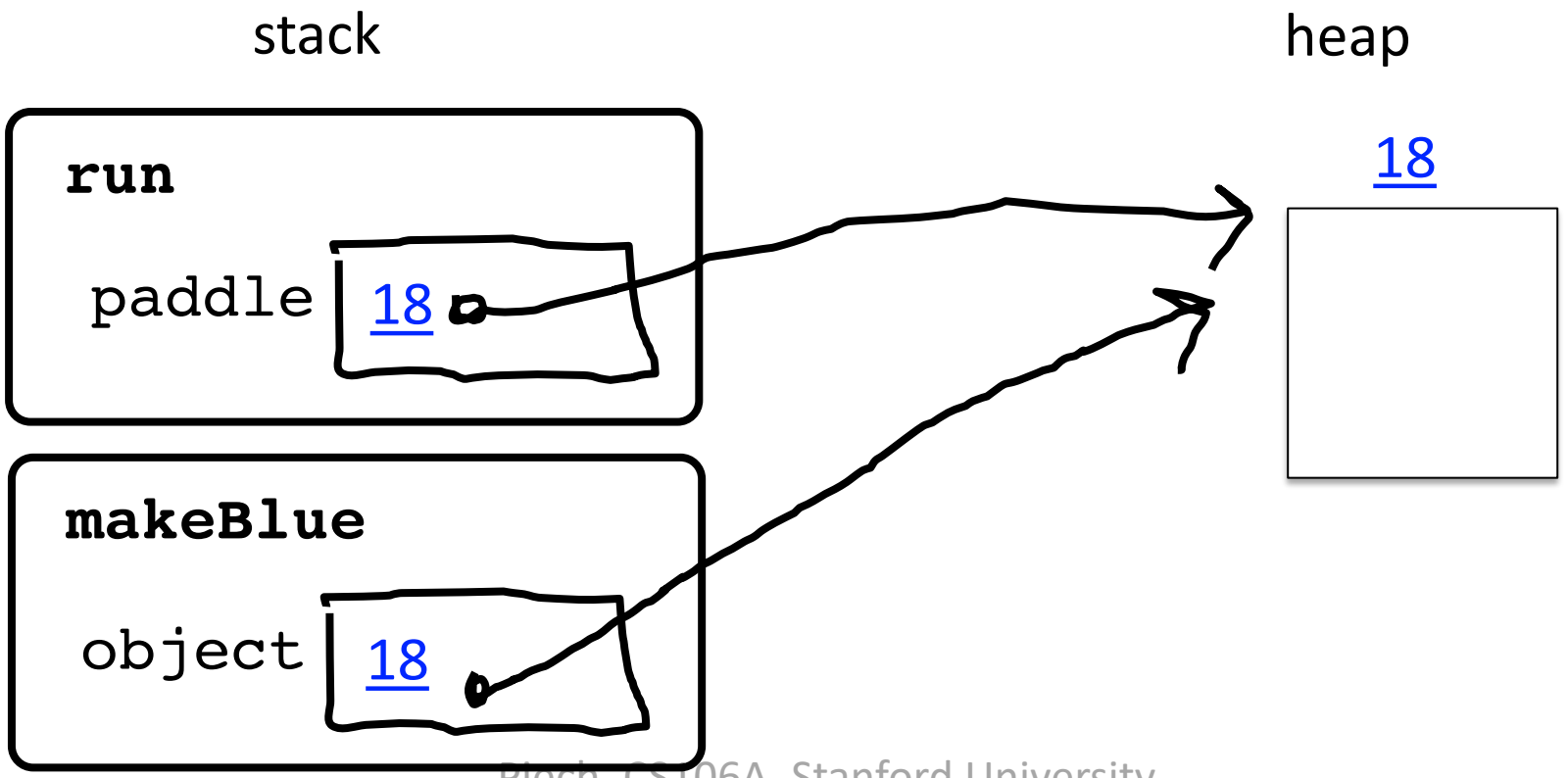

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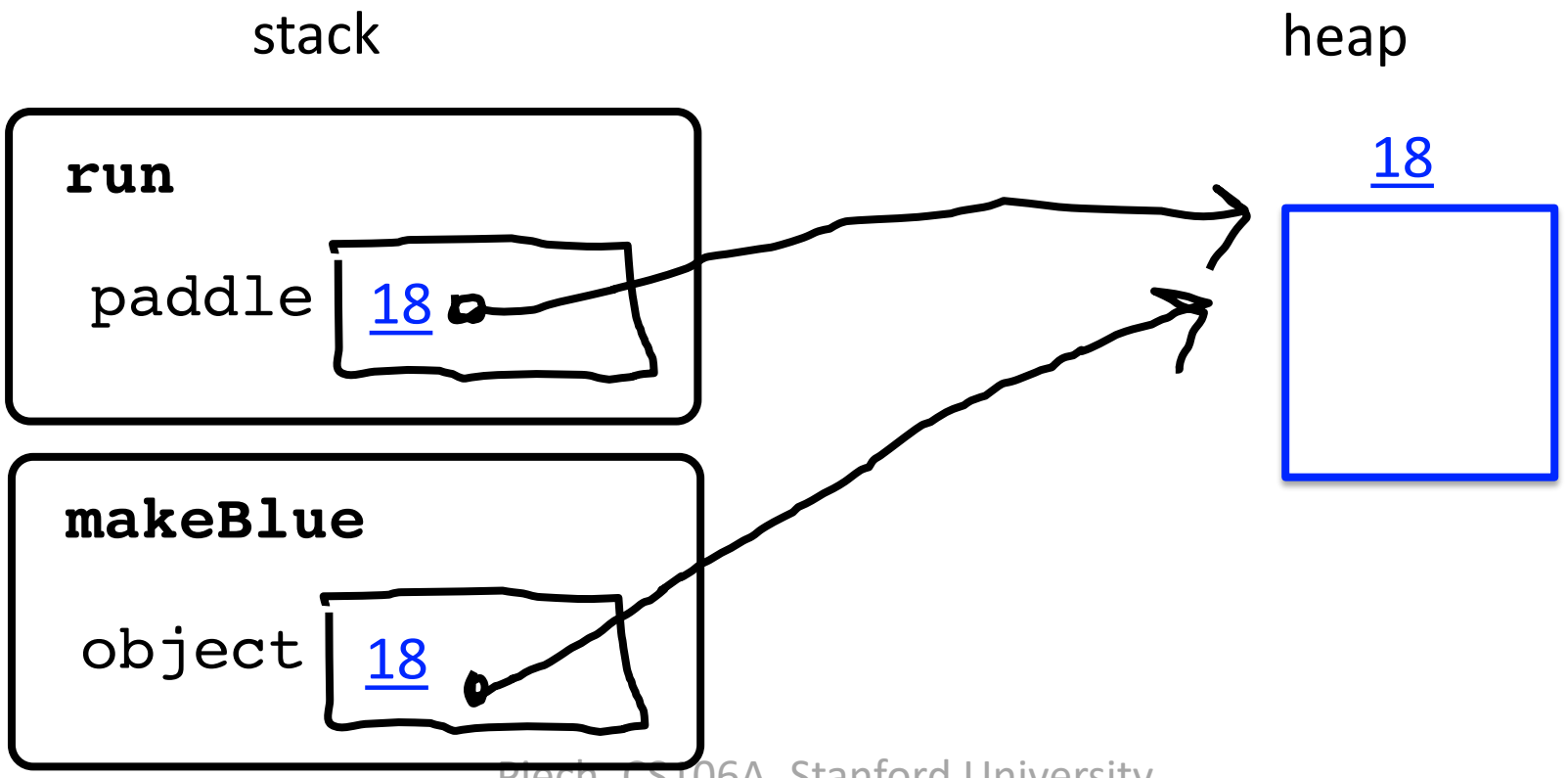
    object.setColor(Color.BLUE);
    object.setFilled(true);
}
```



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    makeBlue(paddle);
    add(paddle, 0, 0);
}
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    object.setColor(Color.BLUE);
    object.setFilled(true);
}
```

