Lab deadlines

- **Group 1** (Friday 25th)
  - Lab 2: deadline (**today)**
  - Lab 3: today's **recursion** lab

- **Group 1** (Monday 28th)
  - Lab 2: deadline
  - Lab 3: **recursion** lab

Peer Feedback

- Code reviews for **lab 1 solutions** starts Monday
- Your **reviewers will be automatically added**
  - They will be emailed confirmation

- **You will be automatically added** to the reviewee projects
  - You will be emailed confirmation

- Reviews:
  1. **Code simplicity**
  2. **Documentation**
  3. **Code conventions**

- **Assessed**:
  - **That you complete your code reviews**
  - Show lab helper your code reviews
- Not assessed:
  - What you actually write

Peer Feedback

1) **Code simplicity:**

- Is the code as simple as it could be?
- Could the code be shorter?
- Could if/while/for statements be removed?
- Is the code more complex than it needs to be?
- Could code be removed without changing a method's output?
- Are there any unused variables?
- Is there any duplication of code in the same Java class file?

- Suggest improvement
    - How to reduce the code's worst case complexity.
    - Removing code
    - Simplifying code

Peer Feedback

2) **Documentation**

- How well is the code documented?
  - Comments above method definitions
  - Comments line by line inside the methods
  - See Section 5 (Comments) of Oracle's "Java coding conventions":

http://www.oracle.com/technetwork/java/codeconventions-150003.pdf

  - Javadocs, @param , @returns , @throws
  - Javadoc documenting style:

https://developer.atlassian.com/server/confluence/javadoc-standards/

Peer Feedback

1) **Code conventions**

- Does the code conform to code conventions?
  - Indentation
  - Declarations
  - Statements
  - Naming conventions

- See "Java Code Conventions"
  http://www.oracle.com/technetwork/java/codeconventions-150003.pdf

Peer Feedback

1. Go to the project
2. Browse the code written
3. Select "Issues" -> "list"
4. Click "New issue"
5. Title "Code review by <username>" e.g. "Code review by rs46"
6. Description:

```
# Code simplicity

<comments here>

# Documentation

<comments here>

# Conventions

<comments here>
```

Peer Feedback

- **Be constructive**
  - Code reviews is about **improving** code
  - **Complement** good programming practise with praise
  - **Offer ideas** on how to improve **specific** code segments

- **Don't criticise**
  - Don't just say "that's bad", "why have you done it like this??"
  - Sarcasm is lost in written English
  - Don't get personal
  - Good code reviews are **overwhelmingly positive**

Software Development 3 (F27SG)

Lecture 6

Linked lists

Rob Stewart

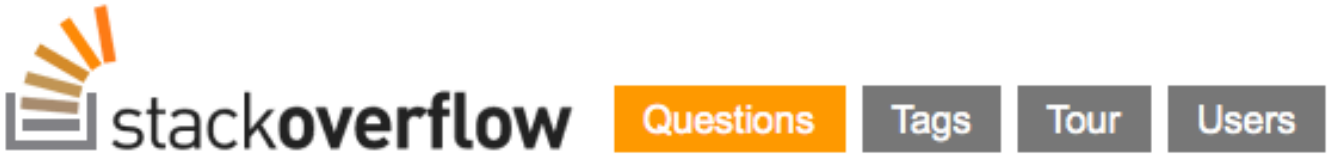
Outline

- By the end of the lecture you should
  - understand the concept of dynamic data structures
  - Understand object references in Java
  - Be familiar with linked lists

Arrays

- Last week we used arrays to implement stacks
- Many problems with arrays
- Harder to implement some ADTs efficiently
    - e.g. queues
  - Not possible to implement some at all
    - But one big issue in most languages….

Arrays



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java dynamic array sizes?

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11

I have a class xClass that I want to load in to an array of xClass so I have a declaration like

```
xClass mysclass[] = new xClass[10];
myclass[0]= new xClass();
myclass[9]= new xClass();
```

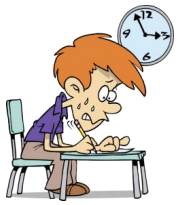
The problem is I dont know if I will need 10. I may need 8 or 12 or any other number for that matter. I won't know until runtime. Can I change the number of elements in an array on the fly? If so, how?

