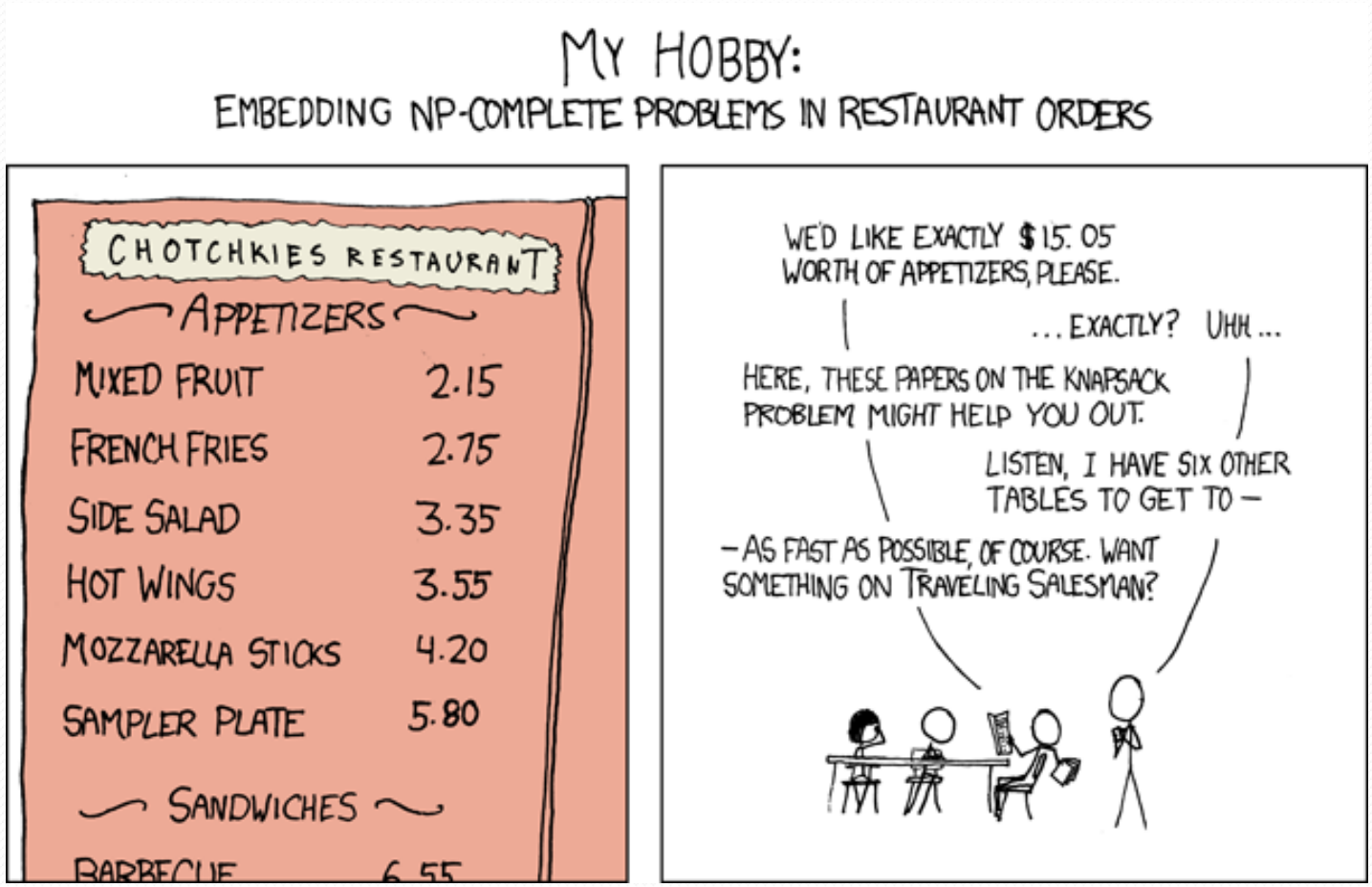
Building Java Programs

Chapter 16

Lecture 16-1: References and linked nodes

reading: 16.1



- NP-complete is a complexity class
  - No known polynomial time (O(n), $O(n^5)$…) solutions!
  - Solutions are, for example, $O(2^n)$ – ouch!

