Announcement

Project 0 Due Friday

- Submit partner request form by 5 PM today.

Exam Prep Sections start this week! +load balancing discussion sections

- See @274 on Piazza.

OH starts today!

- See website for schedule.
- @ SLC: Second floor of Cesar Chavez
  - Along the left side of GBC if entering from upper Sproul

Announcement

Tips on how to use live lecture time (similar tips apply for video lectures):

- Don’t try to transcribe everything I’m saying. There’s webcasts with really good quality captions for that.
- Instead, try to construct your own understanding as we go, and write down a summary of the mental model you’re building in your head.
- If you don’t understand something, make a note of the time and place it occurs in lecture, and go look at the lecture video later. Then:
  - Watch the part of the video that leads up to where you got lost. If possible, attempt to guess what I’m going to say (or if it’s programming, try to write the code). Then watch and see how your guess compares to what I actually do.
- Live lecture threads on Piazza
  - Post your questions here!

CS61B: Spring 2018

Lecture 3: References and Recursion

- Primitive Types
- Reference Types
- Linked Data Structures

datastructur.es

Poll Test: sp18.datastructur.es/lec -- Click the 1st poll!

Is this working?

A. Yes
B. No
C. Cyborgs don’t feel pain.

This is not part of your grade. If this costs you money, don’t spend it on this!

Primitive Types

Polls: sp18.datastructur.es/lec -- left is 2nd poll, right is 3rd poll

```
Walrus a = new Walrus(1000, 8.3);
Walrus b;
b = a;
b.weight = 5;
System.out.println(a);
System.out.println(b);
```

Will the change to b affect a?

A. Yes

B. No

```
weight: 5, tusk size: 8.30
weight: 5, tusk size: 8.30
```

Answer: Visualizer

```
int x = 5;
int y;
y = x;
x = 2;
System.out.println("x is: " + x);
System.out.println("y is: " + y);
```

Will the change to x affect y?

- A. Yes
- B. No

```
x is: 2
y is: 5
```

Bits

Your computer stores information in “memory”.

- Information is stored in memory as a sequence of ones and zeros.
  - Example: 72 stored as 01001000
  - Example: 205.75 stored as … 01000011 01001101 11000000 00000000
  - Example: The letter H stored as 01001000 (same as the number 72)
  - Example: True stored as 00000001

Each Java type has a different way to interpret the bits:

- 8 primitive types in Java: byte, short, **int**, long, float, **double**, boolean, char
- We won’t discuss the precise representations in much detail in 61B.
  - Covered in much more detail in 61C.

Note: Precise representations may vary from machine to machine.

Declaring a Variable (Simplified)

When you declare a variable of a certain type in Java:

- Your computer sets aside exactly enough bits to hold a thing of that type.
  - Example: Declaring an int sets aside a “box” of 32 bits.
  - Example: Declaring a double sets aside a box of 64 bits.
- Java creates an internal table that maps each variable name to a location.
- Java does NOT write anything into the reserved boxes.
  - For safety, Java will not let access a variable that is uninitialized.

```
int x;
double y;
x = -1431195969;
y = 567213.112;
```

