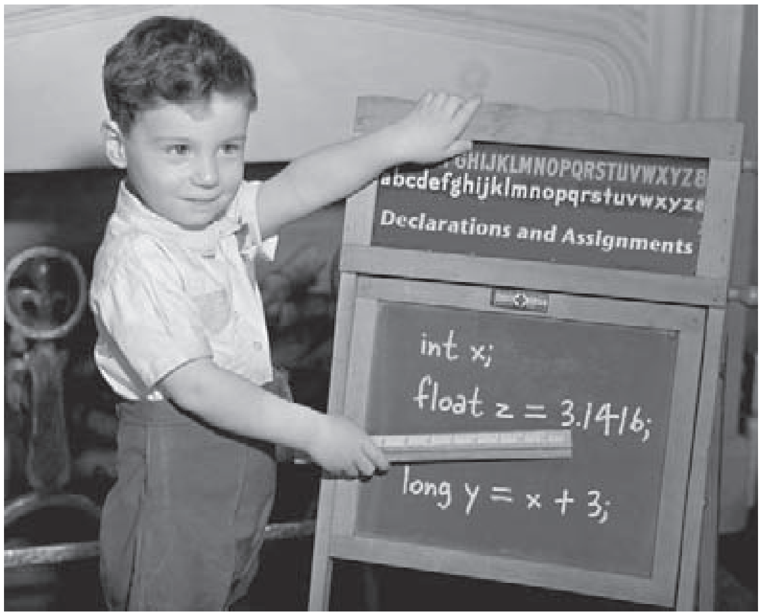
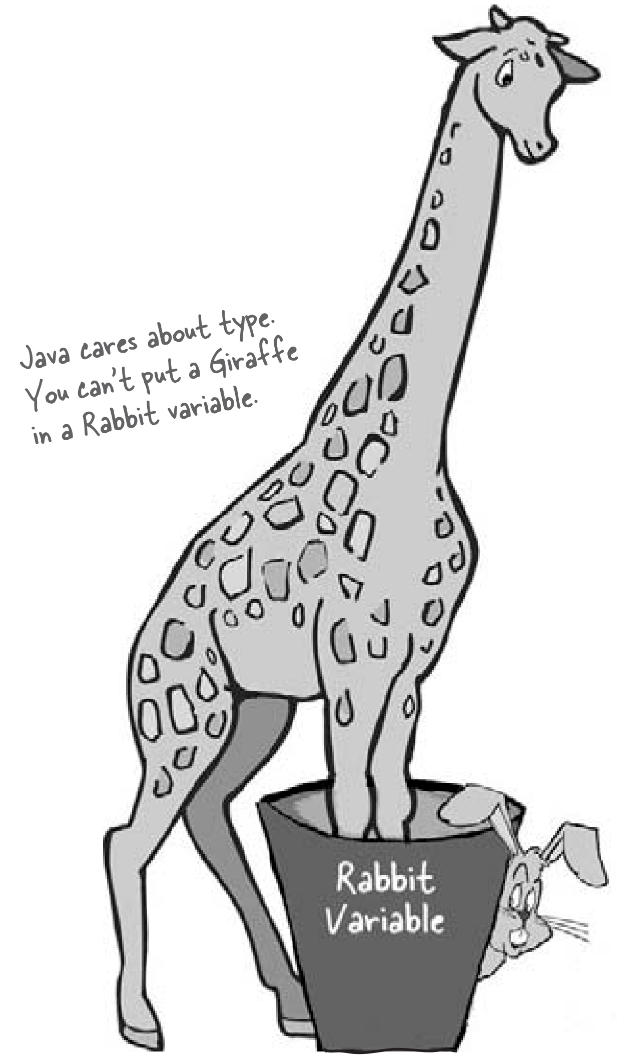
3 **primitives and references**

Know Your Variables


ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
Declarations and Assignments
int x;
float z = 3.1416;
long y = x + 3;

Variables come in two flavors: primitive and reference. So far you've used variables in two places—as object **state** (instance variables), and as **local** variables (variables declared within a *method*). Later, we'll use variables as **arguments** (values sent to a method by the calling code), and as **return types** (values sent back to the caller of the method). You've seen variables declared as simple **primitive** integer values (type `int`). You've seen variables declared as something more **complex** like a String or an array. But **there's gotta be more to life** than integers, Strings, and arrays. What if you have a PetOwner object with a Dog instance variable? Or a Car with an Engine? In this chapter we'll unwrap the mysteries of Java types and look at what you can *declare* as a variable, what you can *put* in a variable, and what you can *do* with a variable. And we'll finally see what life is *truly* like on the garbage-collectible heap.



Declaring a variable

Java cares about type. It won't let you do something bizarre and dangerous like stuff a Giraffe reference into a Rabbit variable—what happens when someone tries to ask the so-called *Rabbit* to `hop()`? And it won't let you put a floating point number into an integer variable, unless you *acknowledge to the compiler* that you know you might lose precision (like, everything after the decimal point).

The compiler can spot most problems:

```
Rabbit hopper = new Giraffe();
```

Don't expect that to compile. *Thankfully*.

For all this type-safety to work, you must declare the type of your variable. Is it an integer? a Dog? A single character? Variables come in two flavors: ***primitive*** and ***object reference***. Primitives hold fundamental values (think: simple bit patterns) including integers, booleans, and floating point numbers. Object references hold, well, *references* to *objects* (gee, didn't *that* clear it up.)

We'll look at primitives first and then move on to what an object reference really means. But regardless of the type, you must follow two declaration rules:

variables must have a type

Besides a type, a variable needs a name, so that you can use that name in code.

variables must have a name

$$\underset{\text{type}}{\texttt{int}}\ \underset{\text{name}}{\texttt{count;}}$$

Note: When you see a statement like: "an object of **type** X", think of *type* and *class* as synonyms. (We'll refine that a little more in later chapters.)

"I'd like a double mocha, no, make it an int."

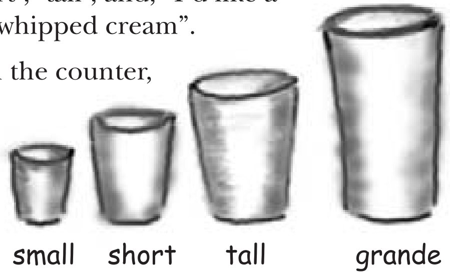
When you think of Java variables, think of cups. Coffee cups, tea cups, giant cups that hold lots and lots of beer, those big cups the popcorn comes in at the movies, cups with curvy, sexy handles, and cups with metallic trim that you learned can never, ever go in the microwave.

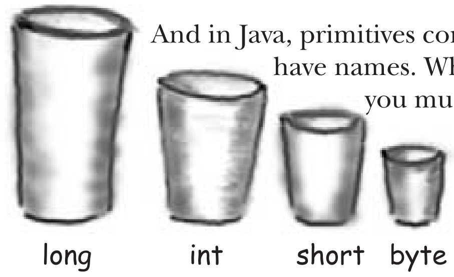
A variable is just a cup. A container. It *holds* something.

It has a size, and a type. In this chapter, we're going to look first at the variables (cups) that hold **primitives**, then a little later we'll look at cups that hold *references to objects*. Stay with us here on the whole cup analogy—as simple as it is right now, it'll give us a common way to look at things when the discussion gets more complex. And that'll happen soon.

Primitives are like the cups they have at the coffeehouse. If you've been to a Starbucks, you know what we're talking about here. They come in different sizes, and each has a name like 'short', 'tall', and, "I'd like a 'grande' mocha half-caff with extra whipped cream".

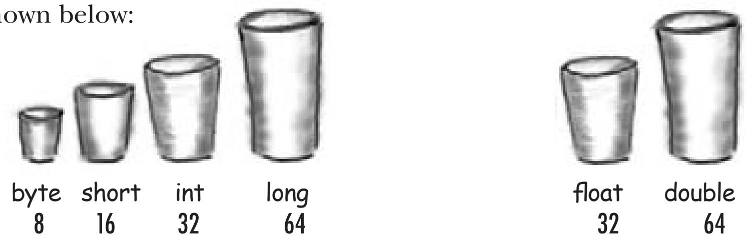
You might see the cups displayed on the counter, so you can order appropriately:





And in Java, primitives come in different sizes, and those sizes have names. When you declare a variable in Java, you must declare it with a specific type. The four containers here are for the four integer primitives in Java.