Collection efficiency

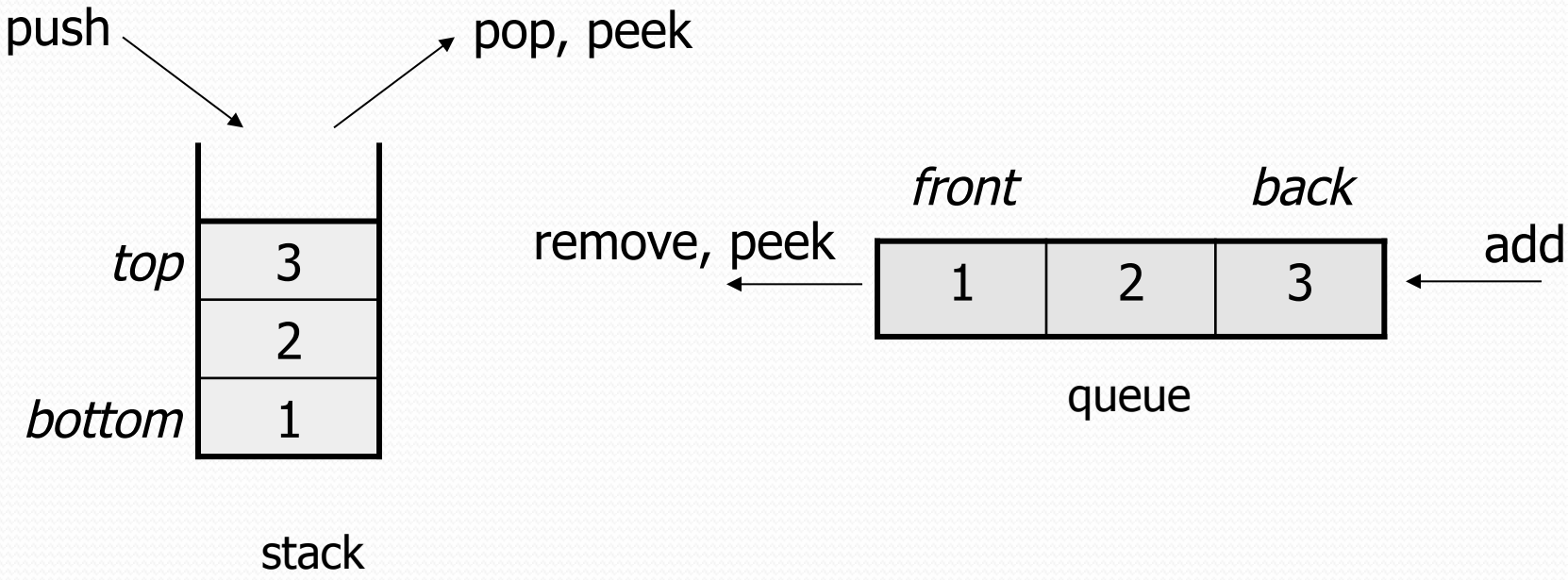
- Complexity class of various operations on collections:

Method	ArrayList	Stack	Queue
`add` (or `push`)	O(1)	O(1)	O(1)
`add(`**index**`,` **value**`)`	O(N)	-	-
`indexOf`	O(N)	-	-
`get`	O(1)	-	-
`remove`	O(N)	O(1)	O(1)
`set`	O(1)	-	-
`size`	O(1)	O(1)	O(1)

  - Which operations are fast, and which are slow?
  - Could we build lists differently to optimize other operations?

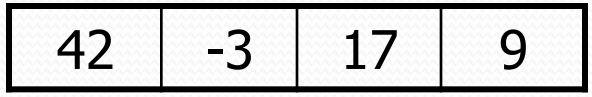
Recall: stacks and queues

- **stack**: retrieves elements in reverse order as added
- **queue**: retrieves elements in same order as added



Array vs. linked structure

- All collections in this course use one of the following:
  - an **array** of all elements
    - examples: `ArrayList`, `Stack`, `HashSet`, `HashMap`



  - **linked objects** storing a value and references to other(s)
    - examples: `LinkedList`, `TreeSet`, `TreeMap`

    - First, we will learn how to create a *linked list*.
    - To understand linked lists, we must understand *references*.

Non-contiguous memory

- Array

42	-3	17	9

- Spread in memory

42			9		-3			17

Arrays vs. linked lists

- Array advantages
  - Random access: can quickly retrieve any value
- Array disadvantages
  - Adding/removing in middle is O(n)
  - Expanding requires creating a new array and copying elements
- Linked list advantages
  - Adding/removing in middle is O(1)
  - Expanding is O(1) (just add a node)
- Linked list disadvantages
  - Sequential access: can't directly retrieve any value

A `swap` method?

- Does the following `swap` method work? Why or why not?

```
public static void main(String[] args) {
    int a = 7;
    int b = 35;

    // swap a with b
    swap(a, b);

    System.out.println(a + " " + b);
}

public static void swap(int a, int b) {
    int temp = a;
    a = b;
    b = temp;
}
```