Many thanks for any help you may be able to provide

Paul

Problems with Arrays

- Array capacity is fixed
- **Exercise:** what is the growth rate using Big-O for this updated push operation for stacks



```
public void push(Object e){
  if(size() == capacity){
     capacity *= 2;
     Object[] tmp = new Object[capacity];
     for(int i = 0; i <= top; i++)
       tmp[i] = S[i];
       S = tmp;}
S[++top] = e;}
```

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Big-O: the Linear Function O(N)

- The linear function:
  $f(n) = n$

- For Big-O this means that

1. number of primitive operations increases at **the same rate** as the size of the input
2. Doubling the input size doubles the worst case computational time complexity

- e.g. iterating over an array:

```
for (int i = 0; i < arr.length; i++) { .. }
```

Arrays

- Arrays are fine if you know how many elements needed
- Wasteful of space

```
Object[] arr = new Object arr[10000000000000000];
```

- Many times we don't know how many elements a data structure will store
- **Solution***: Dynamic Data Structures*

Dynamic Data Structures

- Data structures that **dynamically** contract and expand as the program executes
  - Take up as much space as is necessary
    - and no more!
  - Won't run out of space
    - (unless you run out of memory)
- We will cover two types
  - Linked Lists (lectures 6-11)
  - Trees (lectures 12-15)
- You need to get one important thing….

Java object references

An aside on Java

- Almost everything in Java is an Object
  - Excluding basic data types
    - int, float, double, char, boolean……..
- Need objects to be passed around efficiently
  - In space and time

An Aside on Java

- Object o;
  - Declares a variable of type Object
  - Only allocates enough space to hold a memory address
  - o holds a **reference**
    - In this case a null reference
- o = **new** Object();
  - Allocates memory space to hold an instance of type Object
  - Returns the address of that memory location
  - and stores it in the variable o
    - Hence the assignment operator (=)
- o is not the Object, but tells us where the object lives

An Aside on Java

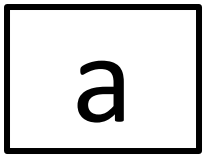
- When you pass o around
  - You are not giving the actual object
    - but a reference to it
- Object p = o;
  - p is assigned the **same object reference** as o
  - They point to the same object
    - i.e. they point to data in the **same memory location**
  - It **does not** copy the object

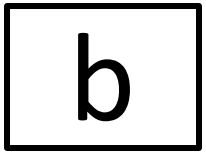
An Aside on Java

```
public class Number{
   public int value;
   public boolean isUsed;

  public static void main(String[] args){
            Number a,b;
            a = new Number();
            a.value = 12;
            b = new Number ();
            b.value = 10;

            a = b;
            b.value = 34;
            a.value = 20;
            System.out.println("The value of b is: ”+b.value);
            }
};
```





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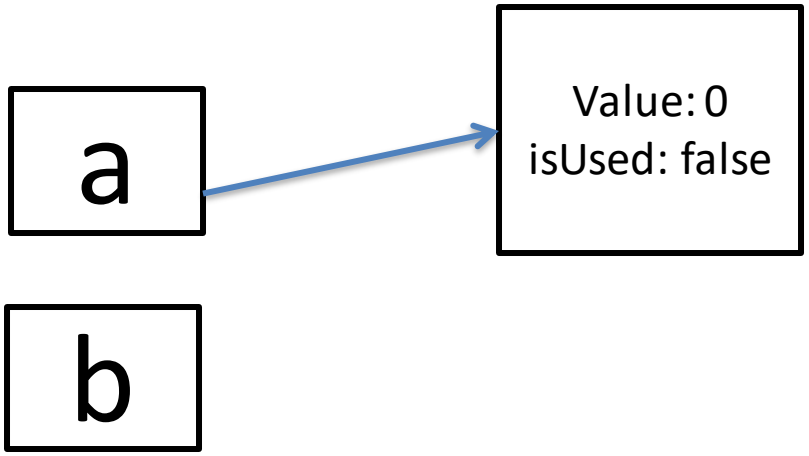