Each cup holds a value, so for Java primitives, rather than saying, "I'd like a tall french roast", you say to the compiler, "I'd like an int variable with the number 90 please." Except for one tiny difference... in Java you also have to give your cup a *name*. So it's actually, "I'd like an int please, with the value of 2486, and name the variable ***height***." Each primitive variable has a fixed number of bits (cup size). The sizes for the six numeric primitives in Java are shown below:



Primitive Types

Type	Bit Depth	Value Range
boolean and char		
boolean	(JVM-specific)	***true*** or ***false***
char	16 bits	0 to 65535
numeric (all are signed)		
integer		
byte	8 bits	-128 to 127
short	16 bits	-32768 to 32767
int	32 bits	-2147483648 to 2147483647
long	64 bits	-huge to huge
floating point		
float	32 bits	varies
double	64 bits	varies

Primitive declarations with assignments:

```
int x;
x = 234;
byte b = 89;
boolean isFun = true;
double d = 3456.98;
char c = 'f';
int z = x;
boolean isPunkRock;
isPunkRock = false;
boolean powerOn;
powerOn = isFun;
long big = 3456789;
float f = 32.5f;
```

Note the 'f'. Gotta have that with a float, because Java thinks anything with a floating point is a double, unless you use 'f'.

You *really* don't want to spill that...

Be sure the value can fit into the variable.

You can't put a large value into a small cup.

Well, OK, you can, but you'll lose some. You'll get, as we say, *spillage.* The compiler tries to help prevent this if it can tell from your code that something's not going to fit in the container (variable/cup) you're using.

For example, you can't pour an int-full of stuff into a byte-sized container, as follows:

```
int x = 24;

byte b = x;

//won't work!!
```

Why doesn't this work, you ask? After all, the value of *x* is 24, and 24 is definitely small enough to fit into a byte. *You* know that, and *we* know that, but all the compiler cares about is that you're trying to put a big thing into a small thing, and there's the *possibility* of spilling. Don't expect the compiler to know what the value of *x* is, even if you happen to be able to see it literally in your code.

You can assign a value to a variable in one of several ways including:

- type a *literal* value after the equals sign (x=***12***, isGood = ***true***, etc.)
- assign the value of one variable to another (x = y)
- use an expression combining the two (x = y + ***43***)

In the examples below, the literal values are in bold italics:

`int size = 32;`	declare an int named *size*, assign it the value *32*
`char initial = 'j';`	declare a char named *initial*, assign it the value *'j'*
`double d = 456.709;`	declare a double named *d*, assign it the value *456.709*
`boolean isCrazy;`	declare a boolean named *isCrazy* (no assignment)
`isCrazy = true;`	assign the value *true* to the previously-declared *isCrazy*
`int y = x + 456;`	declare an int named *y*, assign it the value that is the sum of whatever *x* is now plus *456*

Sharpen your pencil

The compiler won't let you put a value from a large cup into a small one. But what about the other way—pouring a small cup into a big one? ***No problem.***

Based on what you know about the size and type of the primitive variables, see if you can figure out which of these are legal and which aren't. We haven't covered all the rules yet, so on some of these you'll have to use your best judgment. ***Tip:*** The compiler always errs on the side of safety.

From the following list, ***Circle*** the statements that would be legal if these lines were in a single method:

```
1. int x = 34.5;

2. boolean boo = x;

3. int g = 17;

4. int y = g;

5. y = y + 10;

6. short s;

7. s = y;

8. byte b = 3;

9. byte v = b;

10. short n = 12;

11. v = n;

12. byte k = 128;
```

Back away from that keyword!

You know you need a name and a type for your variables.

You already know the primitive types.

But what can you use as names? The rules are simple. You can name a class, method, or variable according to the following rules (the real rules are slightly more flexible, but these will keep you safe):

- **It must start with a letter, underscore (_), or dollar sign ($). You can't start a name with a number.**
- **After the first character, you can use numbers as well. Just don't start it with a number.**
- **It can be anything you like, subject to those two rules, just so long as it isn't one of Java's reserved words.**

are keywords (and other things) that the compiler recognizes. And if you really want to play confuse-a-compiler, then just *try* using a reserved word as a name.

You've already seen some reserved words when we looked at writing our first main class:

```
public   static   void
```

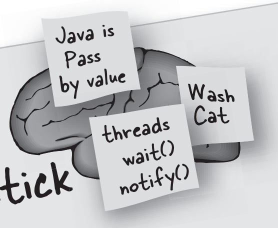
don't use any of these for your own names.

And the primitive types are reserved as well:

```
boolean char byte short int long float double
```

But there are a lot more we haven't discussed yet. Even if you don't need to know what they mean, you still need to know you can't use 'em yourself. ***Do not**–under any circumstances–**try to memorize these now.*** To make room for these in your head, you'd probably have to lose something else. Like where your car is parked. Don't worry, by the end of the book you'll have most of them down cold.

Make it Stick



The eight primitive types are:

boolean **c**har **b**yte **s**hort **i**nt **l**ong **f**loat **d**ouble

And here's a mnemonic for remembering them:

Be **C**areful! **B**ears **S**houldn't **I**ngest **L**arge **F**urry **D**ogs

If you make up your own, it'll stick even better.

B_ C_ B_ S_ I_ L_ F_ D_

No matter what you hear, do not, I repeat, do not let me ingest another large furry dog.

This table reserved.

boolean	byte	char	double	float	int	long	short	public	private
protected	abstract	final	native	static	strictfp	synchronized	transient	volatile	if
else	do	while	switch	case	default	for	break	continue	assert
class	extends	implements	import	instanceof	interface	new	package	super	this
catch	finally	try	throw	throws	return	void	const	goto	enum

Java's keywords and other reserved words (in no useful order). If you use these for names, the compiler will be very, *very* upset.

Controlling your Dog object

You know how to declare a primitive variable and assign it a value. But now what about non-primitive variables? In other words, *what about objects?*

- **There is actually no such thing as an object variable.**
- **There's only an object reference variable.**
- **An object reference variable holds bits that represent a way to *access* an object.**
- **It doesn't hold the object itself, but it holds something like a pointer. Or an address. Except, in Java we don't really know *what* is inside a reference variable. We *do* know that whatever it is, it represents one and only one object. And the JVM knows how to use the reference to get to the object.**

```
Dog d = new Dog();
d.bark();
```

You can't stuff an object into a variable. We often think of it that way... we say things like, "I passed the String to the System.out.println() method." Or, "The method returns a Dog", or, "I put a new Foo object into the variable named myFoo."