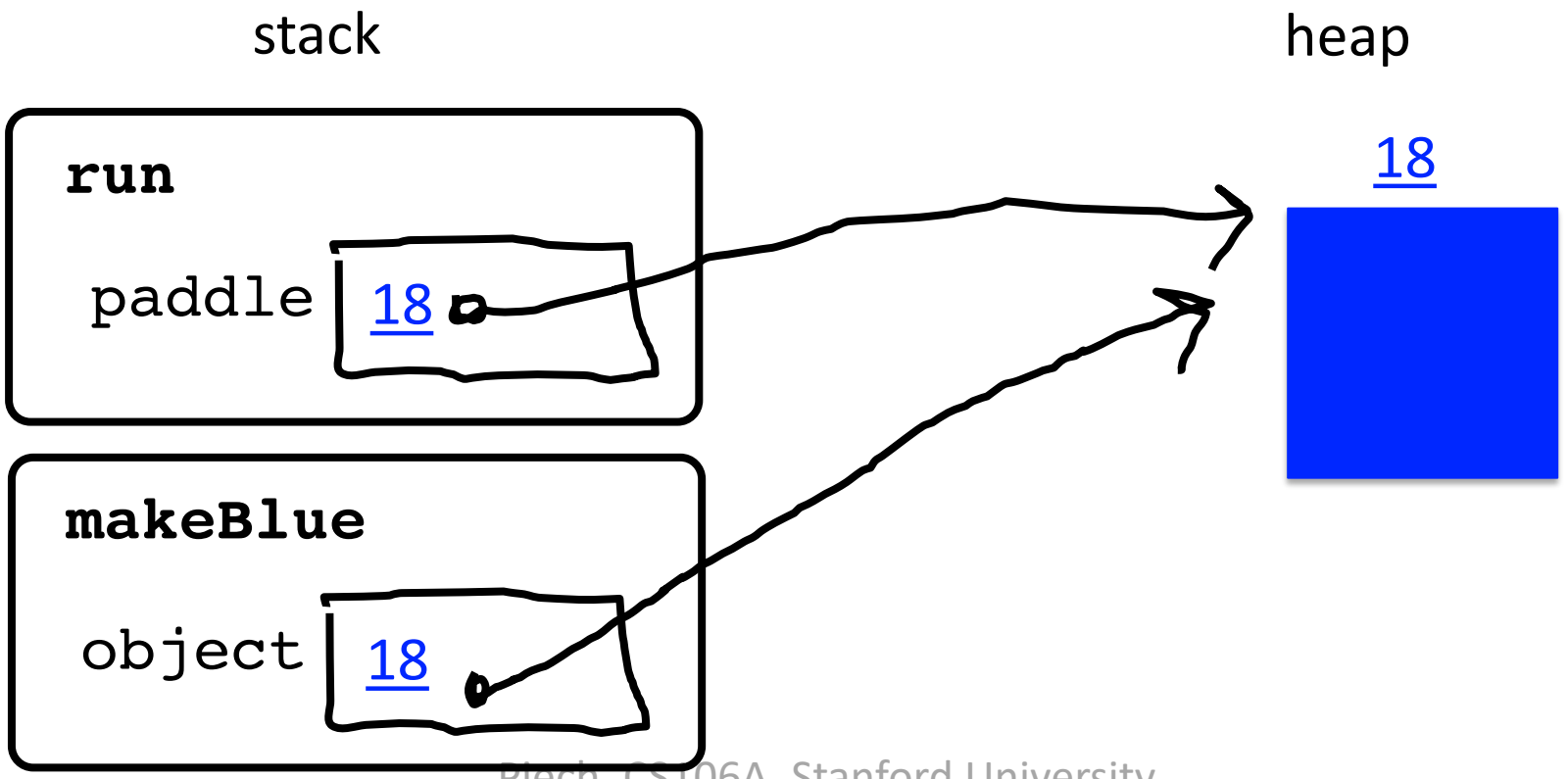

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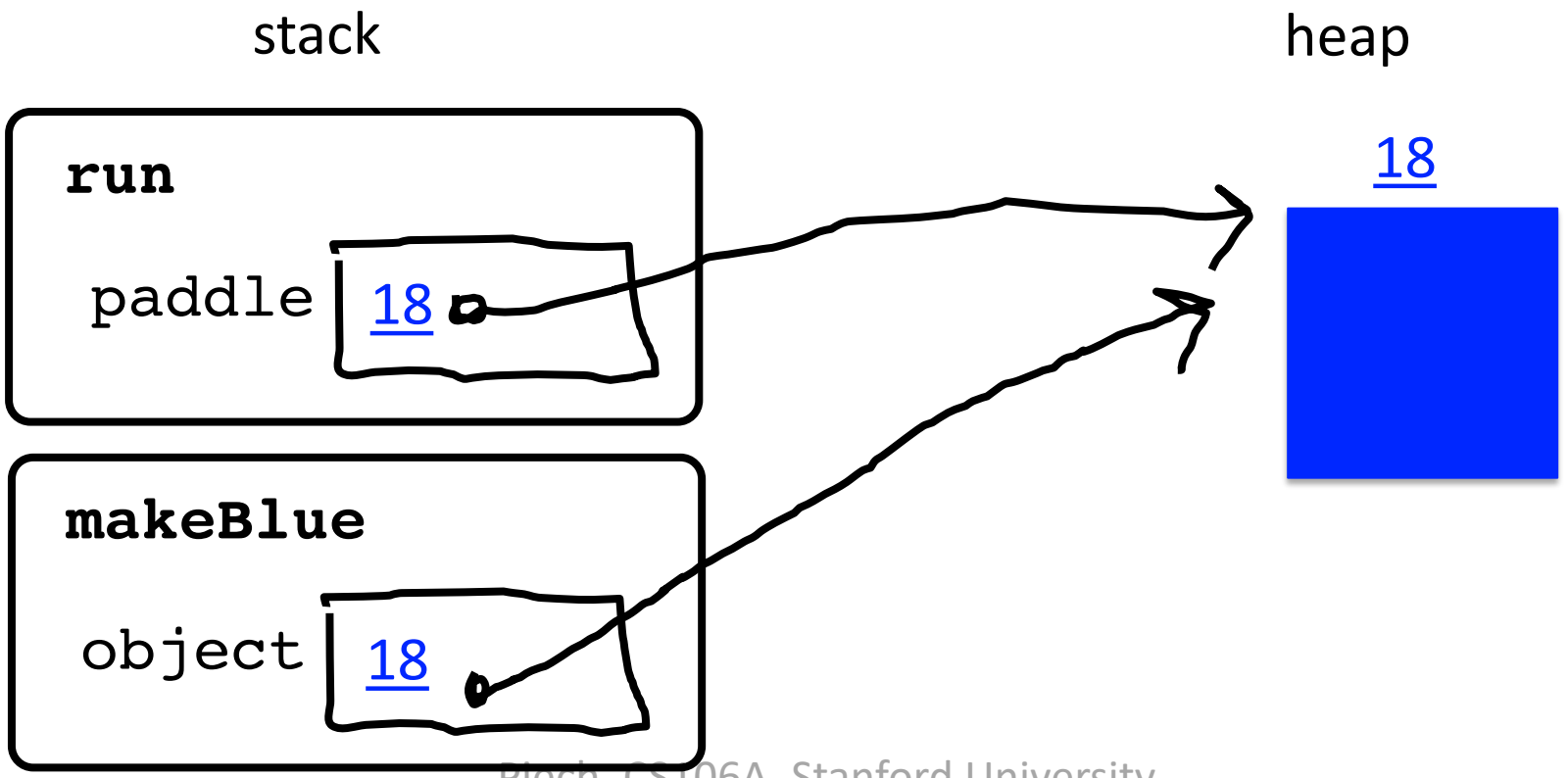
    GRect paddle = new GRect(50, 50);
    makeBlue(paddle);
    add(paddle, 0, 0);
}
private void makeBlue(GRect object) {
    object.setColor(Color.BLUE);
    object.setFilled(true);
}
```



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    object.setFilled(true);
}
```