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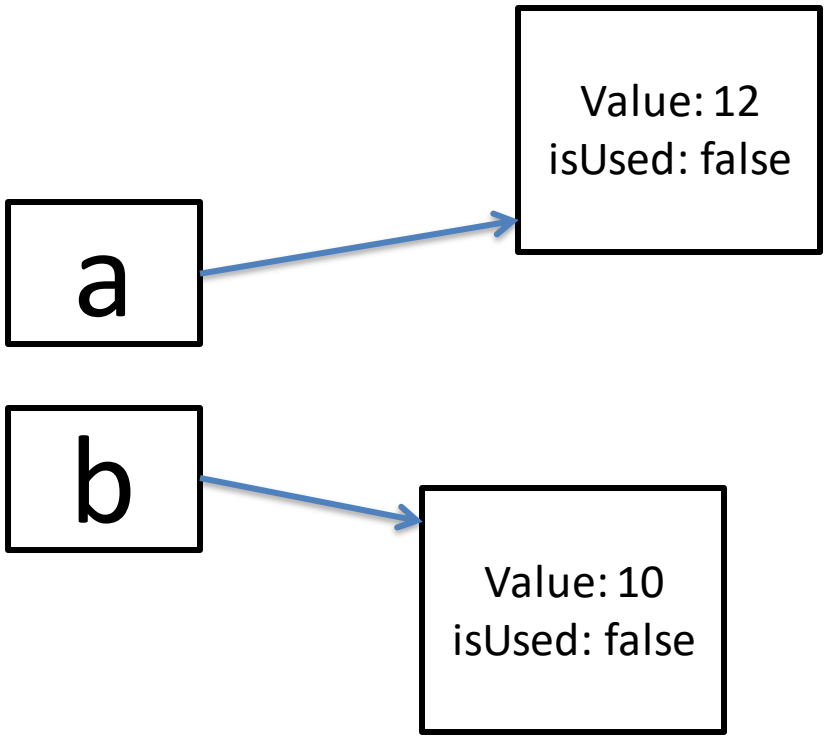

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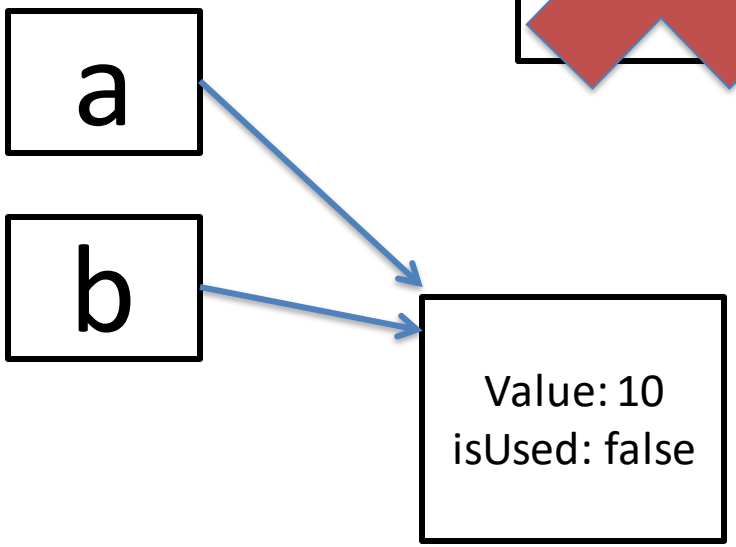