Value semantics

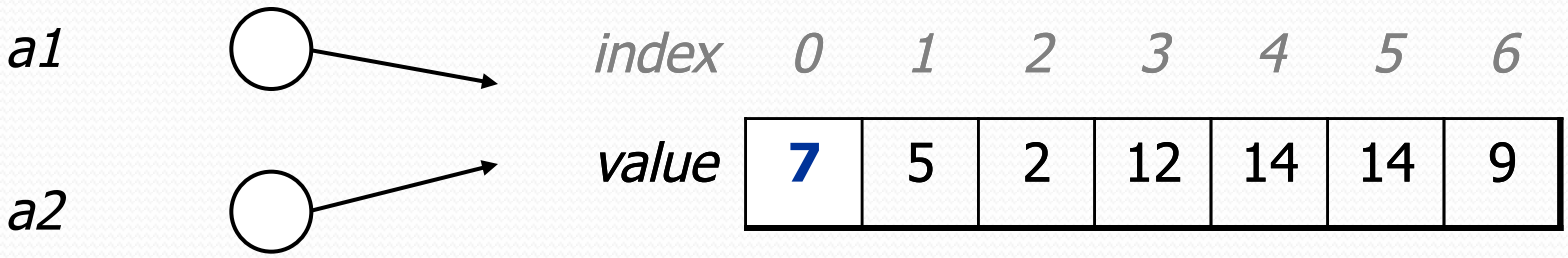
- **value semantics**: Behavior where values are copied when assigned to each other or passed as parameters.
  - When one primitive is assigned to another, its value is copied.
  - Modifying the value of one variable does not affect others.

```
int x = 5;
int y = x;      // x = 5, y = 5
y = 17;         // x = 5, y = 17
x = 8;          // x = 8, y = 17
```

Reference semantics

- **reference semantics**: Behavior where variables actually store the address of an object in memory.
  - When one reference variable is assigned to another, the object is *not* copied; both variables refer to the *same object*.

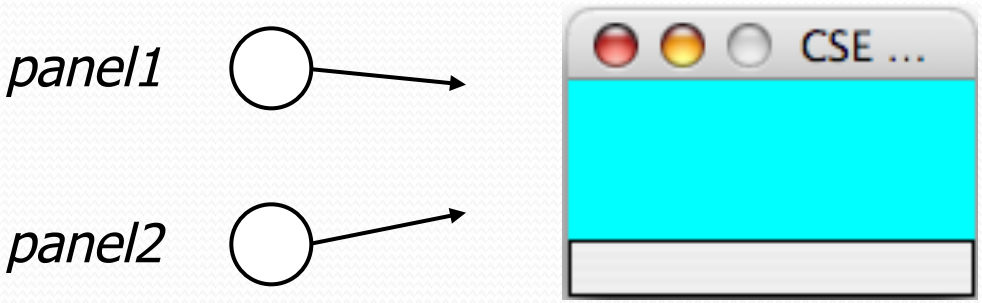
```
int[] a1 = {4, 5, 2, 12, 14, 14, 9};
int[] a2 = a1;      // refers to same array as a1
a2[0] = 7;
System.out.println(a1[0]);   // 7
```



References and objects

- In Java, objects and arrays use reference semantics. Why?
  - *efficiency.* Copying large objects slows down a program.
  - *sharing.* It's useful to share an object's data among methods.

```
DrawingPanel panel1 = new DrawingPanel(80, 50);
DrawingPanel panel2 = panel1;   // same window
panel2.setBackground(Color.CYAN);
```