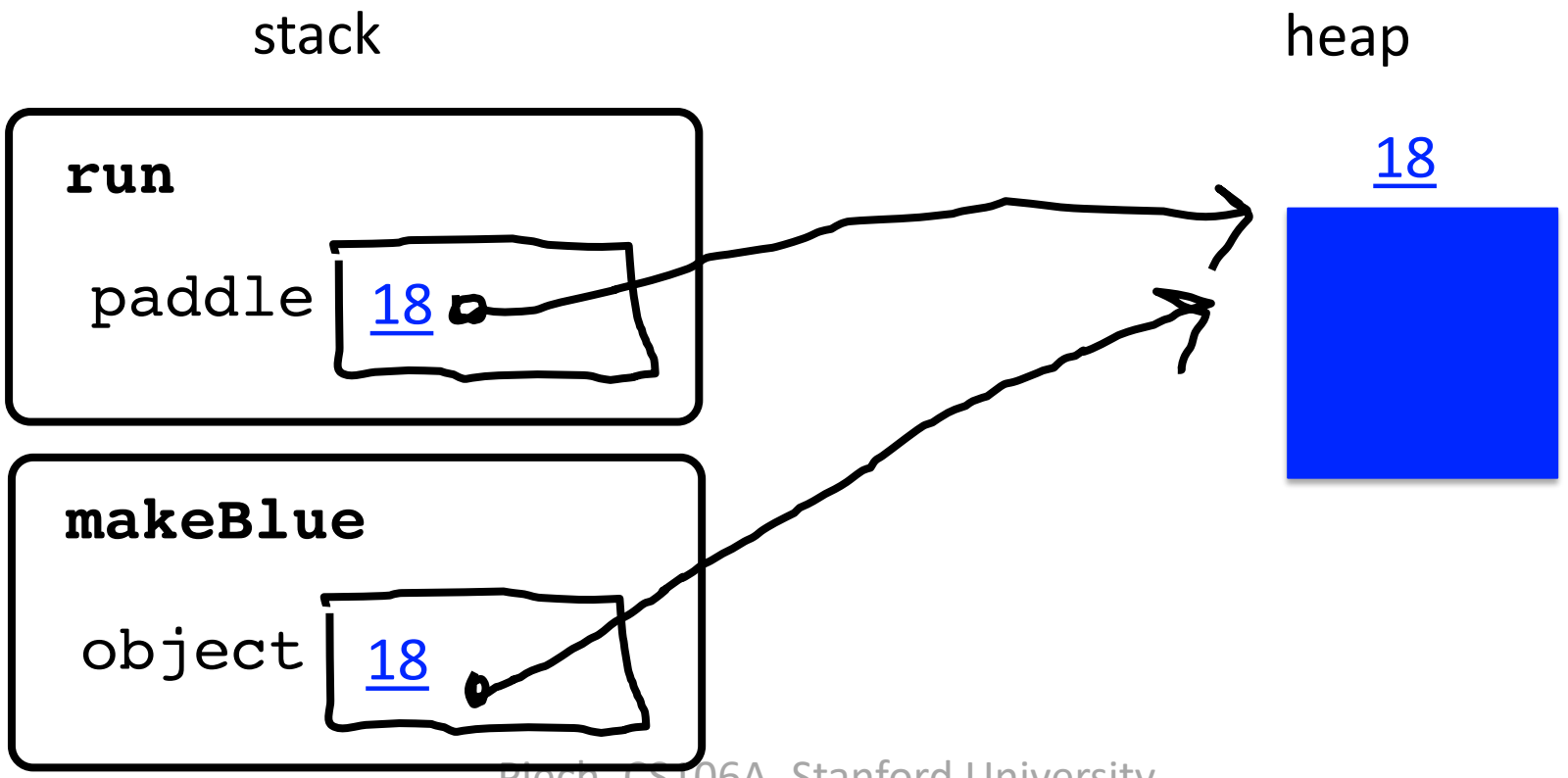

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    makeBlue(paddle);
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}
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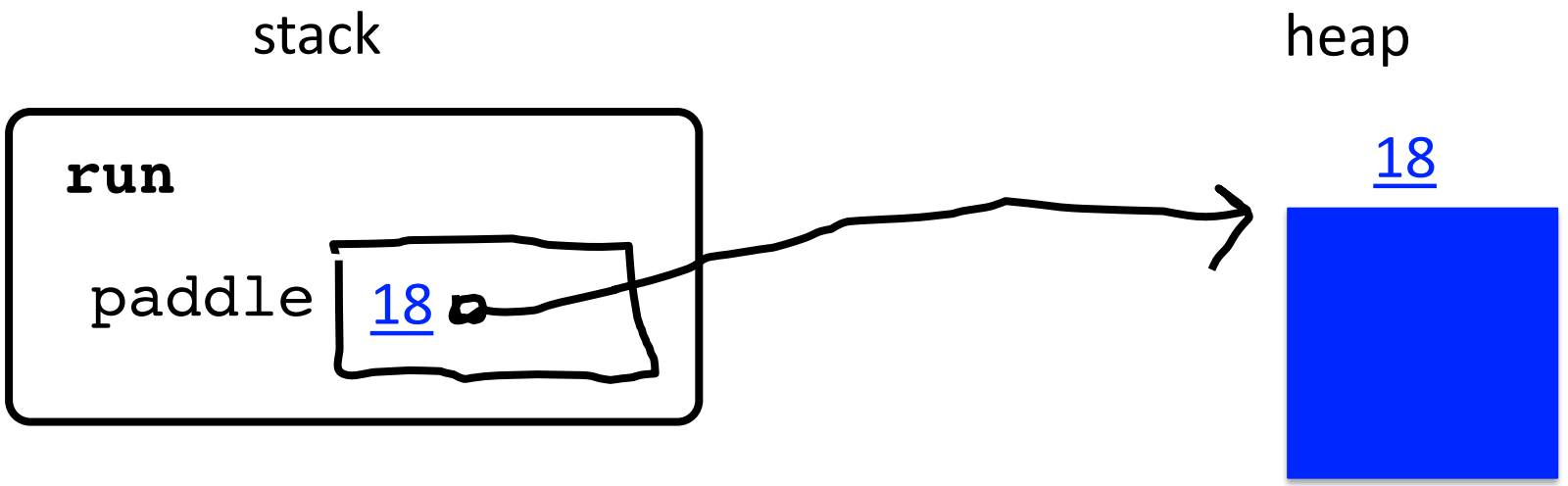
}