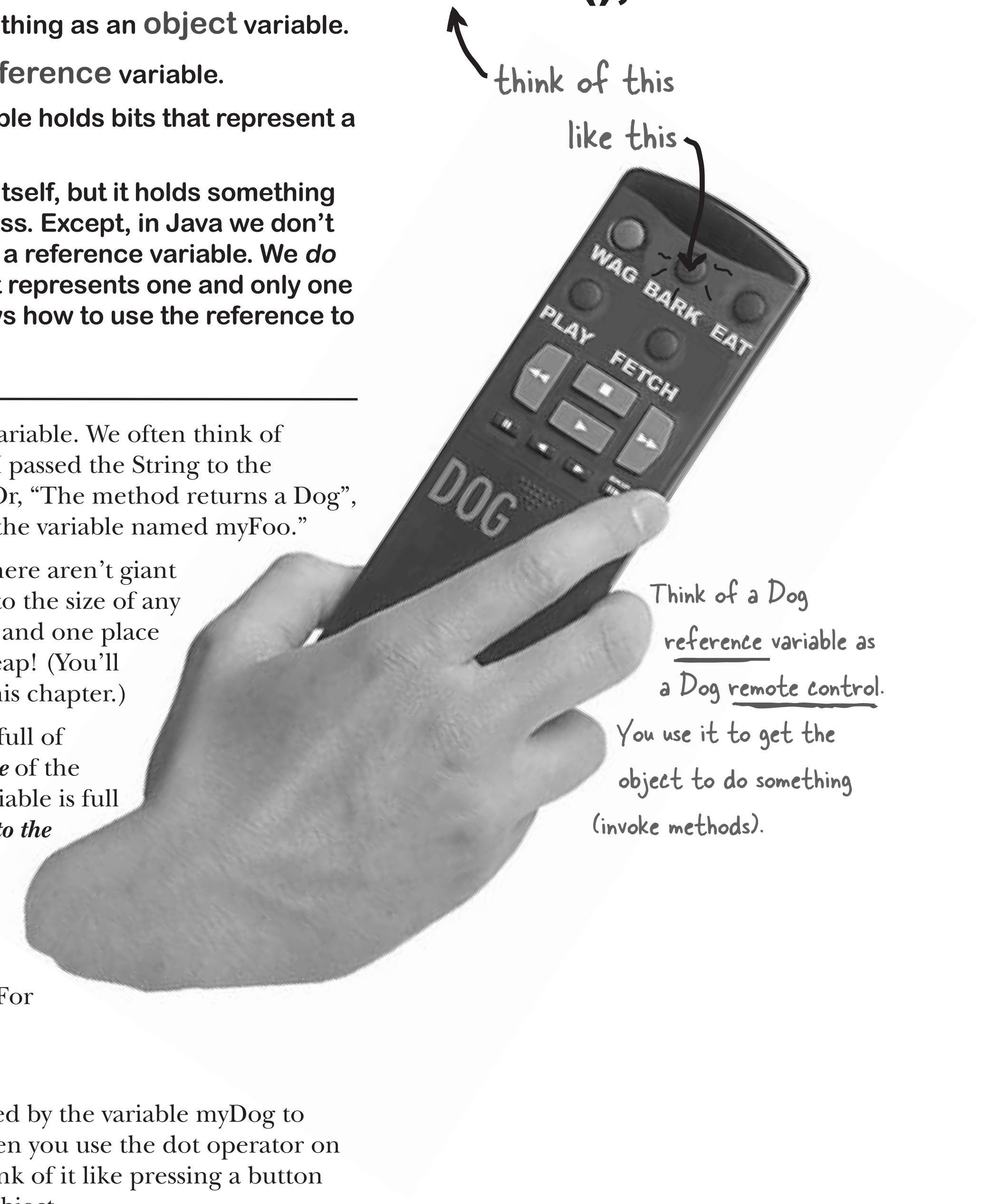
But that's not what happens. There aren't giant expandable cups that can grow to the size of any object. Objects live in one place and one place only—the garbage collectible heap! (You'll learn more about that later in this chapter.)

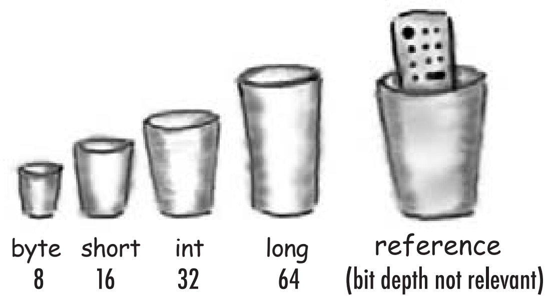
Although a primitive variable is full of bits representing the actual ***value*** of the variable, an object reference variable is full of bits representing ***a way to get to the object.***

You use the dot operator (.) on a reference variable to say, "use the thing *before* the dot to get me the thing *after* the dot." For example:

```
myDog.bark();
```

means, "use the object referenced by the variable myDog to invoke the bark() method." When you use the dot operator on an object reference variable, think of it like pressing a button on the remote control for that object.


think of this
like this
WAG
BARK
EAT
PLAY
FETCH
DOG
Think of a Dog reference variable as a Dog remote control. You use it to get the object to do something (invoke methods).



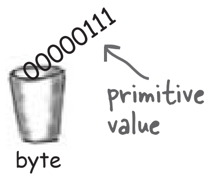
An object reference is just another variable value.

Something that goes in a cup.
Only this time, the value is a remote control.

Primitive Variable

```
byte x = 7;
```

The bits representing 7 go into the variable. (00000111).

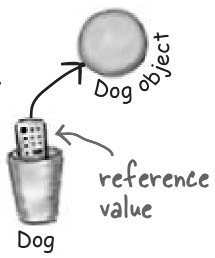


Reference Variable

```
Dog myDog = new Dog();
```

The bits representing a way to get to the Dog object go into the variable.

The Dog object itself does not go into the variable!



With primitive variables, the value of the variable is... the *value* (5, -26.7, 'a').

With reference variables, the value of the variable is... *bits representing a way to get to a specific object.*

You don't know (or care) how any particular JVM implements object references. Sure, they might be a pointer to a pointer to... but even if you *know*, you still can't use the bits for anything other than accessing an object.

We don't care how many 1's and 0's there are in a reference variable.It's up to each JVM and the phase of the moon.

The 3 steps of object declaration, creation and assignment

$$\underbrace{\texttt{Dog myDog}}_{1}\ \overset{3}{=}\ \underbrace{\texttt{new Dog()}}_{2}\texttt{;}$$

1 Declare a reference variable

```
Dog myDog = new Dog();
```

Tells the JVM to allocate space for a reference variable, and names that variable *myDog*. The reference variable is, forever, of type Dog. In other words, a remote control that has buttons to control a Dog, but not a Cat or a Button or a Socket.

2 Create an object

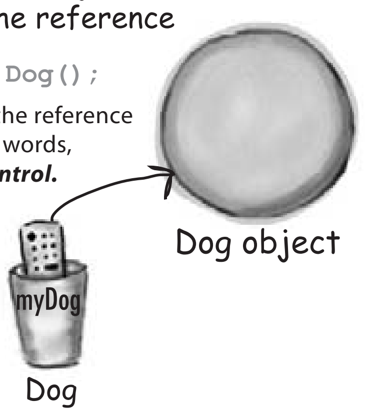
```
Dog myDog = new Dog();
```

Tells the JVM to allocate space for a new Dog object on the heap (we'll learn a lot more about that process, especially in chapter 9.)

3 Link the object and the reference

```
Dog myDog = new Dog();
```

Assigns the new Dog to the reference variable myDog. In other words, ***programs the remote control.***



there are no Dumb Questions

Q: How big is a reference variable?

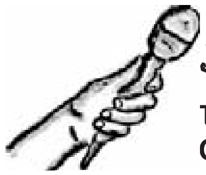
A: You don't know. Unless you're cozy with someone on the JVM's development team, you don't know how a reference is represented. There are pointers in there somewhere, but you can't access them. You won't need to. (OK, if you insist, you might as well just imagine it to be a 64-bit value.) But when you're talking about memory allocation issues, your Big Concern should be about how many *objects* (as opposed to object *references*) you're creating, and how big *they* (the *objects*) really are.

Q: So, does that mean that all object references are the same size, regardless of the size of the actual objects to which they refer?

A: Yep. All references for a given JVM will be the same size regardless of the objects they reference, but each JVM might have a different way of representing references, so references on one JVM may be smaller or larger than references on another JVM.

Q: Can I do arithmetic on a reference variable, increment it, you know – C stuff?

A: Nope. Say it with me again, "Java is not C."



Java Exposed

This week's interview: Object Reference

HeadFirst: So, tell us, what's life like for an object reference?

Reference: Pretty simple, really. I'm a remote control and I can be programmed to control different objects.

HeadFirst: Do you mean different objects even while you're running? Like, can you refer to a Dog and then five minutes later refer to a Car?

Reference: Of course not. Once I'm declared, that's it. If I'm a Dog remote control then I'll never be able to point (oops – my bad, we're not supposed to say *point*) I mean *refer* to anything but a Dog.

HeadFirst: Does that mean you can refer to only one Dog?

Reference: No. I can be referring to one Dog, and then five minutes later I can refer to some *other* Dog. As long as it's a Dog, I can be redirected (like reprogramming your remote to a different TV) to it. Unless... no never mind.

HeadFirst: No, tell me. What were you gonna say?

Reference: I don't think you want to get into this now, but I'll just give you the short version – if I'm marked as `final`, then once I am assigned a Dog, I can never be reprogrammed to anything else but *that* one and only Dog. In other words, no other object can be assigned to me.

HeadFirst: You're right, we don't want to talk about that now. OK, so unless you're `final`, then you can refer to one Dog and then refer to a different Dog later. Can you ever refer to *nothing at all*? Is it possible to not be programmed to anything?

Reference: Yes, but it disturbs me to talk about it.