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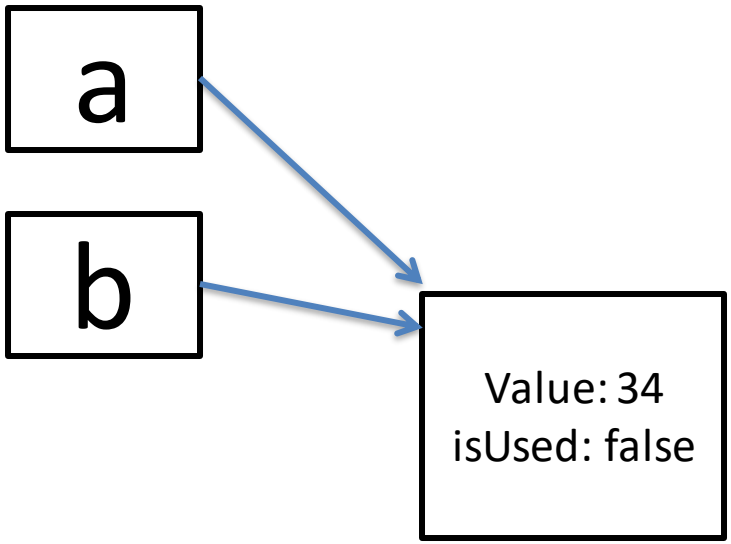

What number is printed (held in b.value)?

```
public class Number{
   public int value;
   public boolean isUsed;

  public static void main(String[] args){
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          a = new Number();
          a.value = 12;
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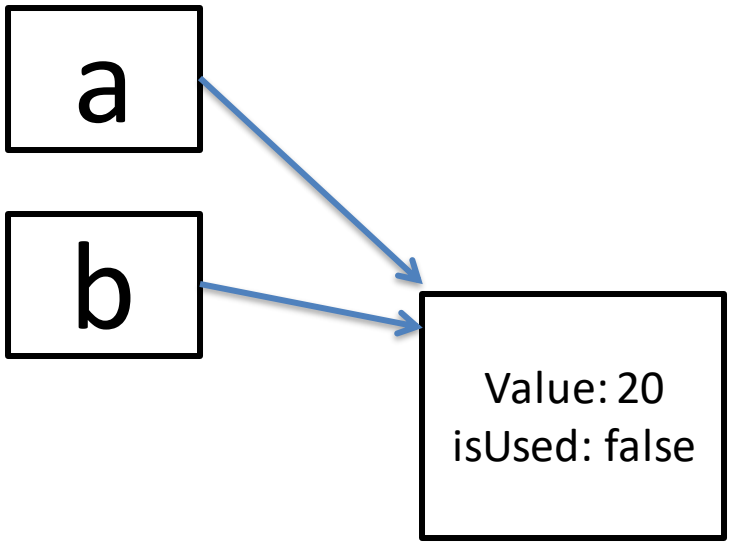
};
```



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Solution

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Why?

An Aside on Java

- Good News
  - Java does all this for you
- Bad News
  - If you don't understand it….
  - Then it will bite you at some point…
- **Referencing is the most important thing you need to know to understand Dynamic Data Structures**

Dynamic Data Structures (DDS)

- DDS can grow and shrink in size as required
- Efficient in space and in operations

```
Collection c = new Collection();
```

- **Empty** collection
  - Using static **array**: **large** space cost
  - Using dynamic **linked list**: **tiny** space cost
- **Large** collection
  - Using static **array**: **large** space cost
  - Using dynamic **linked list**: **large** space cost

Dynamic Data Structures (DDS)

- DDS are formed by exploiting object references
  - to allow an object to
  - **reference** another object
  - of the **same class**.
- This works recursively
- *Recursive algorithms are good*