```



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    makeBlue(paddle);
    add(paddle, 0, 0);
}
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    object.setColor(Color.BLUE);
    object.setFilled(true);
}
```
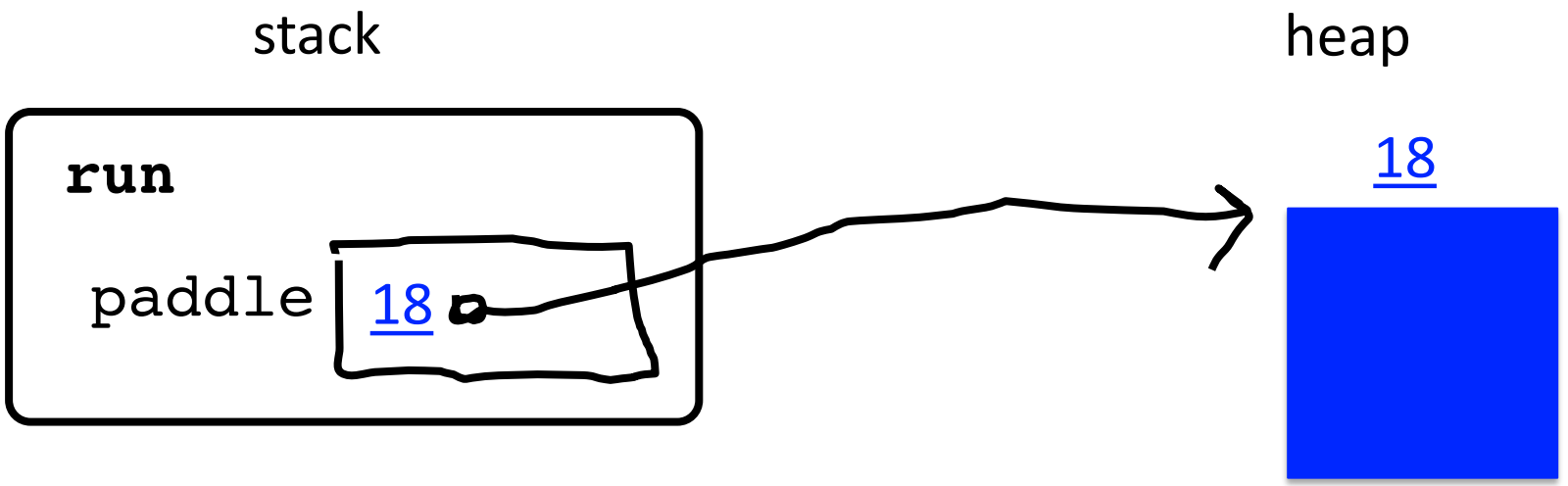