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double y;
x = -1431195969;
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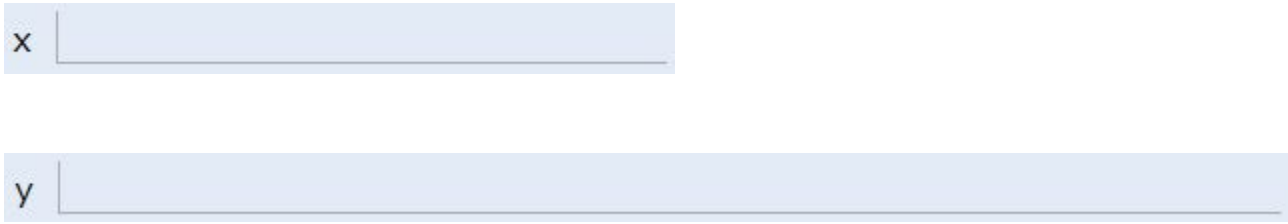
```



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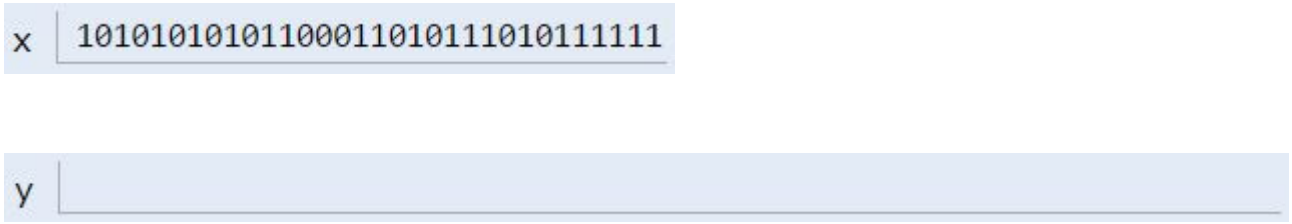

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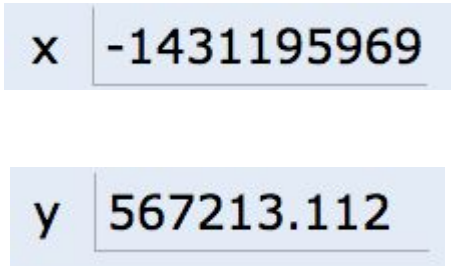
```
int x;
double y;
x = -1431195969;
y = 567213.112;
```

Simplified Box Notation

We'll use simplified box notation from here on out:

- Instead of writing memory box contents in binary, we'll write them in human readable symbols.

```
int x;
double y;
x = -1431195969;
y = 567213.112;
```



The Golden Rule of Equals (GRoE)

Given variables y and x:

- y = x **copies** all the bits from x into y.

Example from earlier: Link

Reference Types

Reference Types

There are 8 primitive types in Java:

- byte, short, **int**, long, float, **double**, boolean, char

Everything else, including arrays, is a **reference type**.

Class Instantiations

When we instantiate an Object (e.g. Dog, Walrus, Planet):

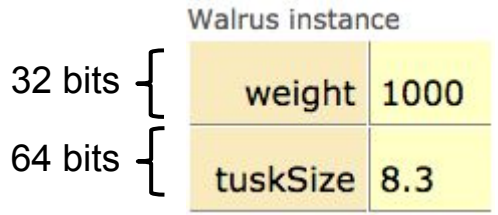
- Java first allocates a box of bits for each instance variable of the class and fills them with a default value (e.g. 0, null).
- The constructor then usually fills every such box with some other value.

```
public static class Walrus {
    public int weight;
    public double tuskSize;

    public Walrus(int w, double ts) {
        weight = w;
        tuskSize = ts;
    }
}
```

```
new Walrus(1000, 8.3);
```

Demo Link



Class Instantiations

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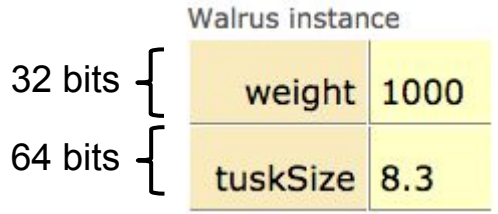
- Java first allocates a box of bits for each instance variable of the class and fills them with a default value (e.g. 0, null).
- The constructor then usually fills every such box with some other value.