HeadFirst: Why is that?

Reference: Because it means I'm `null`, and that's upsetting to me.

HeadFirst: You mean, because then you have no value?

Reference: Oh, `null` *is* a value. I'm still a remote control, but it's like you brought home a new universal remote control and you don't have a TV. I'm not programmed to control anything. They can press my buttons all day long, but nothing good happens. I just feel so... useless. A waste of bits. Granted, not that many bits, but still. And that's not the worst part. If I am the only reference to a particular object, and then I'm set to `null` (deprogrammed), it means that now *nobody* can get to that object I had been referring to.

HeadFirst: And that's bad because...

Reference: You have to *ask*? Here I've developed a relationship with this object, an intimate connection, and then the tie is suddenly, cruelly, severed. And I will never see that object again, because now it's eligible for [producer, cue tragic music] *garbage collection*. Sniff. But do you think programmers ever consider *that*? Snif. Why, *why* can't I be a primitive? *I hate being a reference.* The responsibility, all the broken attachments...

Life on the garbage-collectible heap

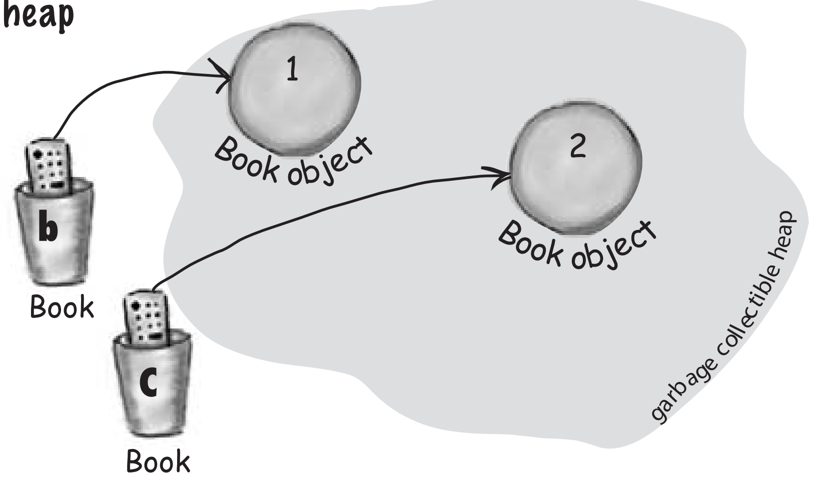
```
Book b = new Book();

Book c = new Book();
```

Declare two Book reference variables. Create two new Book objects. Assign the Book objects to the reference variables.

The two Book objects are now living on the heap.

References: 2

Objects: 2



```
Book d = c;
```

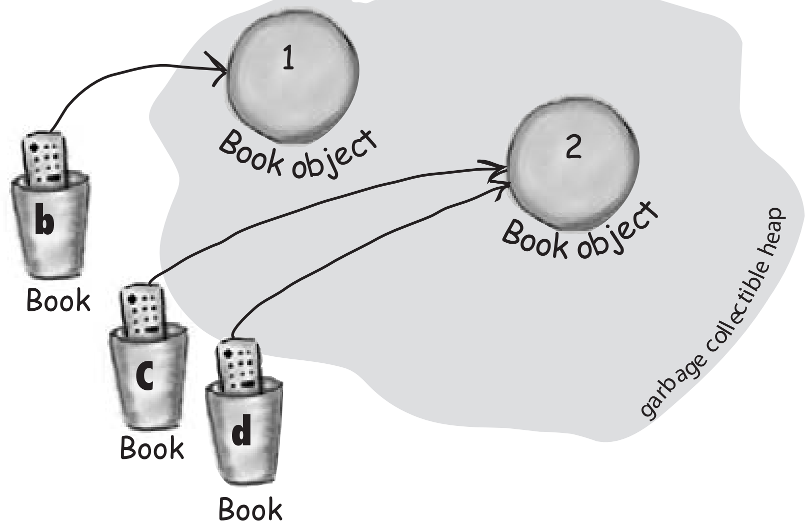
Declare a new Book reference variable. Rather than creating a new, third Book object, assign the value of variable ***c*** to variable ***d***. But what does this mean? It's like saying, "Take the bits in ***c***, make a copy of them, and stick that copy into ***d***."

Both *c* and *d* refer to the same object.

The *c* and *d* variables hold two different copies of the same value. Two remotes programmed to one TV.

References: 3

Objects: 2



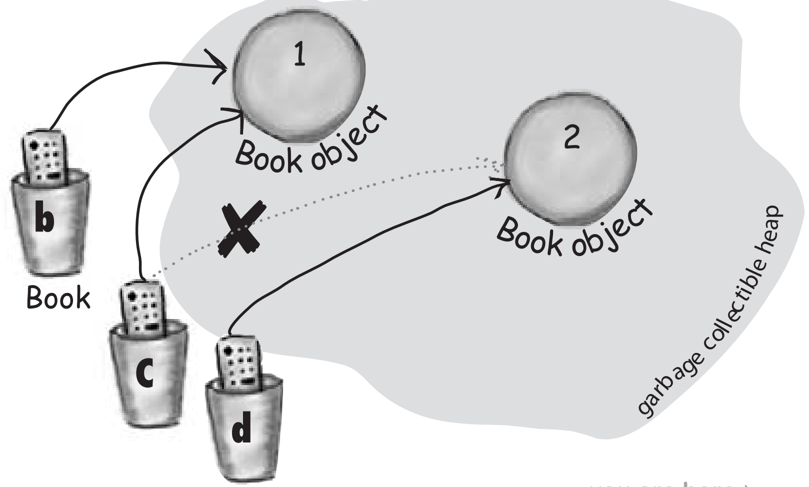
```
c = b;
```

Assign the value of variable ***b*** to variable ***c***. By now you know what this means. The bits inside variable ***b*** are copied, and that new copy is stuffed into variable ***c***.

Both b and c refer to the same object.

References: 3

Objects: 2



Life and death on the heap

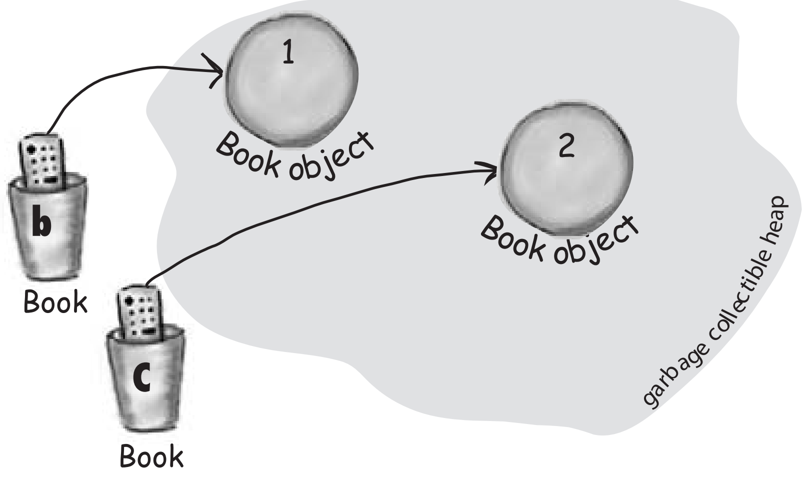
```
Book b = new Book();

Book c = new Book();
```

Declare two Book reference variables. Create two new Book objects. Assign the Book objects to the reference variables.

The two book objects are now living on the heap.

Active References: 2

Reachable Objects: 2



```
b = c;
```

Assign the value of variable ***c*** to variable ***b***. The bits inside variable ***c*** are copied, and that new copy is stuffed into variable ***b***. Both variables hold identical values.