#5: when you pass (or return) an Object, the address is passed.

Aka reference

What does an object store?

Objects store addresses
(which are like URLs)

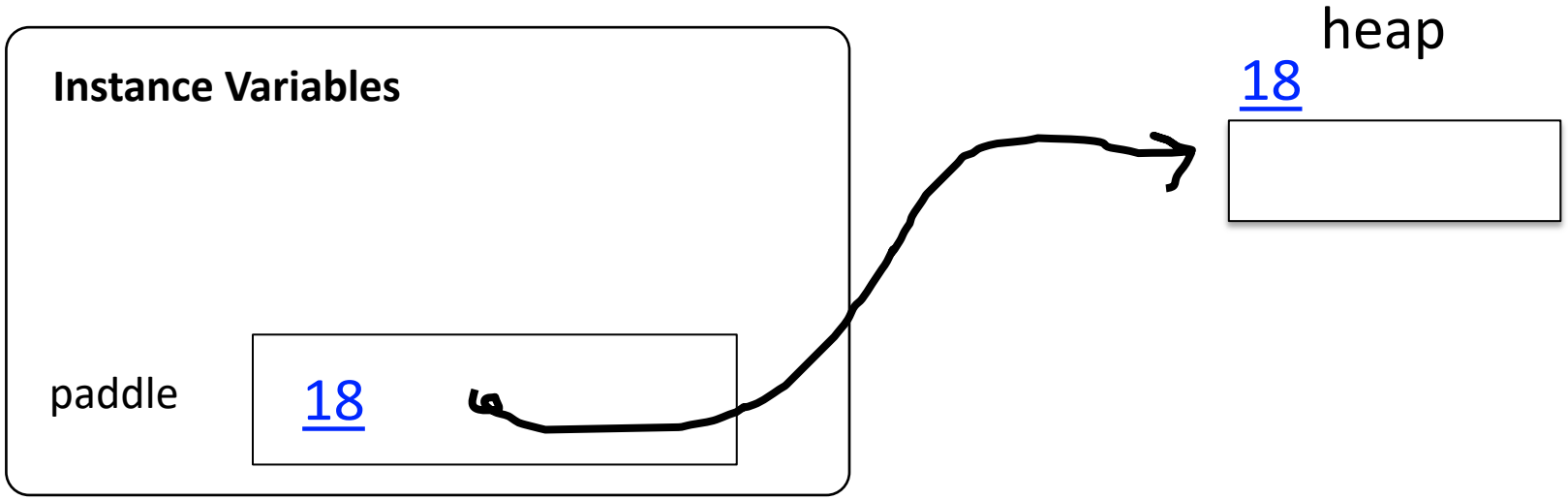
```
GRect paddle = new GRect(20, 30);
public void run() {
    paddle.setColor(Color.BLUE);
    add(paddle, 0, 0);
}
```