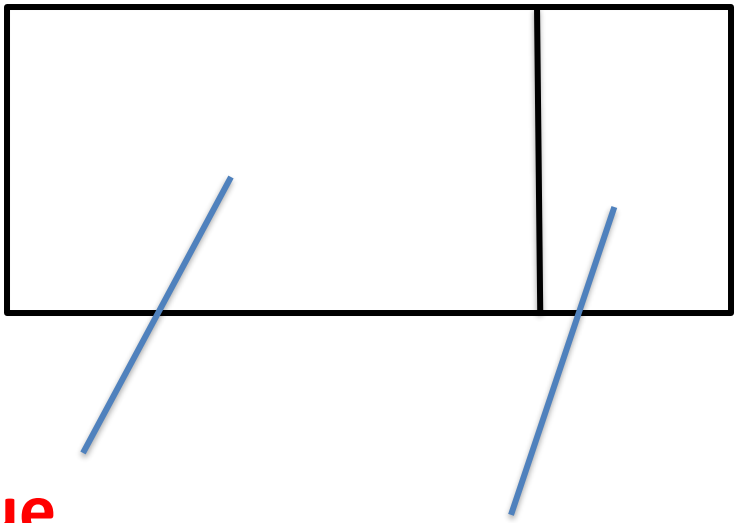
Terminology

- All DDS are formed from Nodes
  - Formed from
    - a **Value** and
    - (at least) one **reference** to the **same type of Object**
  - Values can be anything
    - int variable, String or other object
    - Usually need some sort of comparison function
  - **Reference**(s) allow us to get **to the other Nodes**
    - means we can't randomly access values like arrays
    - Nodes have no idea where they are in the Data Structure

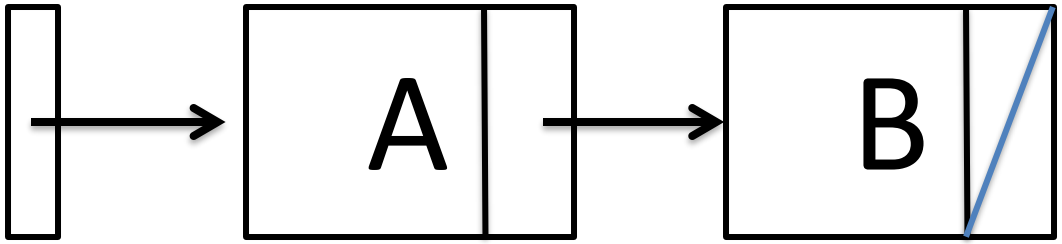
Nodes

```
public class Node{
  public Object value;
  public Node nextNode;

  public Node(Object val){
        value = val;
        nextNode = null;
  }
};
```

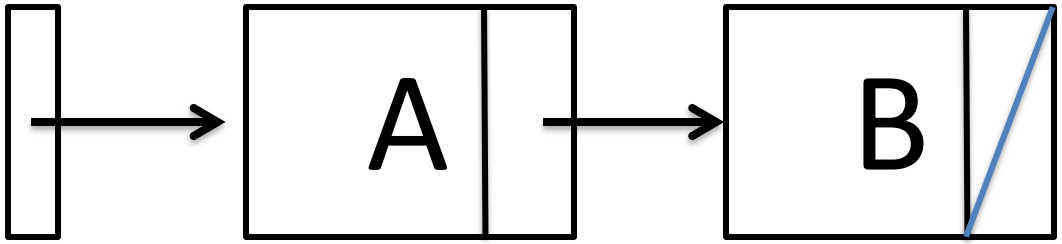


Nodes



- This is how we diagrammatically link nodes
  - There is always **1 root node**
    - this is our way in
  - Nodes are only **aware** of **other Nodes** whose **references they hold**
- We can't jump from the root node to B without going through A

Nodes



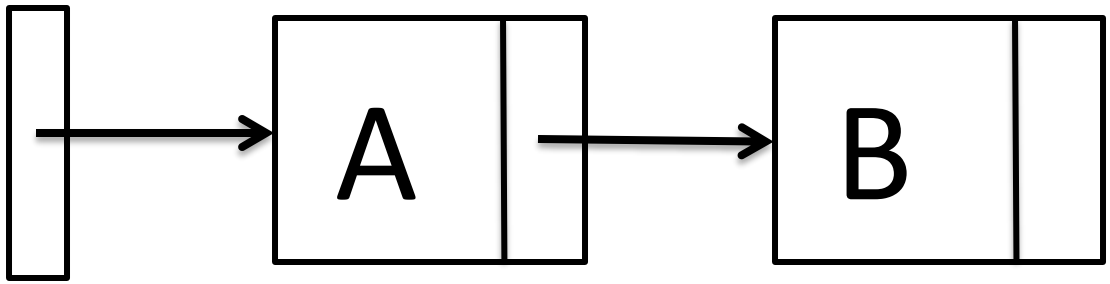
- This is how we diagrammatically link nodes
  - We can only go in the direction of the arrows
    - A holds a reference to B
    - B doesn't hold a reference to A
  - A Node without sibling has its reference set to **null**
    - We need to be explicit and careful about this in code
    - This represents the end of dynamic data structure