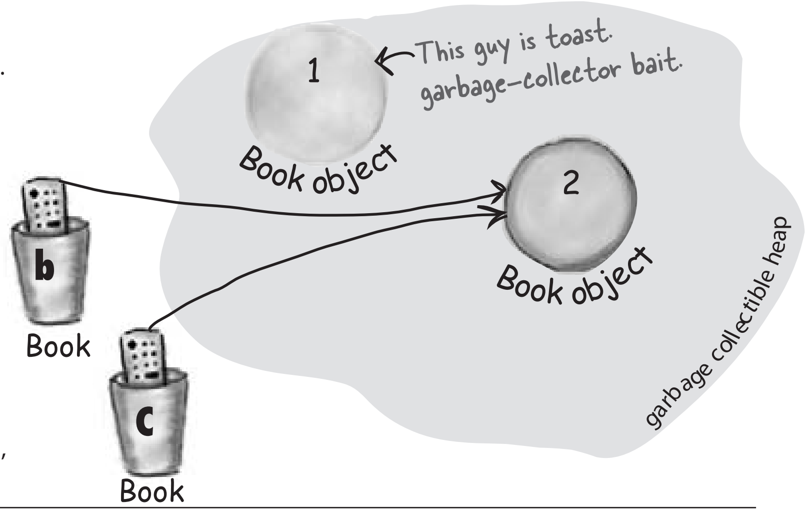
Both b and c refer to the same object. Object 1 is abandoned and eligible for Garbage Collection (GC).

Active References: 2

Reachable Objects: 1

Abandoned Objects: 1

The first object that ***b*** referenced, Object 1, has no more references. It's *unreachable*.



```
c = null;
```

Assign the value `null` to variable ***c***. This makes ***c*** a *null reference*, meaning it doesn't refer to anything. But it's still a reference variable, and another Book object can still be assigned to it.

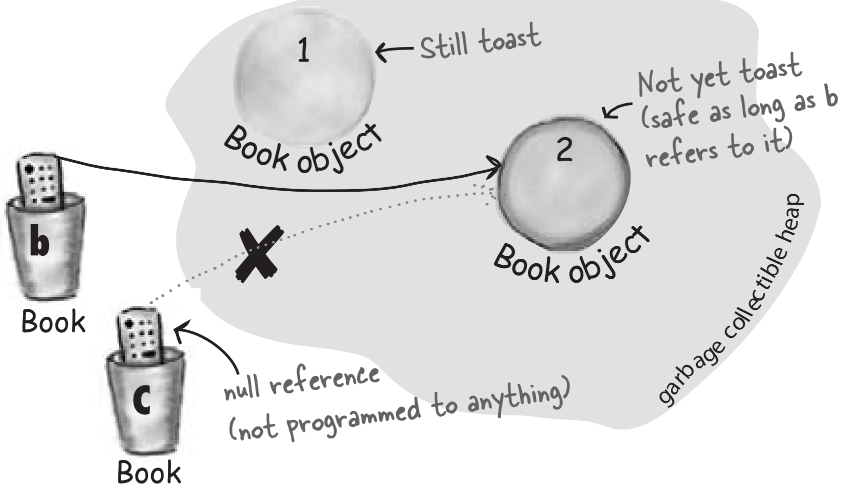
Object 2 still has an active reference (b), and as long as it does, the object is not eligible for GC.

Active References: 1

null References: 1

Reachable Objects: 1

Abandoned Objects: 1


1
Still toast
Book object
Not yet toast (safe as long as b refers to it)
2
Book object
b
Book
c
Book
null reference (not programmed to anything)
garbage collectible heap

An array is like a tray of cups

1 Declare an int array variable. An array variable is a remote control to an array object.

```
int[] nums;
```

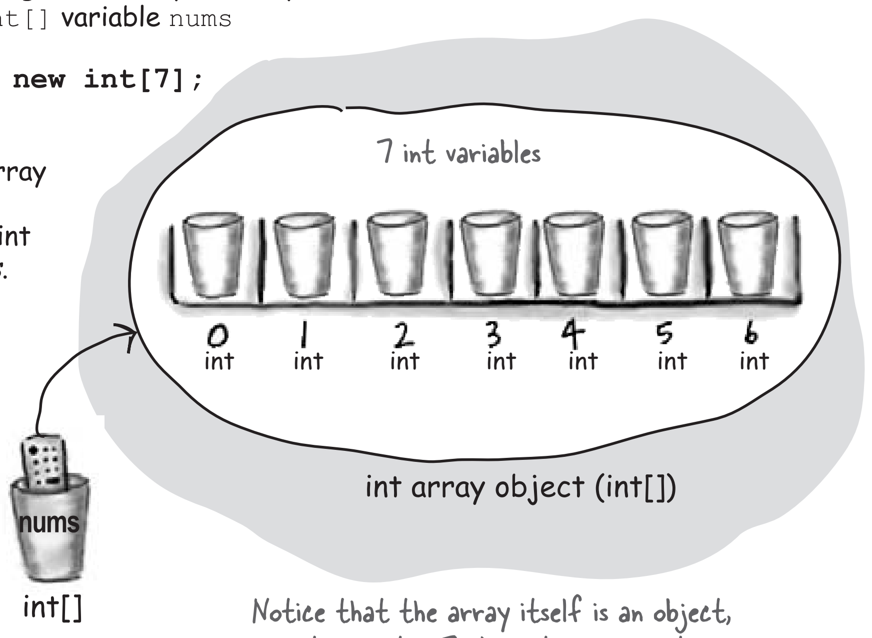
2 Create a new int array with a length of 7, and assign it to the previously-declared `int[]` variable `nums`

```
nums = new int[7];
```

3 Give each element in the array an int value.
Remember, elements in an int *array* are just int *variables*.

7 int variables

```
nums[0] = 6;
nums[1] = 19;
nums[2] = 44;
nums[3] = 42;
nums[4] = 10;
nums[5] = 20;
nums[6] = 1;
```



Notice that the array itself is an object, even though the 7 elements are primitives.

Arrays are objects too

The Java standard library includes lots of sophisticated data structures including maps, trees, and sets (see Appendix B), but arrays are great when you just want a quick, ordered, efficient list of things. Arrays give you fast random access by letting you use an index position to get to any element in the array.

Every element in an array is just a variable. In other words, one of the eight primitive variable types (think: Large Furry Dog) or a reference variable. Anything you would put in a *variable* of that type can be assigned to an *array element* of that type. So in an array of type int (int[]), each element can hold an int. In a Dog array (Dog[]) each element can hold... a Dog? No, remember that a reference variable just holds a reference (a remote control), not the object itself. So in a Dog array, each element can hold a *remote control* to a Dog. Of course, we still have to make the Dog objects... and you'll see all that on the next page.

Be sure to notice one key thing in the picture above – *the array is an object, even though it's an array of primitives.*

Arrays are always objects, whether they're declared to hold primitives or object references. But you can have an array object that's declared to *hold* primitive values. In other words, the array object can have *elements* which are primitives, but the array itself is *never* a primitive. Regardless of what the array holds, the array itself is always an object!

Make an array of Dogs

1 Declare a Dog array variable

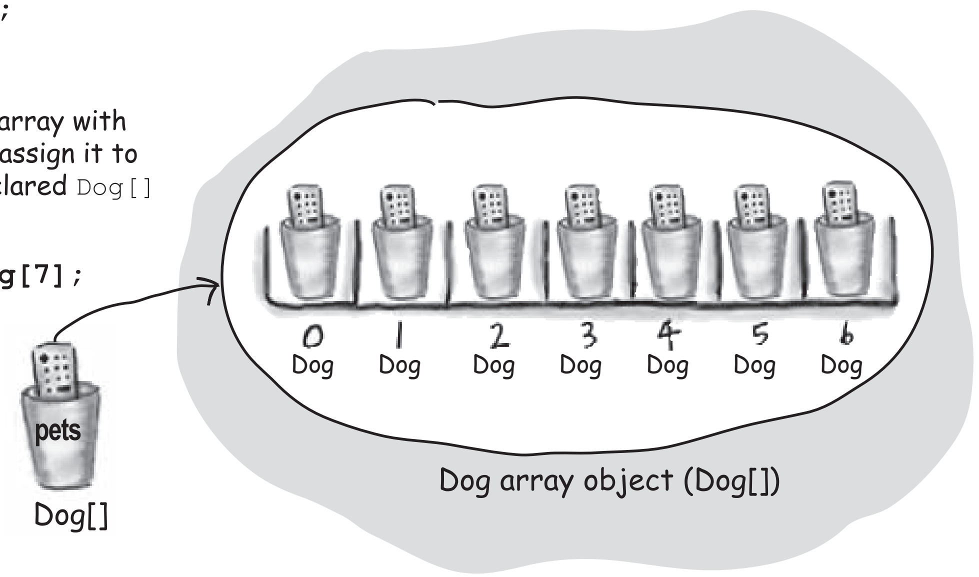
```
Dog[] pets;
```

2 Create a new Dog array with a length of 7, and assign it to the previously-declared `Dog[]` variable `pets`

```
pets = new Dog[7];
```

What's missing?