---

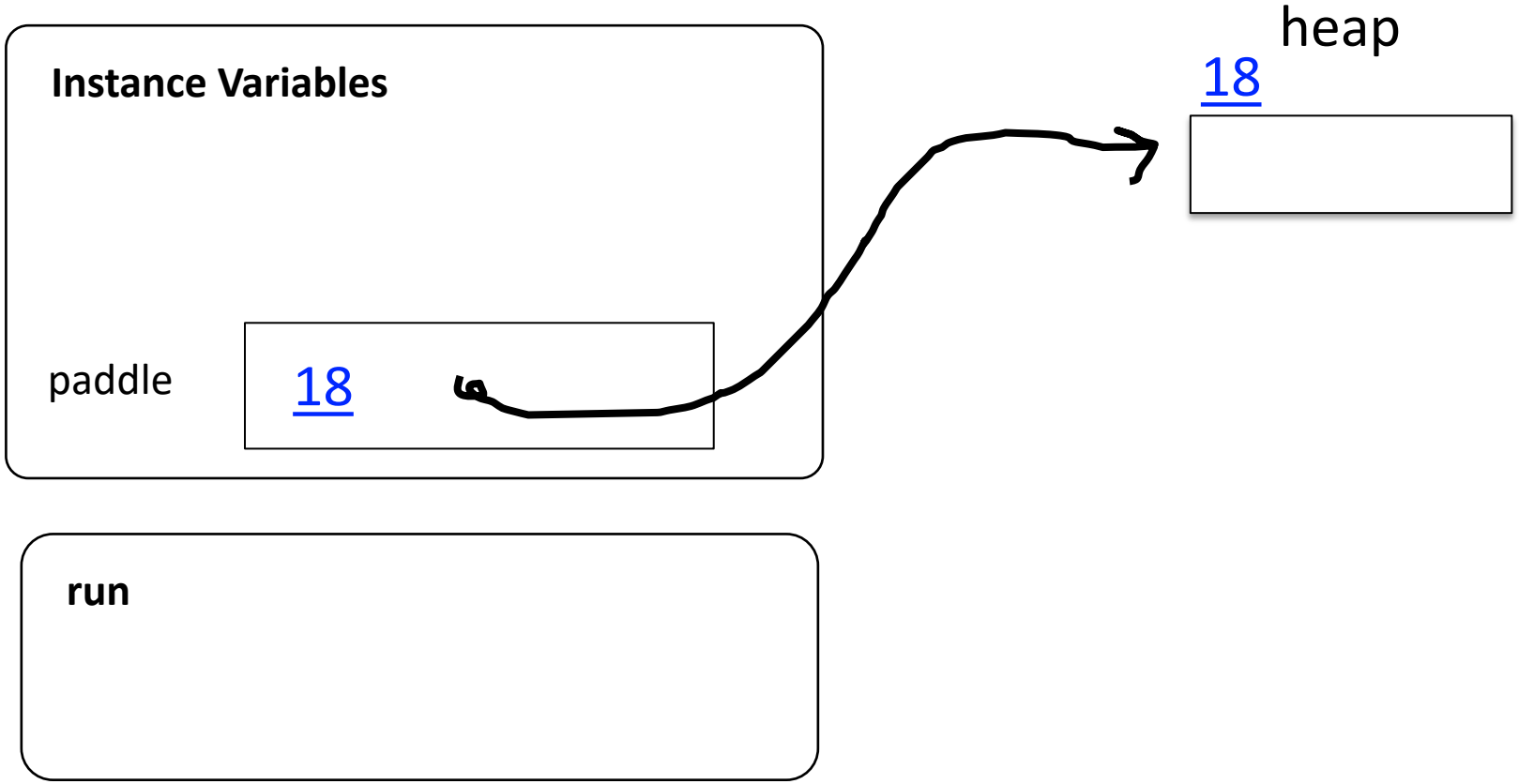
heap

Instance Variables

```
GRect paddle = new GRect(20, 30);
public void run() {
    paddle.setColor(Color.BLUE);
    add(paddle, 0, 0);
}
```



```
GRect paddle = new GRect(20, 30);
public void run() {
    paddle.setColor(Color.BLUE);
    add(paddle, 0, 0);
}
```



```
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public void run() {
    paddle.setColor(Color.BLUE);
    add(paddle, 0, 0);
}
```
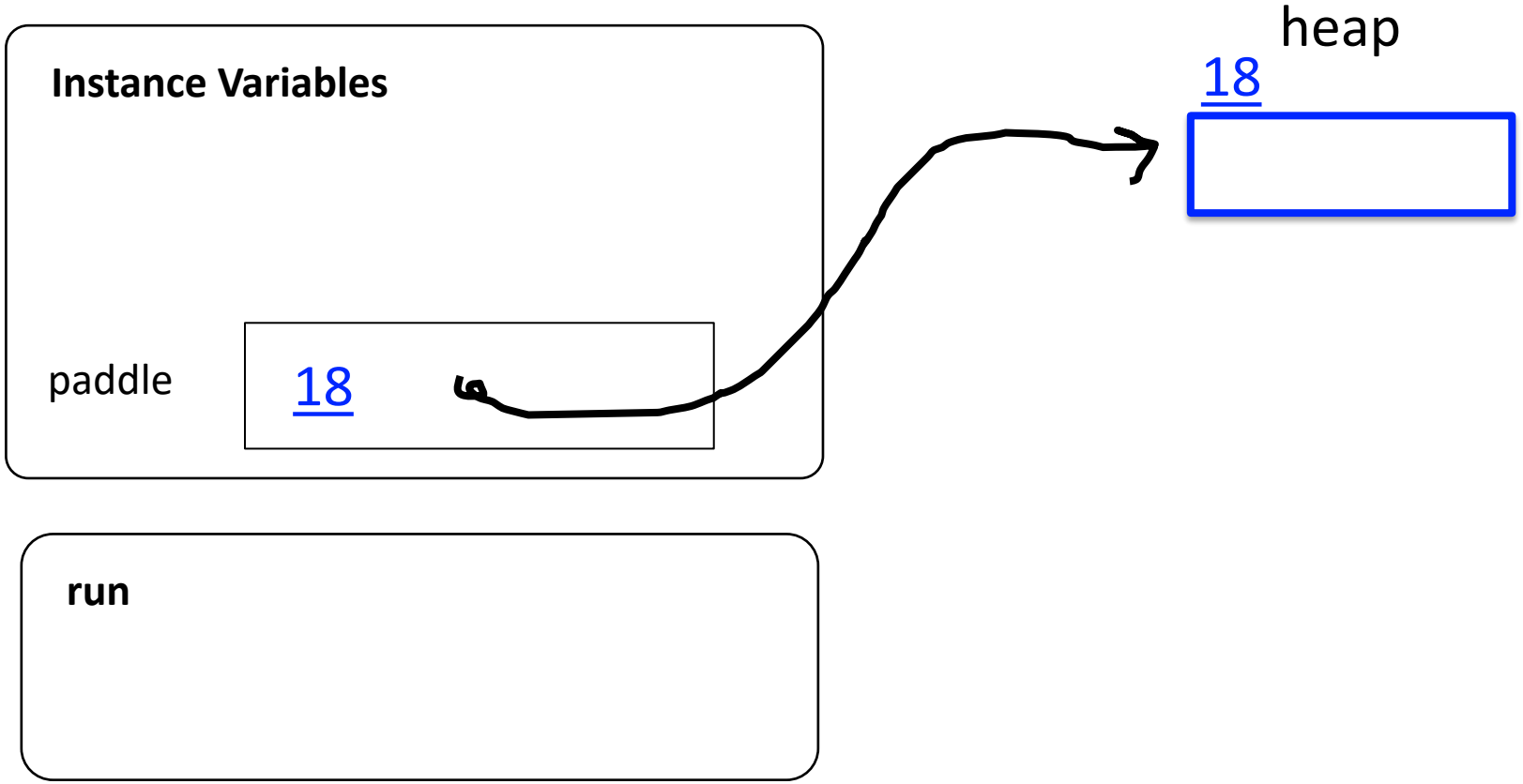



#7: there is space for all instance variables. They are accessible by the entire class

#8: instance variables are initialized before run is called

Common Bug

Question: what does this program do?

```
GRect paddle = new GRect(getWidth(), getHeight());
public void run() {
    paddle.setColor(Color.BLUE);
    add(paddle, 0, 0);
}
```

Answer: makes a square that is 0 by 0 since **`getWidth`** is called before the screen has been made.