Dynamic Data Structures (DDS)

- Congratulations! You now know everything about Dynamic Data Structures. Honestly!
- Three common data structures
  - **Linked-Lists, Trees** and **Graphs**
  - Many variations of each
- The only difference between them is:
  1. the number of references each Node holds
  2. how Nodes can be linked to each other.
- This is called the **Topology**

Linked Lists

- Linked List is **linearly** ordered sequence of Nodes
- We can step along the sequence to access the value in each node



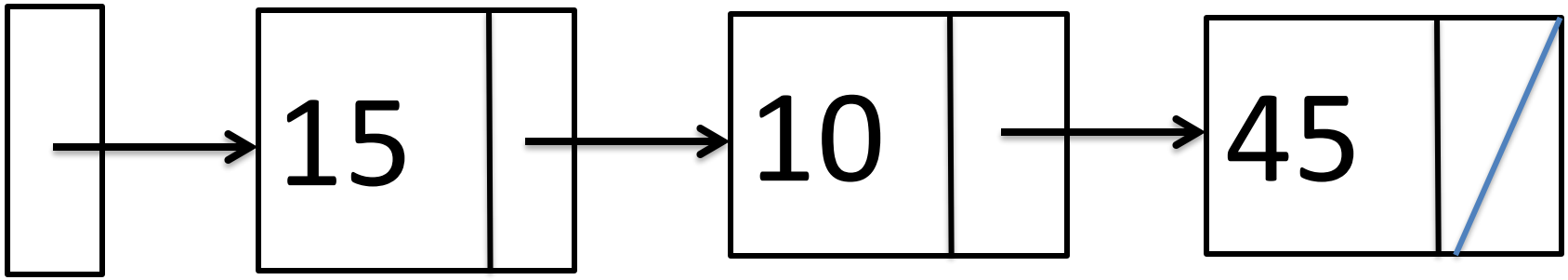
Example:
Print out the contents of a linked list

```
public class Node {
  public int value;
  public Node nextNode;

  public Node(int val){
    value = val;
    nextNode = null; //always do this
  }

  public static void main(String[] args){
            Node root; //the head nodede
```

}}



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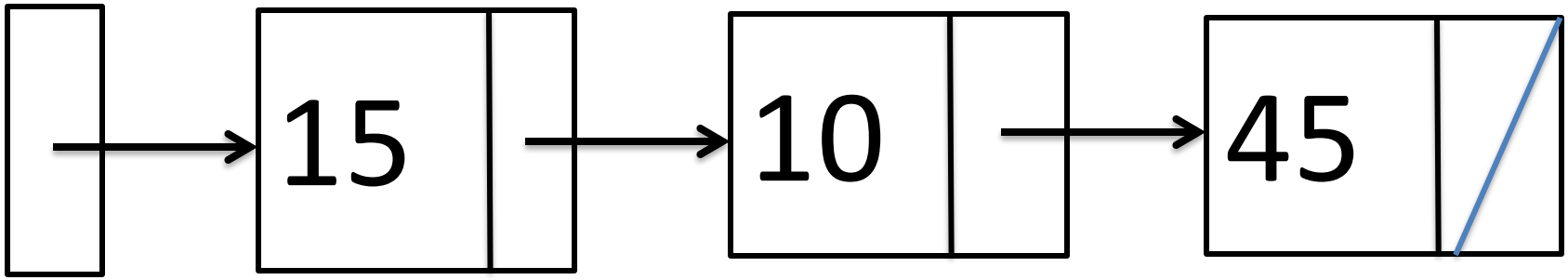
  public static void main(String[] args){
            Node root; //the head node
            Node currentNode = root;
           // work through the linked list and print off each value in turn
           while (currentNode != null){