Dogs! We have an array of Dog *references*, but no actual Dog *objects*!



3 Create new Dog objects, and assign them to the array elements.
Remember, elements in a Dog *array* are just Dog reference *variables*. We still need Dogs!

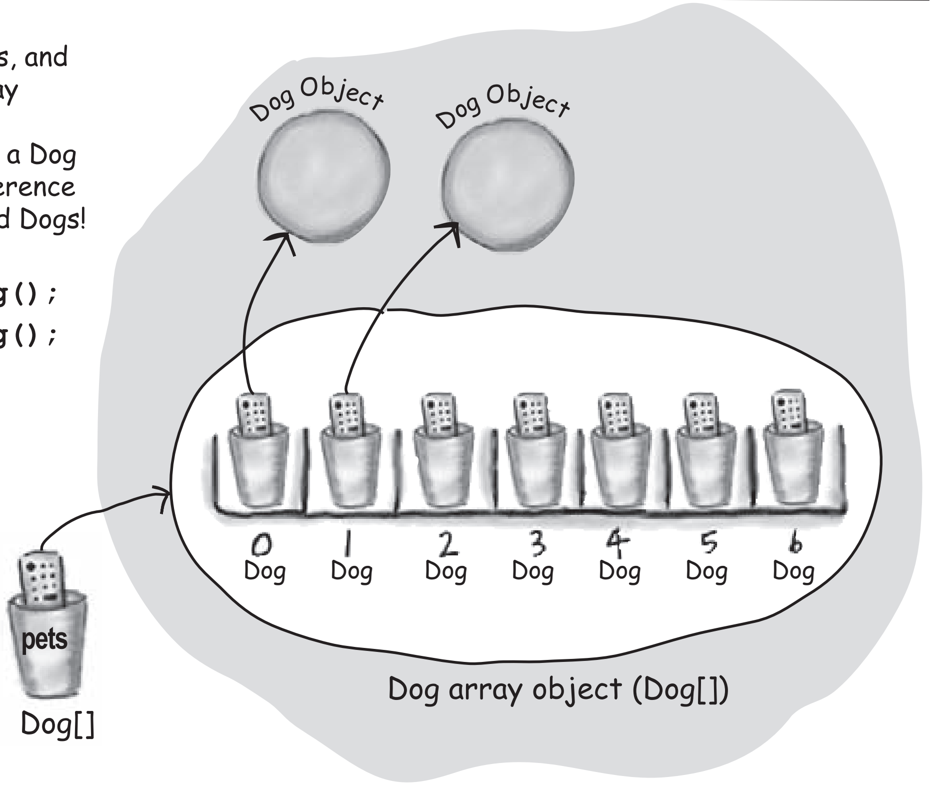
```
pets[0] = new Dog();
pets[1] = new Dog();
```

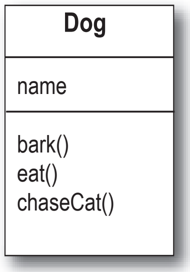
Sharpen your pencil

What is the current value of pets[2]? ___________

What code would make pets[3] refer to one of the two existing Dog objects?

____



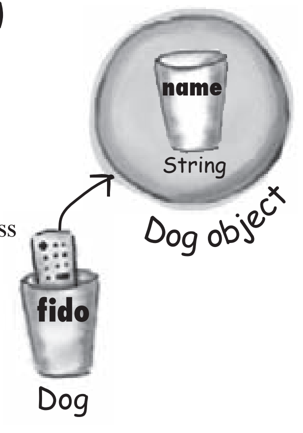


Control your Dog

(with a reference variable)

```
Dog fido = new Dog();
fido.name = "Fido";
```

We created a Dog object and used the dot operator on the reference variable ***fido*** to access the name variable.*



We can use the ***fido*** reference to get the dog to bark() or eat() or chaseCat().

```
fido.bark();
fido.chaseCat();
```

What happens if the Dog is in a Dog array?

We know we can access the Dog's instance variables and methods using the dot operator, but *on what?*

When the Dog is in an array, we don't have an actual variable name (like ***fido***). Instead we use array notation and push the remote control button (dot operator) on an object at a particular index (position) in the array:

```
Dog[] myDogs = new Dog[3];
myDogs[0] = new Dog();
myDogs[0].name = "Fido";
myDogs[0].bark();
```

Java cares about type.

Once you've declared an array, you can't put anything in it except things that are of the declared array type.

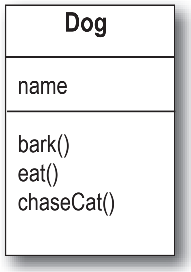
For example, you can't put a Cat into a Dog array (it would be pretty awful if someone thinks that only Dogs are in the array, so they ask each one to bark, and then to their horror discover there's a cat lurking.) And you can't stick a `double` into an `int` array (spillage, remember?). You can, however, put a `byte` into an `int` array, because a `byte` will always fit into an `int`-sized cup. This is known as an **implicit widening. We'll get into the details later, for now just remember that the compiler won't let you put the wrong thing in an array, based on the array's declared type.**

*Yes we know we're not demonstrating encapsulation here, but we're trying to keep it simple. For now. We'll do encapsulation in chapter 4.

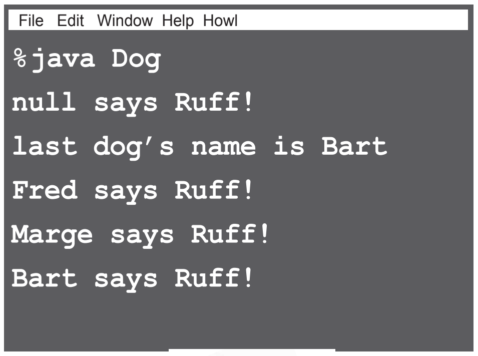
```
class Dog {
  String name;
  public static void main (String[] args) {
    // make a Dog object and access it
    Dog dog1 = new Dog();
    dog1.bark();
    dog1.name = "Bart";

    // now make a Dog array
    Dog[] myDogs = new Dog[3];
    // and put some dogs in it
    myDogs[0] = new Dog();
    myDogs[1] = new Dog();
    myDogs[2] = dog1;

    // now access the Dogs using the array
    // references
    myDogs[0].name = "Fred";
    myDogs[1].name = "Marge";

    // Hmmmm... what is myDogs[2] name?
    System.out.print("last dog's name is ");
    System.out.println(myDogs[2].name);

    // now loop through the array
    // and tell all dogs to bark
    int x = 0;
    while(x < myDogs.length) {
      myDogs[x].bark();
      x = x + 1;
    }
  }

  public void bark() {
    System.out.println(name + " says Ruff!");
  }
  public void eat() {  }
  public void chaseCat() {  }
}
```

arrays have a variable 'length' that gives you the number of elements in the array

A Dog example



Output

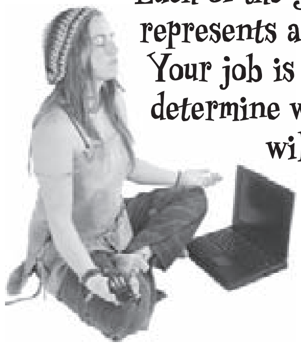


```
%java Dog
null says Ruff!
last dog's name is Bart
Fred says Ruff!
Marge says Ruff!
Bart says Ruff!
```

BULLET POINTS

- Variables come in two flavors: primitive and reference.
- Variables must always be declared with a name and a type.
- A primitive variable value is the bits representing the value (5, 'a', true, 3.1416, etc.).
- A reference variable value is the bits representing a way to get to an object on the heap.
- A reference variable is like a remote control. Using the dot operator (.) on a reference variable is like pressing a button on the remote control to access a method or instance variable.
- A reference variable has a value of `null` when it is not referencing any object.
- An array is always an object, even if the array is declared to hold primitives. There is no such thing as a primitive array, only an array that *holds* primitives.

BE the compiler



Each of the Java files on this page represents a complete source file. Your job is to play compiler and determine whether each of these files will compile. If they won't compile, how would you fix them?