```
....00000000000000000000000000000000000000
00000000000000000000000000000000000000000
00000000000000000000000000000000000000000
00000000000000000000000000000001111101
00001000000001000001001100110011001100110
01100110011001100110100000000000000000000
00000000000000000000000000000000000000000
00000000000000000000000000000000000000000
00000000000000000000000000000000000000000
00000000000000000000000000000000000000000
00000000000000000000000000000000000000000
00000000000000000000000000000000000000000
00000000000000000000....
```

```
new Walrus(1000, 8.3);
```



Green is weight, blue is tuskSize.

(In reality, total Walrus size is slightly larger than 96 bits.)

Class Instantiations

Can think of new as returning the address of the newly created object.

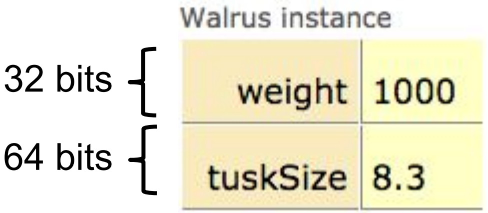
- Addresses in Java are 64 bits.
- Example (rough picture): If object is created in memory location 2384723423, then new returns 2384723423.

2384723423th bit

```
....00000000000000000000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000000000000000001111101
000010000000001000001001100110011001100110011
011001100110011001101000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000000000000000000000000
000000000000000000000000....
```

2384723423

```
new Walrus(1000, 8.3);
```

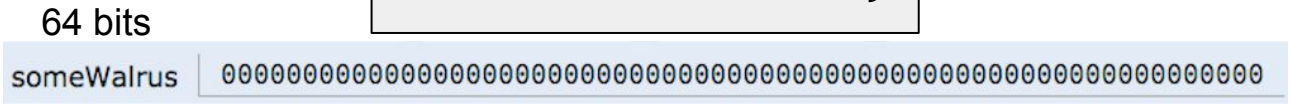


Reference Type Variable Declarations

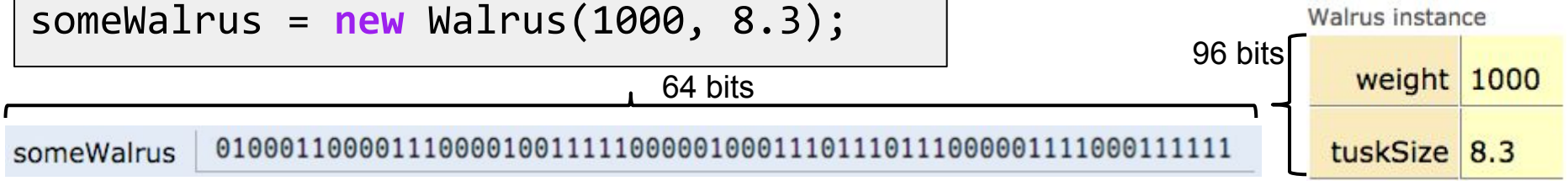
When we declare a variable of any reference type (Walrus, Dog, Planet):

- Java allocates exactly a box of size 64 bits, no matter what type of object.
- These bits can be either set to:
  - Null (all zeros).
  - The 64 bit "address" of a specific instance of that class (returned by **new**).

```
Walrus someWalrus;
someWalrus = null;
```




```
Walrus someWalrus;
someWalrus = new Walrus(1000, 8.3);
```

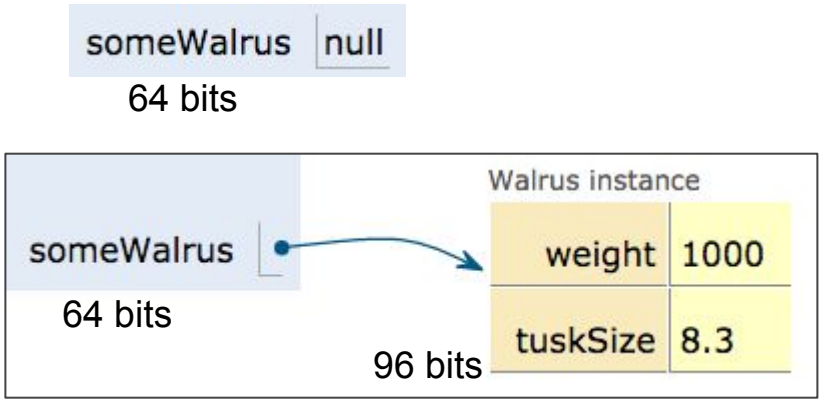


Reference Type Variable Declarations

The 64 bit addresses are meaningless to us as humans, so we'll represent:

- All zero addresses with "null".
- Non-zero addresses as arrows.

This is sometimes called "box and pointer" notation.

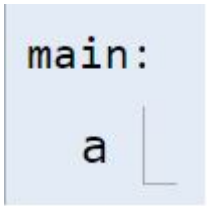


Reference Types Obey the Golden Rule of Equals

Just as with primitive types, the equals sign copies the bits.

- In terms of our visual metaphor, we “copy” the arrow by making the arrow in the b box point at the same instance as a.