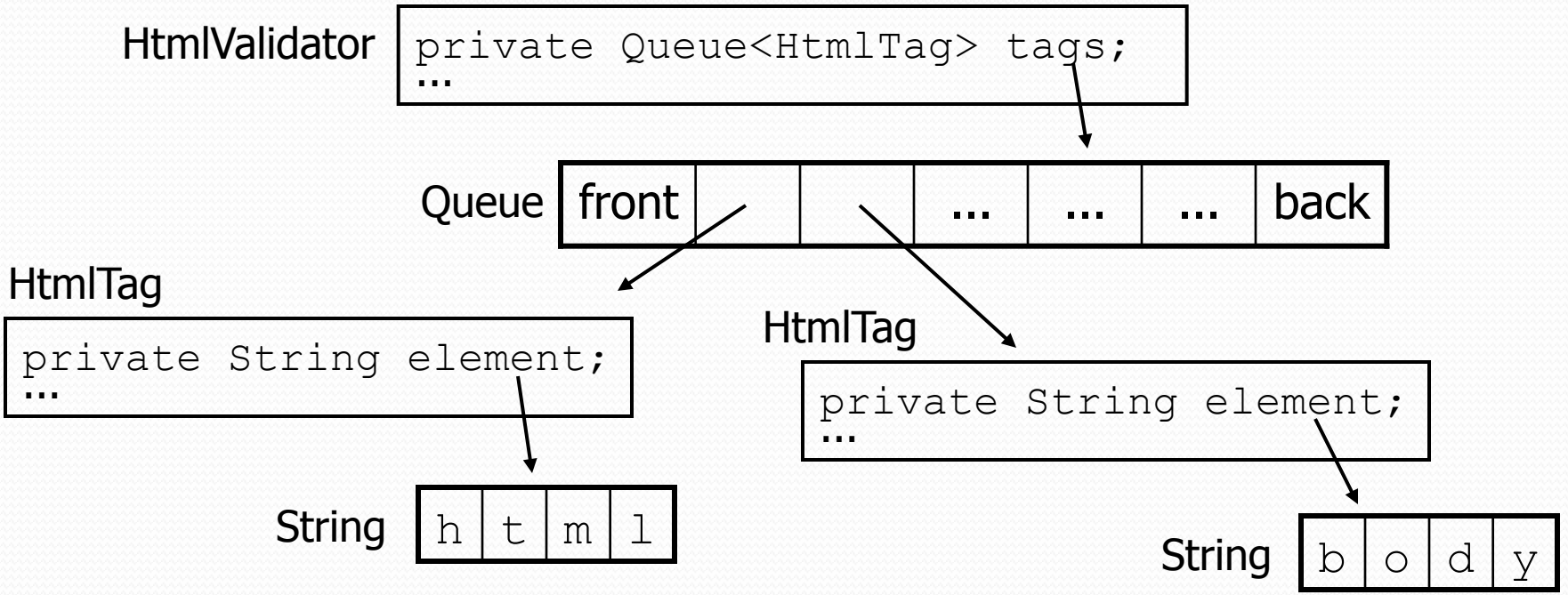


References as fields

- Objects can store references to other objects as fields.

  Example: Homework 2 (HTML Validator)

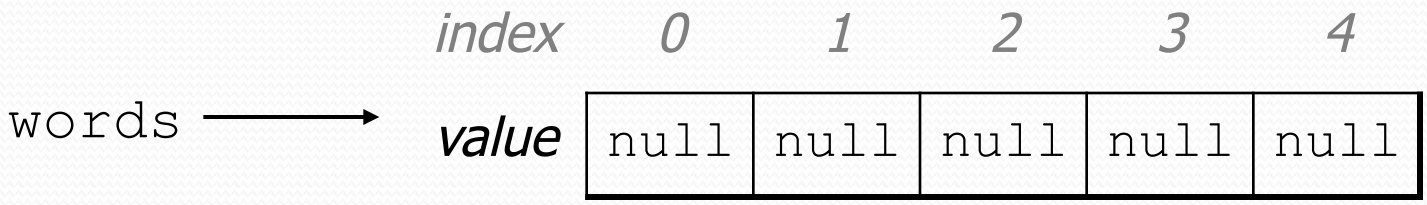
  - `HtmlValidator` stores a reference to a `Queue`
  - the `Queue` stores many references to `HtmlTag` objects
  - each `HtmlTag` object stores a reference to its element `String`



Null references

- **`null` :** A value that does not refer to any object.
  - The elements of an array of objects are initialized to `null`.

```
String[] words = new String[5];
```

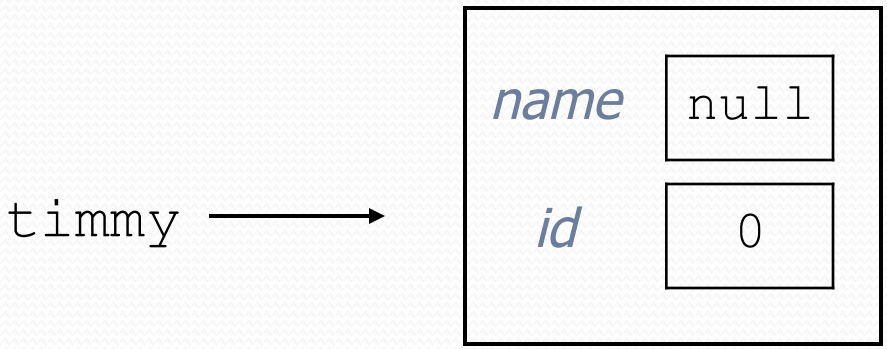


  - not the same as the empty string `""` or the string `"null"`
  - Why does Java have `null` ? What is it used for?

Null references

- Unset reference fields of an object are initialized to `null`.

```
public class Student {
    String name;
    int id;
}

Student timmy = new Student();
```



Things you can do w/ `null`

- store `null` in a variable or an array element

```
String s = null;
words[2] = null;
```

- print a `null` reference

```
System.out.println(timmy.name);       // null
```

- ask whether a variable or array element is `null`

```
if (timmy.name == null) { ...         // true
```

- pass `null` as a parameter to a method
  - some methods don't like `null` parameters and throw exceptions