#9: for objects == checks if the variables store the same address

Recall the start of class?

Who thinks this prints **`true`**?

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


Who thinks this prints **`true`**?

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


Who thinks this prints **`true`**?

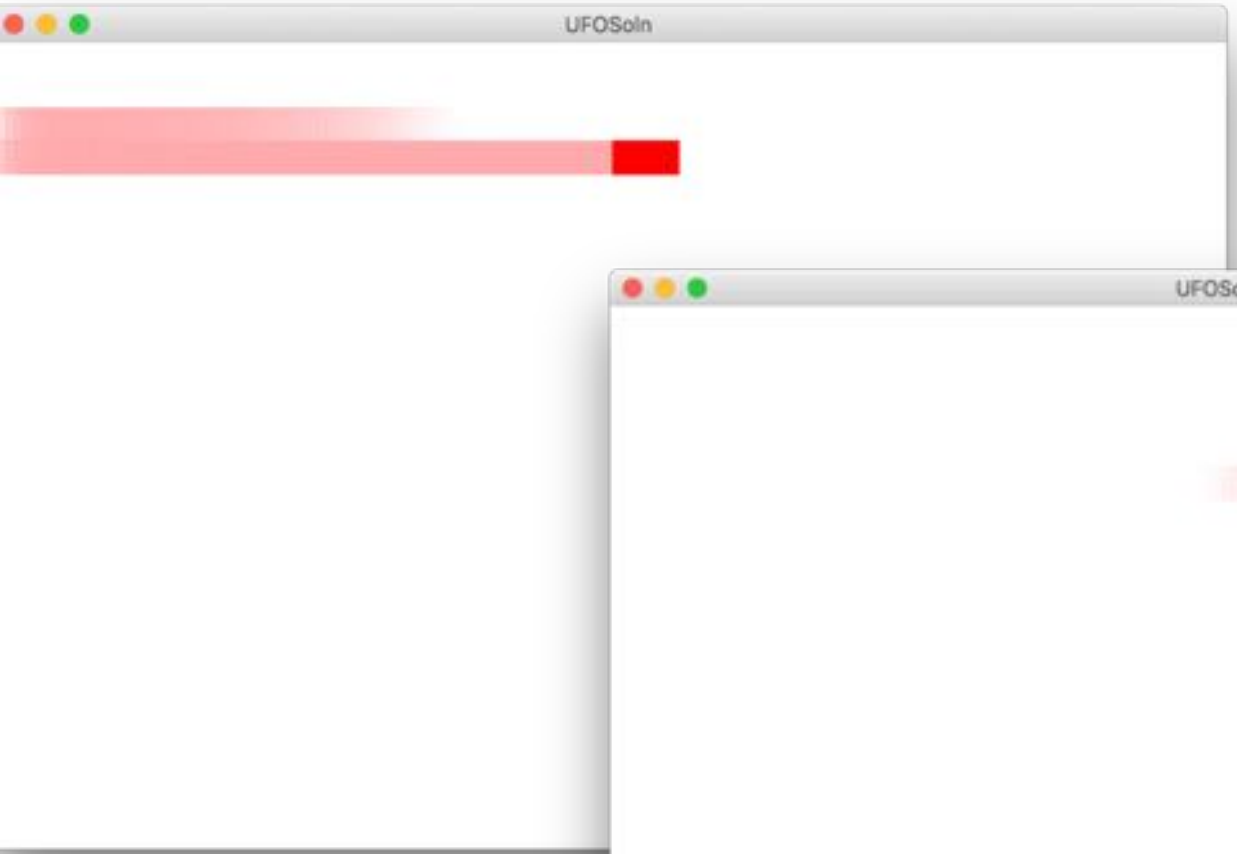
```
private GRect first = new GRect(20, 30);
public void run() {
    first.setFilled(true);
    add(first, 0, 0);
    GObject second = getElementAt(1, 1);
    println(first == second);
}
```


What does an object store?