```
Walrus a;
a = new Walrus(1000, 8.3);
Walrus b;
b = a;
```



a is 64 bits

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Walrus b;
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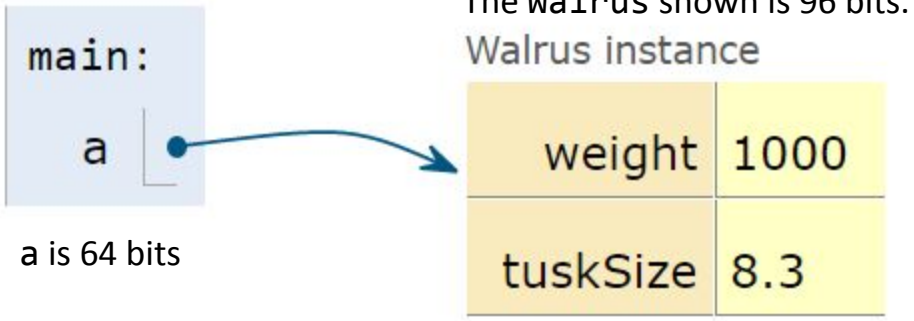

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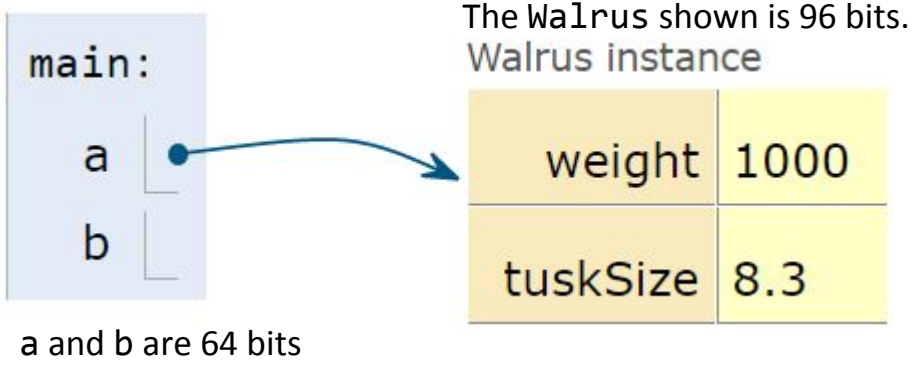

Note: b is currently undefined, not null!

Reference Types Obey the Golden Rule of Equals

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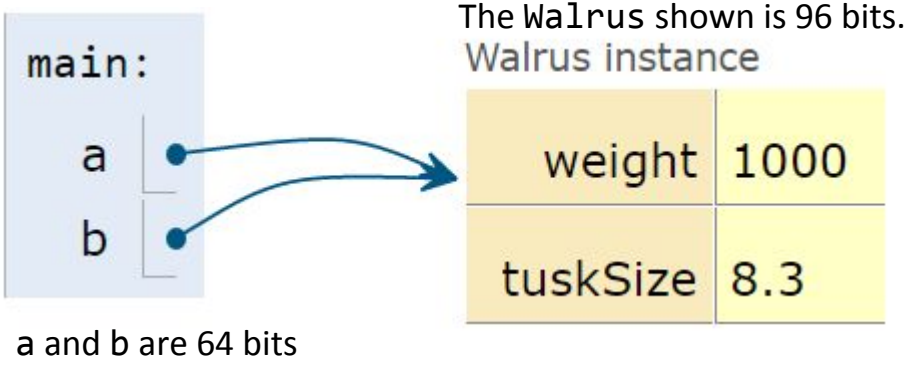


Parameter Passing

The Golden Rule of Equals (and Parameter Passing)

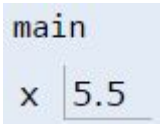
Given variables b and a:

- b = a **copies** all the bits from a into b.

Passing parameters obeys the same rule: Simply **copy the bits** to the new scope**.**