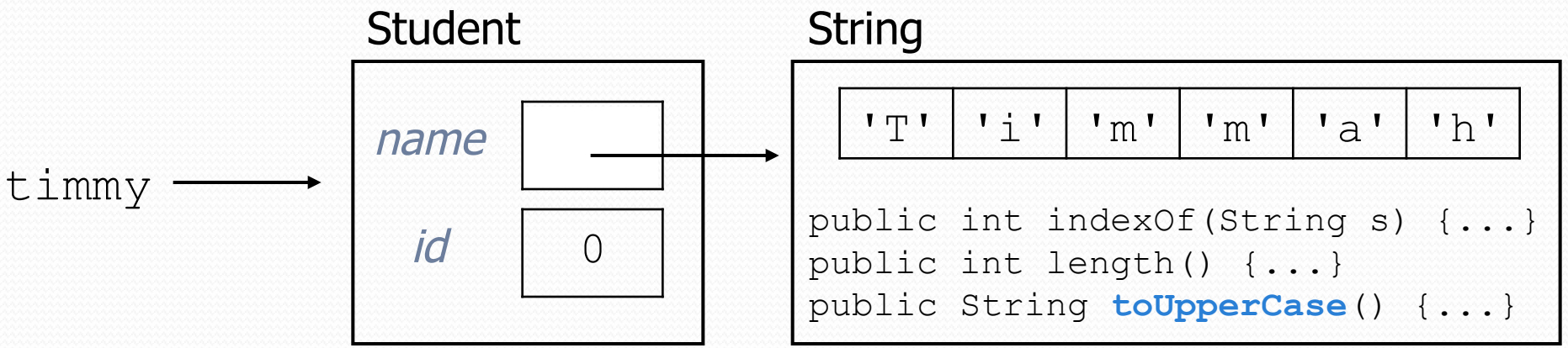
- return `null` from a method (often to indicate failure)

```
return null;
```

Dereferencing

- **dereference**: To access data or methods of an object.
  - Done with the dot notation, such as `s.length()`
  - When you use a `.` after an object variable, Java goes to the memory for that object and looks up the field/method requested.

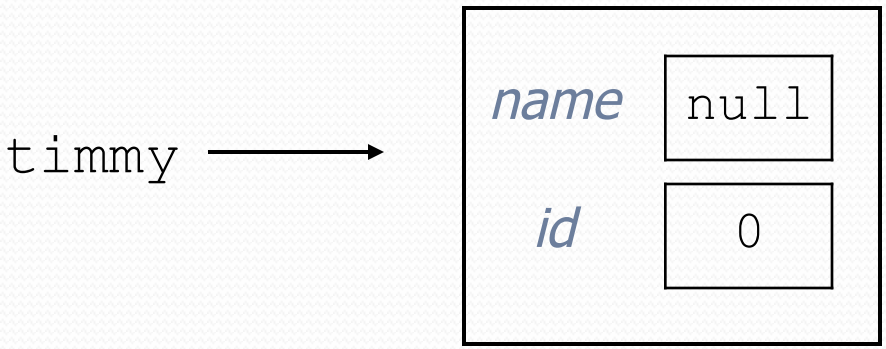
```
Student timmy = new Student();
timmy.name = "Timmah";
String s = timmy.name.toUpperCase();
```



Null pointer exception

- It is illegal to dereference `null` (it causes an exception).
  - `null` does not refer to any object; it has no methods or data.

```
Student timmy = new Student();
String s = timmy.name.toUpperCase();   // ERROR
```



Output:

```
Exception in thread "main"
java.lang.NullPointerException
        at Example.main(Example.java:8)
```

References to same type

- What would happen if we had a class that declared one of its own type as a field?

```
public class Strange {
    private String name;
    private Strange other;
}
```

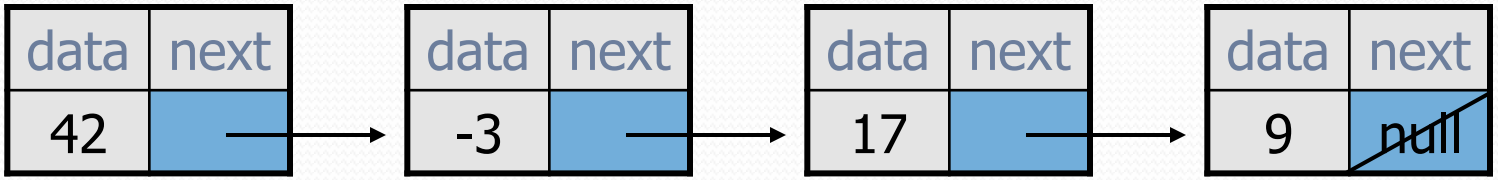
  - Will this compile?
    - If so, what is the behavior of the `other` field? What can it do?
    - If not, why not? What is the error and the reasoning behind it?