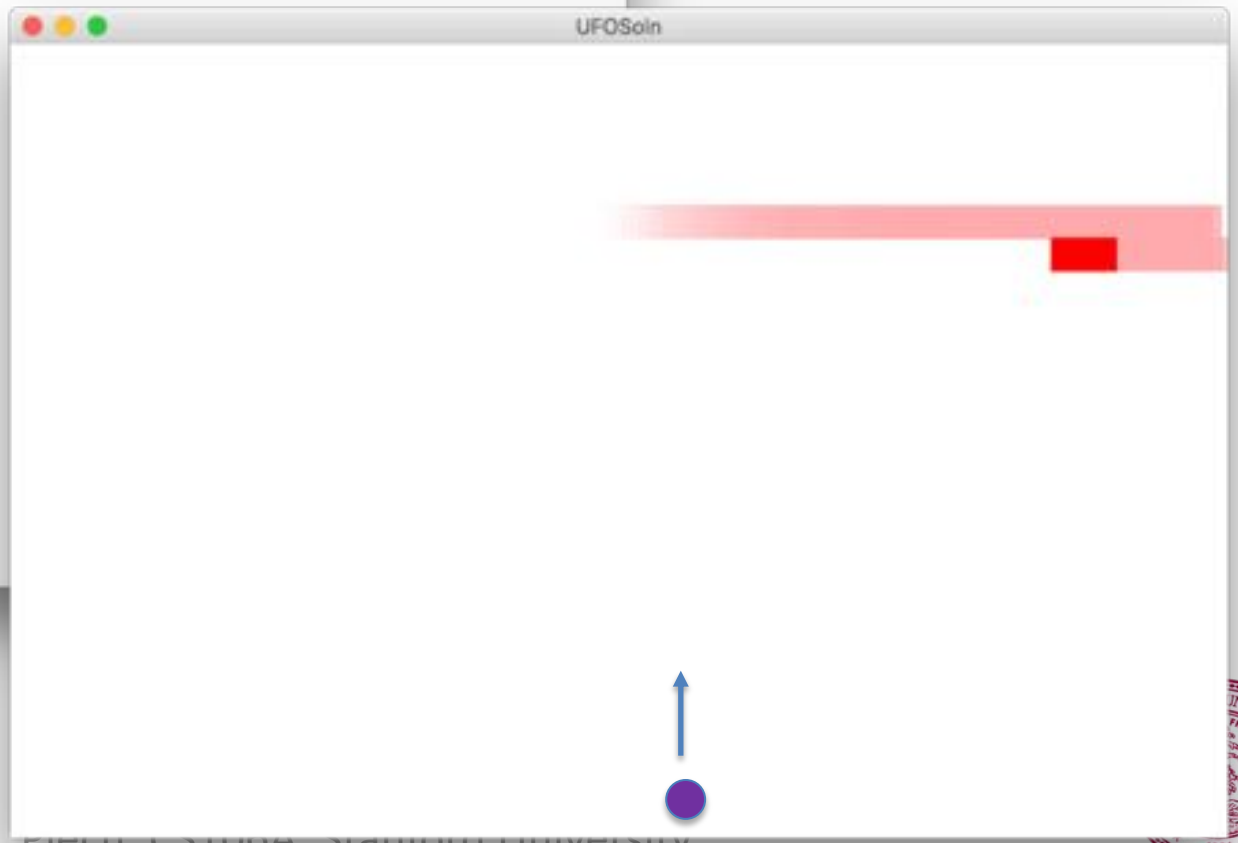
Objects store addresses
(which are like URLs)

Milestones

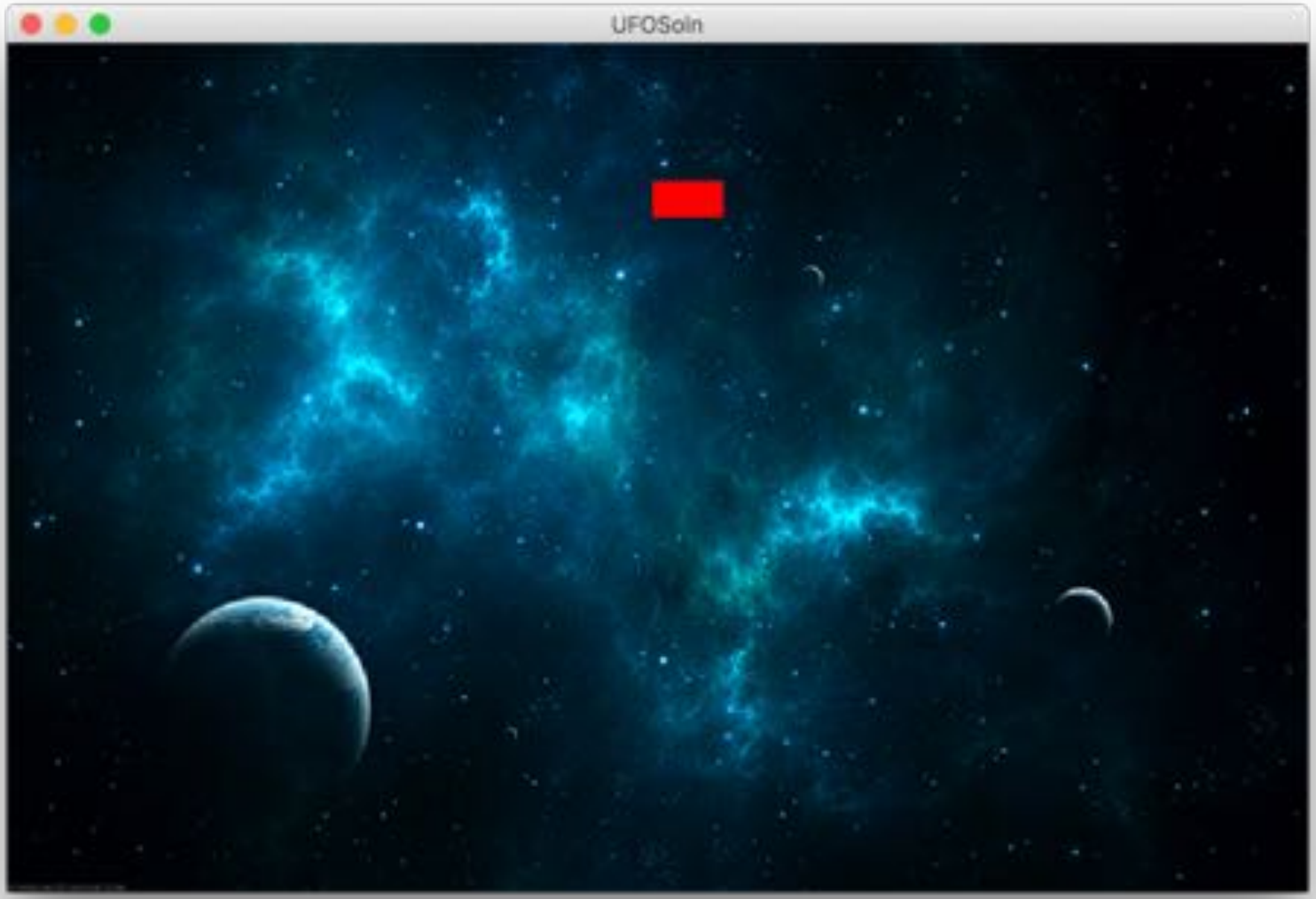
Milestone 1



Milestone 2



Finish Up



Learning Goals

1. Be able to trace memory with references