```
public static double average(double a, double b) {
    return (a + b) / 2;
}

public static void main(String[] args) {
 →  double x = 5.5;
    double y = 10.5;
    double avg = average(x, y);
}
```



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```

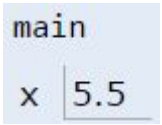

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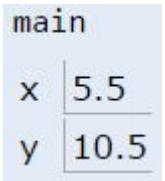

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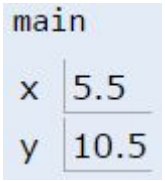


The Golden Rule of Equals (and Parameter Passing)

Given variables b and a:

- b = a **copies** all the bits from a into b.

This is also called pass by value.

Passing parameters obeys the same rule: Simply **copy the bits** to the new scope.

```
public static double average(double a, double b) {
    return (a + b) / 2;
}

public static void main(String[] args) {
    double x = 5.5;
    double y = 10.5;
    double avg = average(x, y);
}
```

average	
a	5.5
b	10.5

main	
x	5.5
y	10.5

The Golden Rule: Summary

There are 9 types of variables in Java:

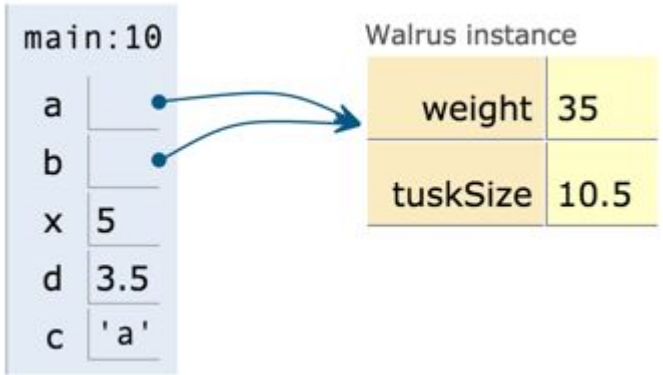
- 8 primitive types (byte, short, int, long, float, double, boolean, char).
- The 9th type is references to Objects (an arrow). References may be null.

In box-and-pointer notation, each variable is drawn as a labeled box and values are shown in the box.

- Addresses are represented by arrows to object instances.

The golden rule:

- b = a **copies the bits** from a into b.
- Passing parameters **copies the bits**.



Test Your Understanding: sp18.datastructur.es/lec -- 4th poll

Does the call to doStuff(walrus, x) have an affect on `walrus` and/or main's x?

A. Neither will change.
B. `walrus` will lose 100 lbs, but main's x will not change.
C. `walrus` will not change, but main's x will decrease by 5.
D. Both will decrease.

```
public static void main(String[] args) {
    Walrus walrus = new Walrus(3500, 10.5);
    int x = 9;
    doStuff(walrus, x);
    System.out.println(walrus);
    System.out.println(x);
}
public static void doStuff(Walrus W, int x) {
    W.weight = W.weight - 100;
    x = x - 5;
}
```

Try to convince your neighbor of your answer:

sp18.datastructur.es/lec -- 5th poll

Does the call to doStuff(walrus, x) have an affect on `walrus` and/or main's x?

A. Neither will change.
B. `walrus` will lose 100 lbs, but main's x will not change.
C. `walrus` will not change, but main's x will decrease by 5.
D. Both will decrease.

Answer: http://goo.gl/ngsxkq