           }
}}
```



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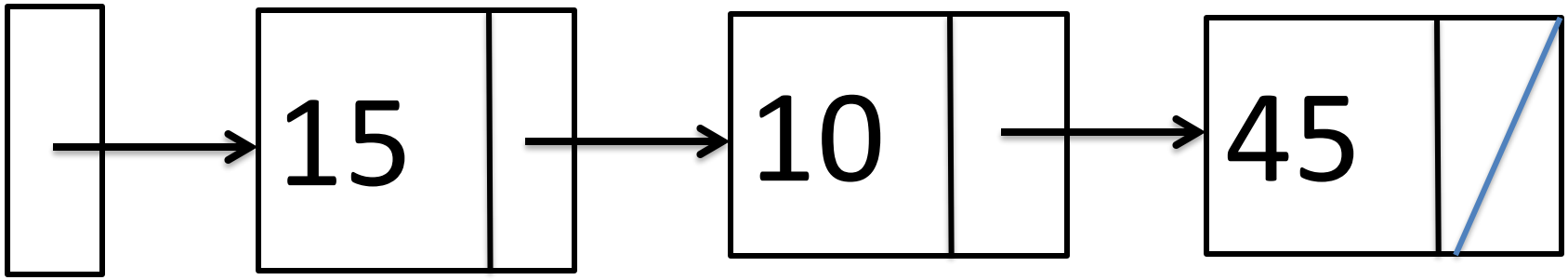
             // work through the linked list and print off each value in turn
             while (currentNode != null){
                        System.out.print(currentNode.value+" ");

             }
}}
```



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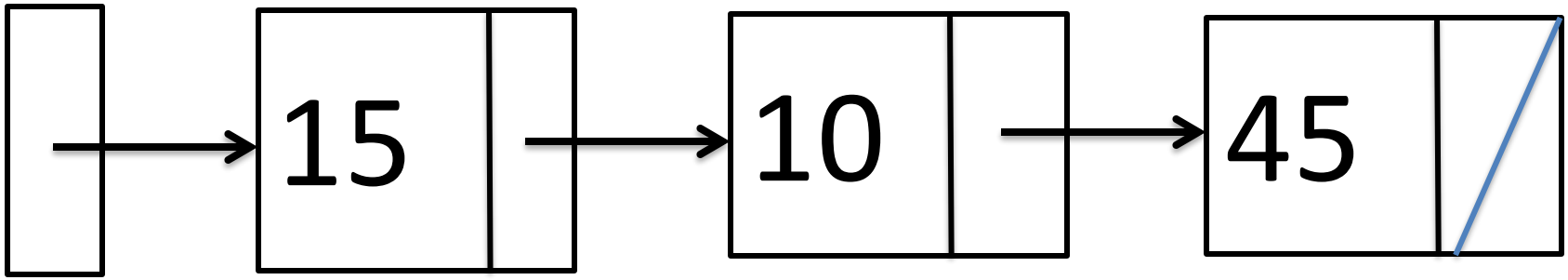

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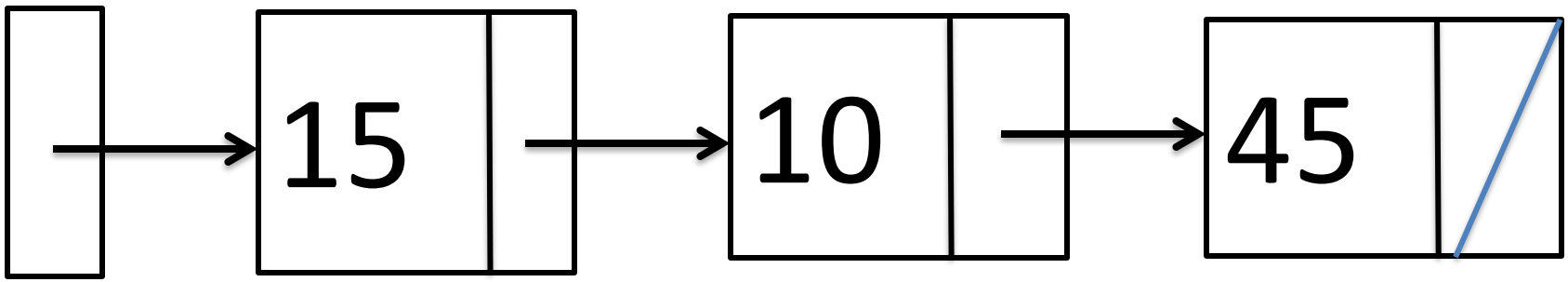
            Node currentNode = root;