A

```
class Books {
  String title;
  String author;
}

class BooksTestDrive {
  public static void main(String [] args) {

    Books [] myBooks = new Books[3];
    int x = 0;
    myBooks[0].title = "The Grapes of Java";
    myBooks[1].title = "The Java Gatsby";
    myBooks[2].title = "The Java Cookbook";
    myBooks[0].author = "bob";
    myBooks[1].author = "sue";
    myBooks[2].author = "ian";

    while (x < 3) {
      System.out.print(myBooks[x].title);
      System.out.print(" by ");
      System.out.println(myBooks[x].author);
      x = x + 1;
    }
  }
}
```

B

```
class Hobbits {

  String name;

  public static void main(String [] args) {

    Hobbits [] h = new Hobbits[3];
    int z = 0;

    while (z < 4) {
      z = z + 1;
      h[z] = new Hobbits();
      h[z].name = "bilbo";
      if (z == 1) {
        h[z].name = "frodo";
      }
      if (z == 2) {
        h[z].name = "sam";
      }
      System.out.print(h[z].name + " is a ");
      System.out.println("good Hobbit name");
    }
  }
}
```

Exercise

Code Magnets

A working Java program is all scrambled up on the fridge. Can you reconstruct the code snippets to make a working Java program that produces the output listed below? Some of the curly braces fell on the floor and they were too small to pick up, so feel free to add as many of those as you need!

```
int y = 0;
```

```
ref = index[y];
```

```
islands[0] = "Bermuda";
islands[1] = "Fiji";
islands[2] = "Azores";
islands[3] = "Cozumel";
```

```
int ref;
while (y < 4) {
```

```
System.out.println(islands[ref]);
```

```
index[0] = 1;
index[1] = 3;
index[2] = 0;
index[3] = 2;
```

```
String [] islands = new String[4];
```

```
System.out.print("island = ");
```

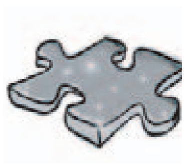
```
int [] index = new int[4];
```

```
y = y + 1;
```

```
class TestArrays {

  public static void main(String [] args) {
```

File Edit Window Help Bikini

```
% java TestArrays
island = Fiji
island = Cozumel
island = Bermuda
island = Azores
```



Pool Puzzle

Your ***job*** is to take code snippets from the pool and place them into the blank lines in the code. You **may** use the same snippet more than once, and you won't need to use all the snippets. Your ***goal*** is to make a class that will compile and run and produce the output listed.

Output

```
 File  Edit  Window  Help  Bermuda
%java Triangle
triangle 0, area = 4.0
triangle 1, area = 10.0
triangle 2, area = 18.0
triangle 3, area = ____
y = ______________________
```

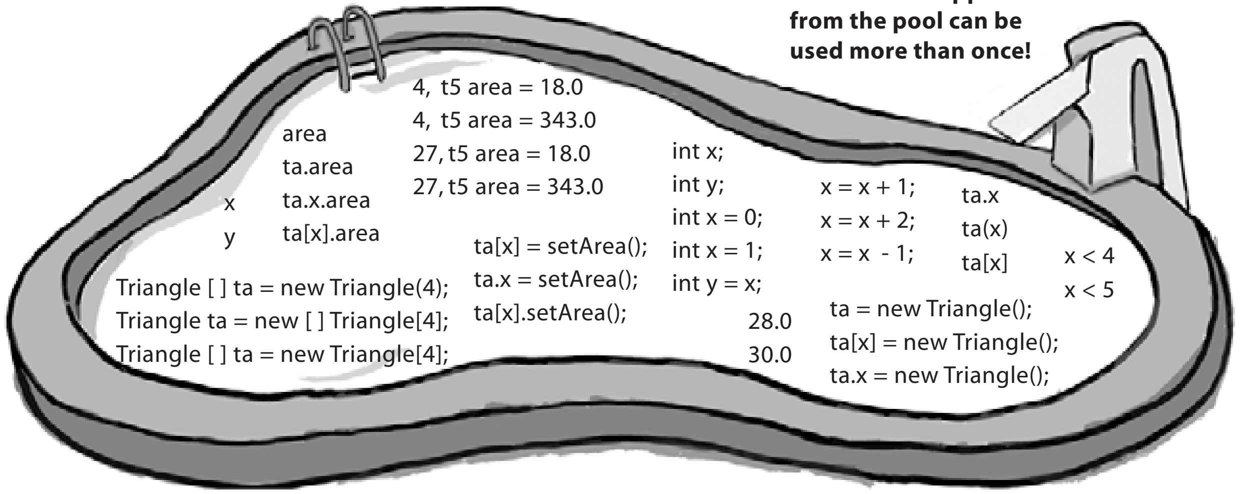
Bonus Question!

For extra bonus points, use snippets from the pool to fill in the missing output (above).

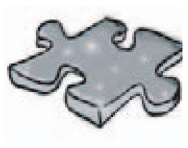
(Sometimes we don't use a separate test class, because we're trying to save space on the page)

```
class Triangle {
  double area;
  int height;
  int length;
  public static void main(String [] args) {
    ____________
    ______________________
    while ( __________ ) {
      __________________________
      ________.height = (x + 1) * 2;
      ________.length = x + 4;
      __________________________
      System.out.print("triangle "+x+", area");
      System.out.println(" = " + _______.area);
      ________________
    }
    ______________
    x = 27;
    Triangle t5 = ta[2];
    ta[2].area = 343;
    System.out.print("y = " + y);
    System.out.println(", t5 area = "+ t5.area);
  }
  void setArea() {
    ____________ = (height * length) / 2;
  }
}
```

Note: Each snippet from the pool can be used more than once!



```
4, t5 area = 18.0
4, t5 area = 343.0
27, t5 area = 18.0
27, t5 area = 343.0

area
ta.area
ta.x.area
ta[x].area

x
y

Triangle [ ] ta = new Triangle(4);
Triangle ta = new [ ] Triangle[4];
Triangle [ ] ta = new Triangle[4];

ta[x] = setArea();
ta.x = setArea();
ta[x].setArea();

int x;
int y;
int x = 0;
int x = 1;
int y = x;

28.0
30.0

x = x + 1;
x = x + 2;
x = x - 1;

ta.x
ta(x)
ta[x]

x < 4
x < 5

ta = new Triangle();
ta[x] = new Triangle();
ta.x = new Triangle();
```



A Heap o' Trouble

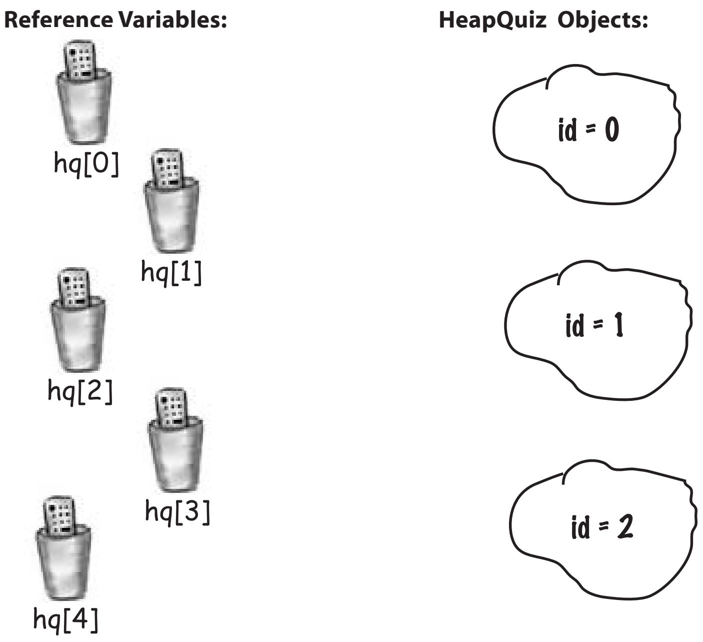
A short Java program is listed to the right. When '// do stuff' is reached, some objects and some reference variables will have been created. Your task is to determine which of the reference variables refer to which objects. Not all the reference variables will be used, and some objects might be referred to more than once. Draw lines connecting the reference variables with their matching objects.