```
public static void main(String[] args) {
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    int x = 9;
    doStuff(walrus, x);
    System.out.println(walrus);
    System.out.println(x);
}
public static void doStuff(Walrus W, int x) {
    W.weight = W.weight - 100;
    x = x - 5;
}
```

Instantiation of Arrays

Declaration and Instantiation of Arrays

Arrays are also Objects. As we've seen, objects are (usually) instantiated using the ***new*** keyword.

- `Planet p = new Planet(0, 0, 0, 0, 0, "blah.png");`
- `int[] x = new int[]{0, 1, 2, 95, 4};`

Declaration

```
int[] a;
```

- Declaration creates a 64 bit box intended only for storing a reference to an int array. **No object is instantiated.**

Instantiation (HW0 covers this syntax)

```
new int[]{0, 1, 2, 95, 4};
```

- Instantiates a new Object, in this case an int array.
- Object is anonymous!

Minor technical note: I'm abusing the term instantiate a little by applying it to arrays.

Assignment of Arrays

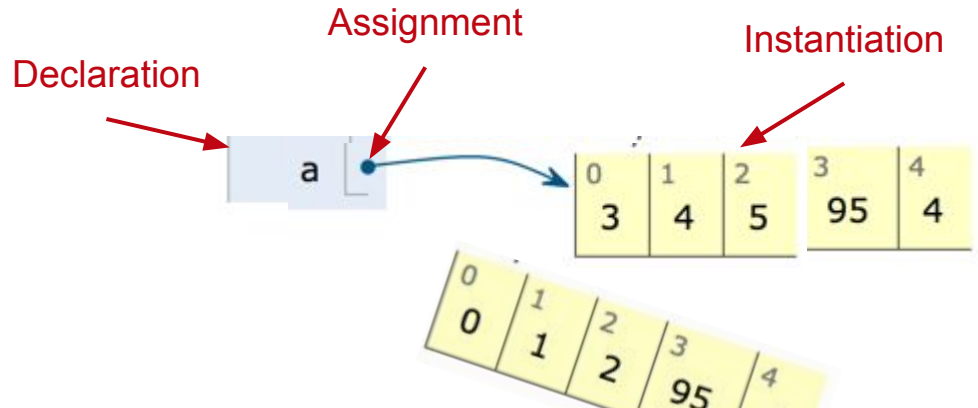
Declaration, instantiation, and assignment.

```
int[] a = new int[]{0, 1, 2, 95, 4};
```

- Creates a 64 bit box for storing an int array address. (declaration)
- Creates a new Object, in this case an int array. (instantiation)
- Puts the address of this new Object into the 64 bit box named a. (assignment)

Note: Instantiated objects can be lost!

- If we were to reassign a to something else, we'd never be able to get the original Object back!



IntList and Linked Data Structures

IntList

Let's define an `IntList` as an object containing two member variables:

- `int first;`
- `IntList rest;`

And define two versions of the same method:

- `size()`
- `iterativeSize()`

Challenge

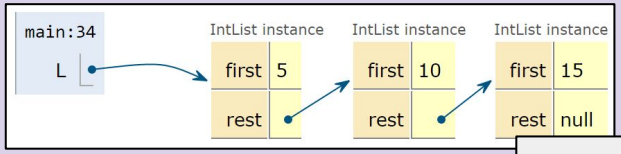
See the video online for a solution:
https://www.youtube.com/watch?v=qnmxD_21DNk

Write a method `int get(int i)` that returns the ith item in the list.

- For simplicity, OK to assume the item exists.
- Front item is the 0th item.

Ways to work:

- Paper (best)
- Laptop (see lectureCode repo)
  - lists1/exercises/IntList.java
- In your head (worst)




```
L.get(0): 5
L.get(1): 10
```

```java
public class IntList {
   public int first;
   public IntList rest;
   public IntList(int f, IntList r) {
      first = f;
      rest = r;
   }