A list node class

```
public class ListNode {
    int data;
    ListNode next;
}
```

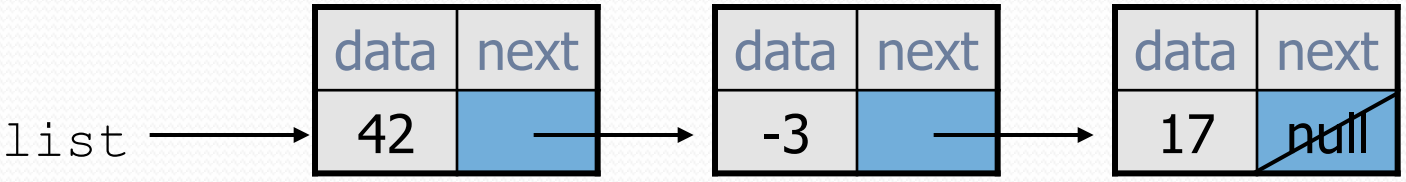
- Each list node object stores:
  - one piece of integer data
  - a reference to another list node

- `ListNode`s can be "linked" into chains to store a list of values:



List node client example

```
public class ConstructList1 {
    public static void main(String[] args) {
        ListNode list = new ListNode();
        list.data = 42;
        list.next = new ListNode();
        list.next.data = -3;
        list.next.next = new ListNode();
        list.next.next.data = 17;
        list.next.next.next = null;
        System.out.println(list.data + " " + list.next.data
                           + " " + list.next.next.data);
        // 42 -3 17
    }
}
```



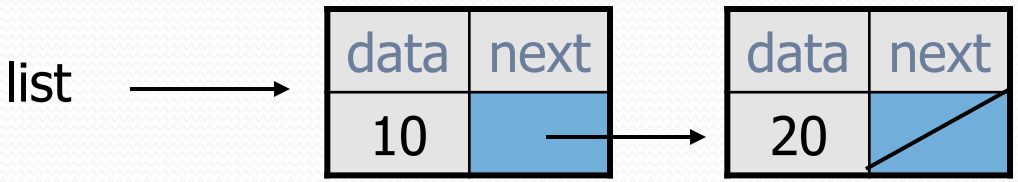
List node w/ constructor

```
public class ListNode {
    int data;
    ListNode next;

    public ListNode(int data) {
        this.data = data;
        this.next = null;
    }

    public ListNode(int data, ListNode next) {
        this.data = data;
        this.next = next;
    }
}
```

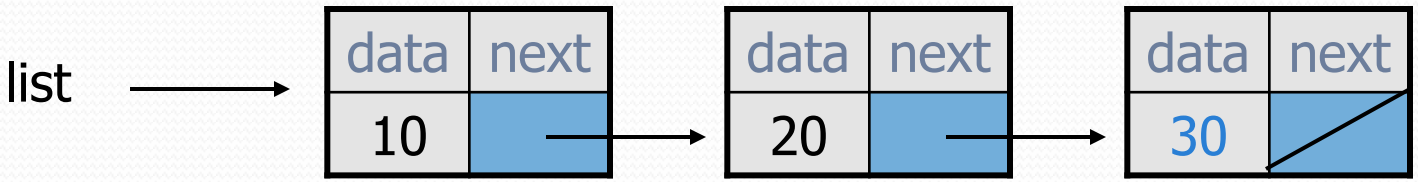
- Exercise: Modify the previous client to use these constructors.

Linked node problem 1

- What set of statements turns this picture:



- Into this?



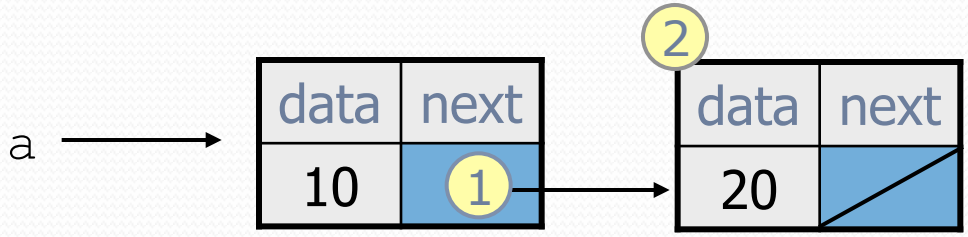
References vs. objects

variable = **value**;

a *variable* (left side of =) is an arrow (the base of an arrow)

a *value* (right side of =) is an object (a box; what an arrow points at)

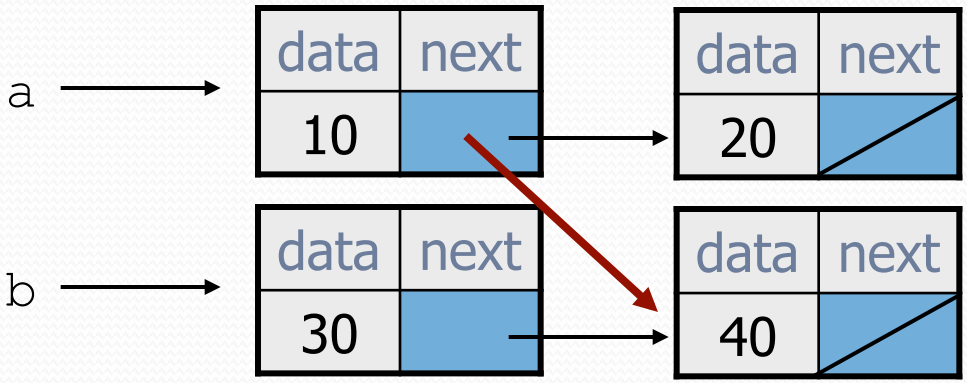
- For the list at right:
  - `a.next` = **value**;
    means to adjust where (1) points
  - **variable** = `a.next;`
    means to make **variable** point at (2)