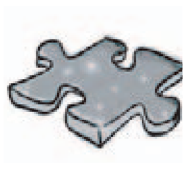
Tip: Unless you're way smarter than us, you probably need to draw diagrams like the ones on page 55 and 56 of this chapter. Use a pencil so you can draw and then erase reference links (the arrows going from a reference remote control to an object).

```
class HeapQuiz {
  int id = 0;
  public static void main(String [] args) {
    int x = 0;
    HeapQuiz [ ] hq = new HeapQuiz[5];
    while ( x < 3 ) {
      hq[x] = new HeapQuiz();
      hq[x].id = x;
      x = x + 1;
    }
    hq[3] = hq[1];
    hq[4] = hq[1];
    hq[3] = null;
    hq[4] = hq[0];
    hq[0] = hq[3];
    hq[3] = hq[2];
    hq[2] = hq[0];
    // do stuff
  }
}
```

match each reference variable with matching object(s)

You might not have to use every reference.





The case of the pilfered references

Five-Minute Mystery

It was a dark and stormy night. Tawny strolled into the programmers' bullpen like she owned the place. She knew that all the programmers would still be hard at work, and she wanted help. She needed a new method added to the pivotal class that was to be loaded into the client's new top-secret Java-enabled cell phone. Heap space in the cell phone's memory was as tight as Tawny's top, and everyone knew it. The normally raucous buzz in the bullpen fell to silence as Tawny eased her way to the white board. She sketched a quick overview of the new method's functionality and slowly scanned the room. "Well boys, it's crunch time", she purred. "Whoever creates the most memory efficient version of this method is coming with me to the client's launch party on Maui tomorrow... to help me install the new software."

The next morning Tawny glided into the bullpen wearing her short Aloha dress. "Gentlemen", she smiled, "the plane leaves in a few hours, show me what you've got!". Bob went first; as he began to sketch his design on the white board Tawny said, "Let's get to the point Bob, show me how you handled updating the list of contact objects." Bob quickly drew a code fragment on the board:

```
Contact [] ca = new Contact[10];
while ( x < 10 ) {   // make 10 contact objects
  ca[x] = new Contact();
  x = x + 1;
}
// do complicated Contact list updating stuff with ca
```

"Tawny I know we're tight on memory, but your spec said that we had to be able to access individual contact information for all ten allowable contacts, this was the best scheme I could cook up", said Bob. Kent was next, already imagining coconut cocktails with Tawny, "Bob," he said, "your solution's a bit kludgy don't you think?" Kent smirked, "Take a look at this baby":

```
Contact refc;
while ( x < 10 ) {   // make 10 contact objects
  refc = new Contact();
  x = x + 1;
}
// do complicated Contact list updating stuff with refc
```

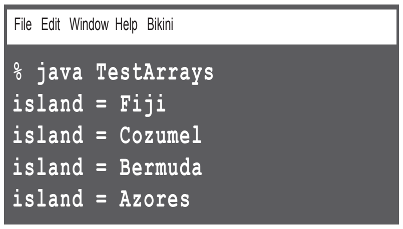
"I saved a bunch of reference variables worth of memory, Bob-o-rino, so put away your sunscreen", mocked Kent. "Not so fast Kent!", said Tawny, "you've saved a little memory, but Bob's coming with me.".

Why did Tawny choose Bob's method over Kent's, when Kent's used less memory?

Exercise Solutions

Code Magnets:

```
class TestArrays {
  public static void main(String [] args) {
    int [] index = new int[4];
    index[0] = 1;
    index[1] = 3;
    index[2] = 0;
    index[3] = 2;
    String [] islands = new String[4];
    islands[0] = "Bermuda";
    islands[1] = "Fiji";
    islands[2] = "Azores";
    islands[3] = "Cozumel";
    int y = 0;
    int ref;
    while (y < 4) {
      ref = index[y];
      System.out.print("island = ");
      System.out.println(islands[ref]);
      y = y + 1;
    }
  }
}
```



```
% java TestArrays
island = Fiji
island = Cozumel
island = Bermuda
island = Azores
```

A

```
class Books {
  String title;
  String author;
}
class BooksTestDrive {
  public static void main(String [] args) {
    Books [] myBooks = new Books[3];
    int x = 0;
    myBooks[0] = new Books();
    myBooks[1] = new Books();
    myBooks[2] = new Books();
    myBooks[0].title = "The Grapes of Java";
    myBooks[1].title = "The Java Gatsby";
    myBooks[2].title = "The Java Cookbook";
    myBooks[0].author = "bob";
    myBooks[1].author = "sue";
    myBooks[2].author = "ian";
    while (x < 3) {
      System.out.print(myBooks[x].title);
      System.out.print(" by ");
      System.out.println(myBooks[x].author);
      x = x + 1;
    }
  }
}
```

Remember: We have to actually make the Books objects !

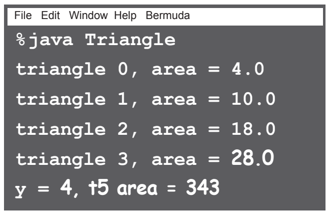
B

```
class Hobbits {
  String name;
  public static void main(String [] args) {
    Hobbits [] h = new Hobbits[3];
    int z = -1;
    while (z < 2) {
    z = z + 1;
    h[z] = new Hobbits();
    h[z].name = "bilbo";
    if (z == 1) {
      h[z].name = "frodo";
    }
    if (z == 2) {
      h[z].name = "sam";
    }
    System.out.print(h[z].name + " is a ");
    System.out.println("good Hobbit name");
    }
  }
}
```

Remember: arrays start with element 0 !

Puzzle Solutions

```
class Triangle {
  double area;
  int height;
  int length;
  public static void main(String [] args) {
    int x = 0;
    Triangle [ ] ta = new Triangle[4];
    while ( x < 4 ) {
      ta[x] = new Triangle();
      ta[x].height = (x + 1) * 2;
      ta[x].length = x + 4;
      ta[x].setArea();
      System.out.print("triangle "+x+", area");
      System.out.println(" = " + ta[x].area);
      x = x + 1;
    }
    int y = x;
    x = 27;
    Triangle t5 = ta[2];
    ta[2].area = 343;
    System.out.print("y = " + y);
    System.out.println(", t5 area = "+ t5.area);
  }
  void setArea() {
    area = (height * length) / 2;
  }
}
```

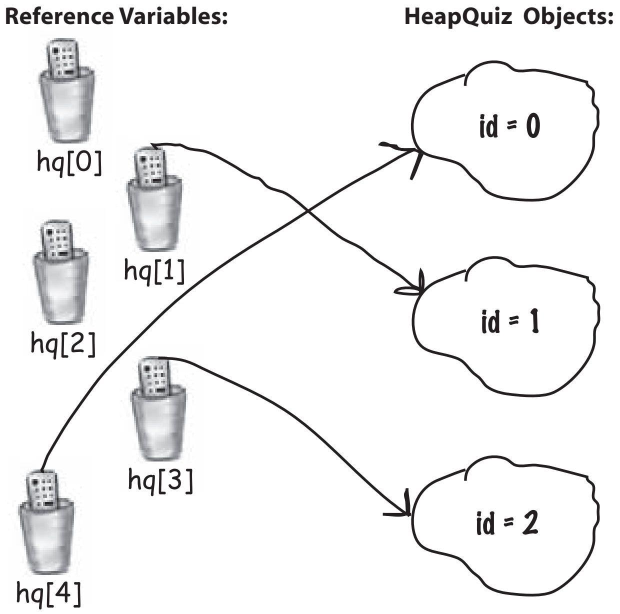


```
%java Triangle
triangle 0, area = 4.0
triangle 1, area = 10.0
triangle 2, area = 18.0
triangle 3, area = 28.0
y = 4, t5 area = 343
```

The case of the pilfered references

Tawny could see that Kent's method had a serious flaw. It's true that he didn't use as many reference variables as Bob, but there was no way to access any but the last of the Contact objects that his method created. With each trip through the loop, he was assigning a new object to the one reference variable, so the previously referenced object was abandoned on the heap – *unreachable*. Without access to nine of the ten objects created, Kent's method was useless.

(The software was a huge success and the client gave Tawny and Bob an extra week in Hawaii. We'd like to tell you that by finishing this book you too will get stuff like that.)


Reference Variables:
HeapQuiz Objects:
hq[0]
hq[1]
hq[2]
hq[3]
hq[4]
id = 0
id = 1
id = 2