   /** Return the size of this IntList. */
   public int size() {
      if (rest == null) {
         return 1;
      }
    return 1 + this.rest.size();
   ...
```

Question: sp18.datastructur.es/lec -- 6th poll

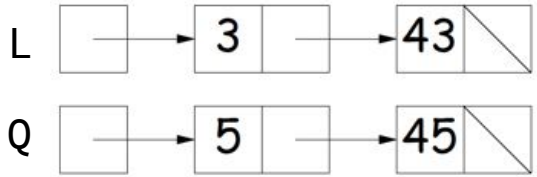
What is your comfort level with recursive data structure code?

A. Very comfortable.
B. Comfortable.
C. Somewhat comfortable.
D. I have never done this.

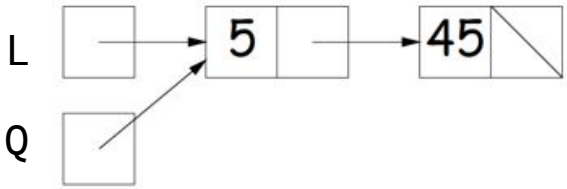
ExtraIntListPractice.java

For further practice with IntLists, fill out the code for the methods listed below in the **lists1/exercises/ExtraIntListPractice.java** in **lectureCode** github directory.

- `public static IntList incrList(IntList L, int x)`
  - Returns an IntList identical to L, but with all values incremented by x.
  - Values in L cannot change!



- `public static IntList dincrList(IntList L, int x)`
  - Returns an IntList identical to L, but with all values incremented by x.
  - Not allowed to use 'new' (to save memory).



This week's discussion also features optional IntList problems.

Citations

Old Deprecated Slides

Quick Aside on Class Instantiation

Any class that we've created so far in 61B can be instantiated.

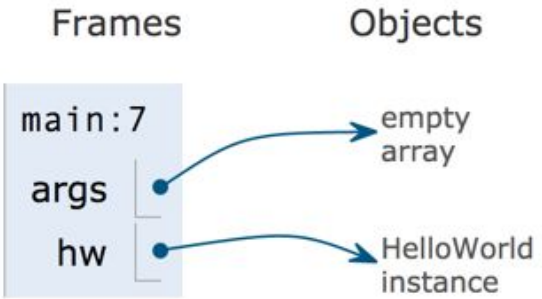
- Would be silly (but possible) to instantiate HelloWorld.

```
public class HelloWorld {
        public static void main(String[] args) {
                System.out.println("Hello World.");
        }
}
```

```
$ java HelloWorld
Hello World.
```

```
public class HelloWorldMaker {
        public static void main(String[] args) {
                HelloWorld hw = new HelloWorld();
        }
}
```

```
$ java HelloWorldMaker
```



(nothing happens) -- HelloWorld.main does not run!!

null

Java (for better or worse) allows null references.

- Danger lurks: null references do NOT have instance variables.
  - Blame Sir Tony Hoare (more when we talk about Quicksort)

Example:

```
Planet earth = new Planet(6e24, 6.37e6);
System.out.println(Planet.surfaceGravity(earth));

Planet x = null;
System.out.println(Planet.surfaceGravity(x));
```

```
9.862754424315312
Exception in thread "main" java.lang.NullPointerException
    at Planet.surfaceGravity(Planet.java:17)
    at Planet.main(Planet.java:36)
```

Java is “Pass by Value”

All method (and constructor) calls are pass by value!

- The exact contents of the container in the outside world are delivered to the containers in the function. If the container has an arrow, so be it.

```
1  public class PassByValueFigure {
2      public static void main(String[] args) {
3          Walrus walrus = new Walrus(3500, 10.5);
4          int x = 9;
5
6          doStuff(walrus, x);
7          System.out.println(walrus);
8          System.out.println(x);
9      }
10
11     public static void doStuff(Walrus W, int x) {
12         W.weight = W.weight - 100;
13         x = x - 5;
14     }
```