Reassigning references

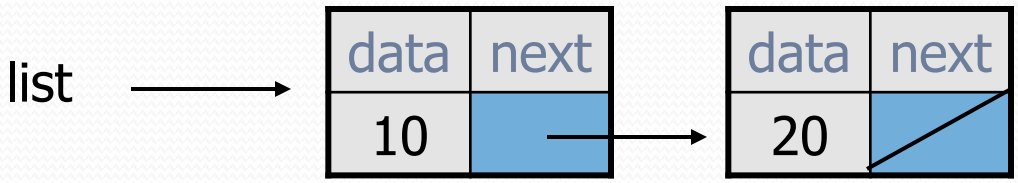
- when you say:
  - `a.next = b.next;`

- you are saying:
  - "Make *variable* `a.next` refer to the same *value* as `b.next`."
  - Or, "Make `a.next` point to the same place that `b.next` points."

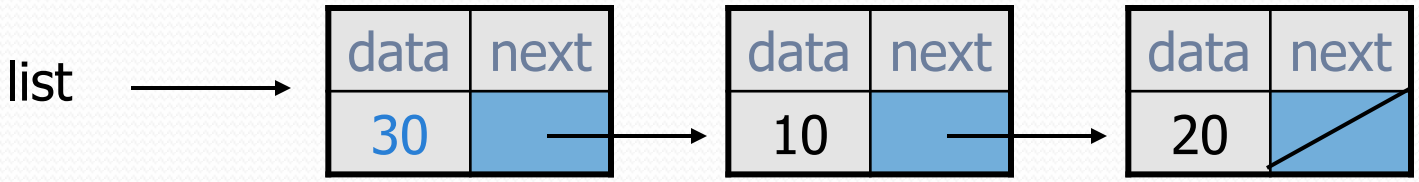


Linked node problem 2

- What set of statements turns this picture:

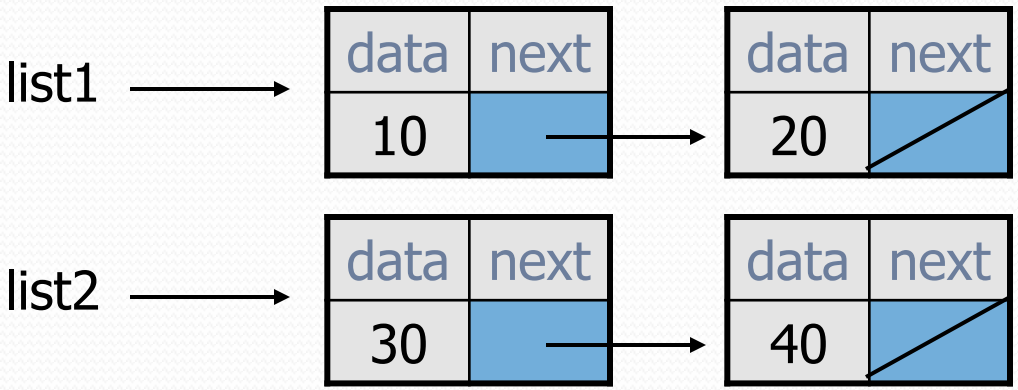


- Into this?

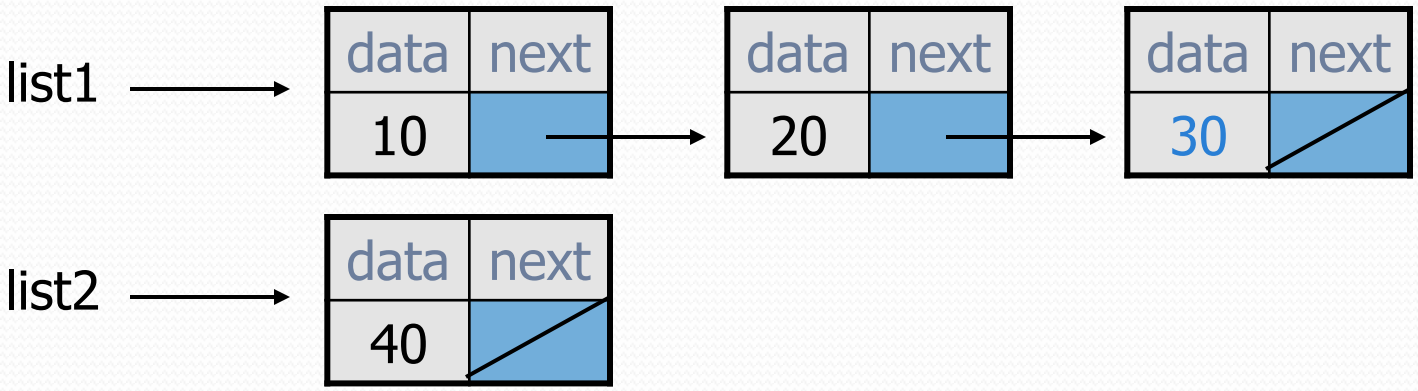


Linked node problem 3

- What set of statements turns this picture:

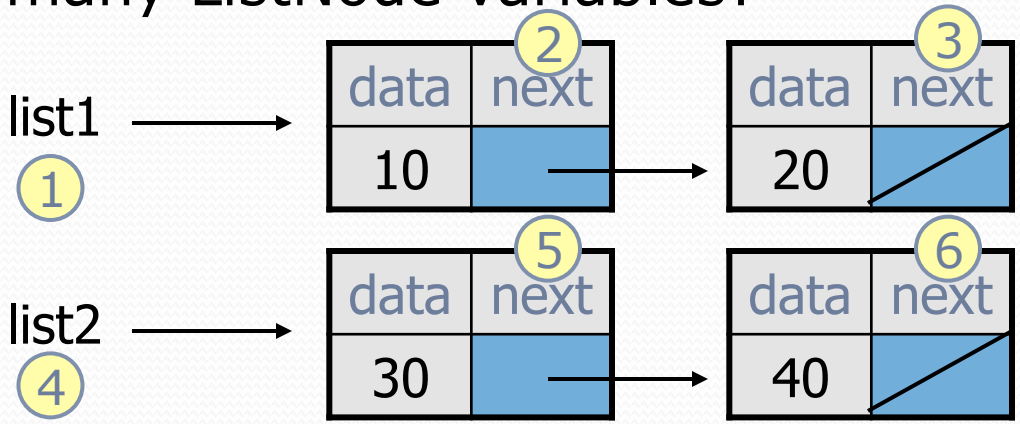


- Into this?

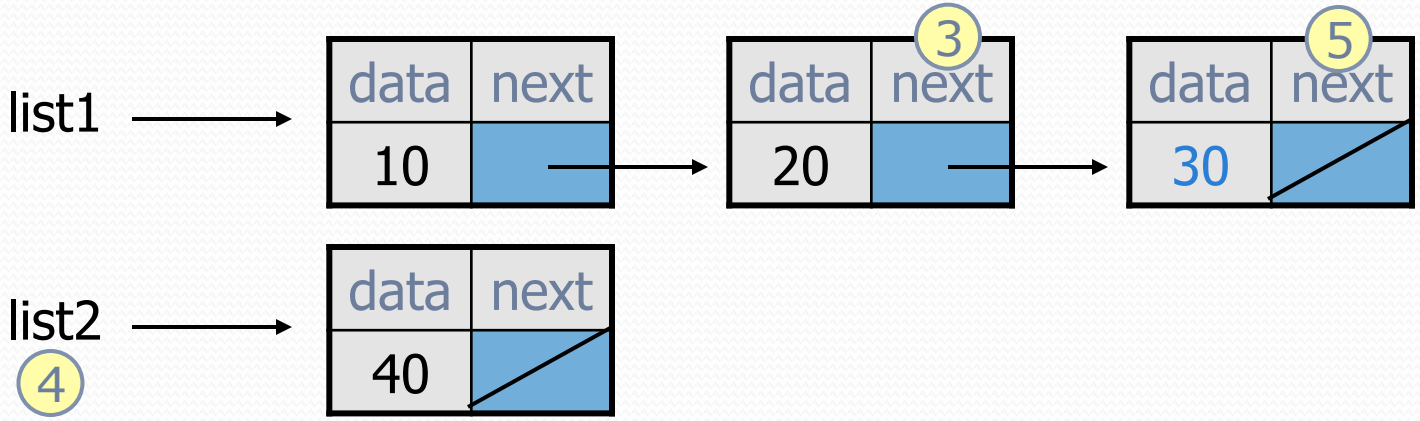


Linked node problem 3

- How many ListNode variables?

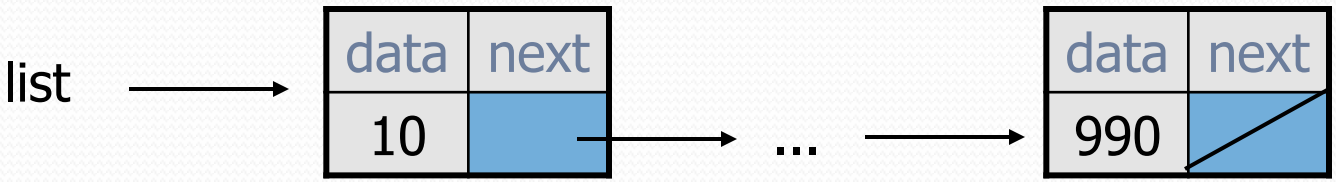


- Which variables change?



Linked node problem 4

- What set of statements turns this picture:



- Into this?