            //  your code goes here

}}
```

Exercise:

Make currentNode point to last element of linked list



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public class Node {
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  public Node nextNode;

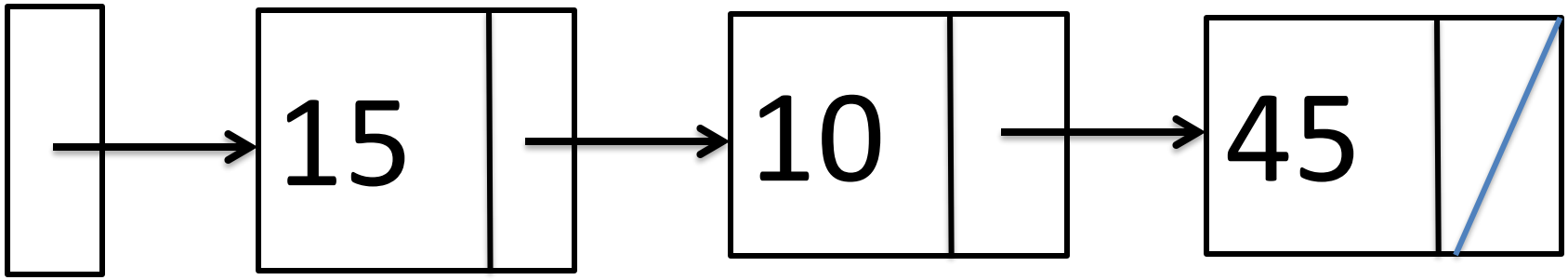
  public Node(int val){
    value = val;
    nextNode = null; //always do this
  }

  public static void main(String[] args){
            Node root; //the head node
            Node currentNode = root;

            If (currentNode != null) {
                while (currentNode.nextNode  != null){
                        // your code here
                }
            }
}}
```

SOLUTION:

Make currentNode point to last element of linked list



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                }
            }
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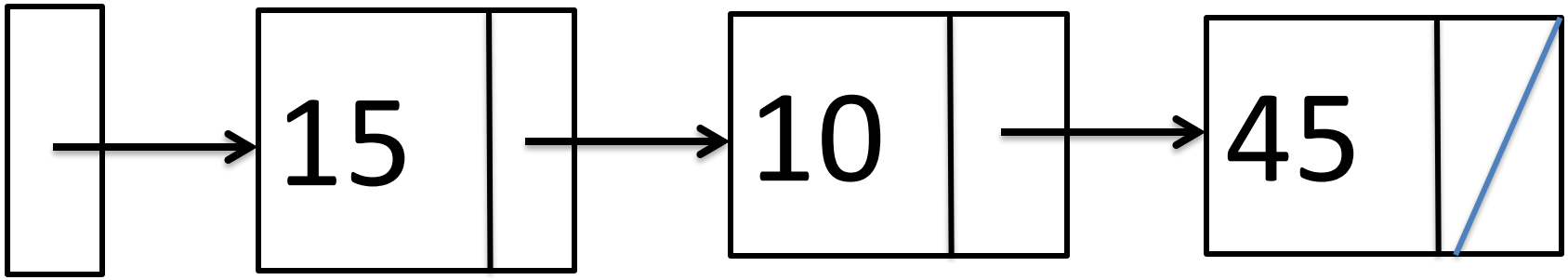
```

SOLUTION:

Make currentNode point to last element of linked list



Recursion

```
public class Node {
  public int value;
  public Node nextNode;
…
```

- All Dynamic Data Structures are **recursive**
  - Removing Nodes from a Linked List
    - just leaves a much simpler Linked List
  - Recursive Algorithms work really well here
    - fits with our logical model of the DDS.
  - E.g.

```
root.printList();
```

```
public void printList(){
        System.out.print(value + " ");
        if(nextNode != null){
            nextNode.printList();
        }
}
```

```
public class Node {
  public int value;
  public nextNode;

  public Node (int val){
    value = val;
    nextNode  = null; //always do this
  }

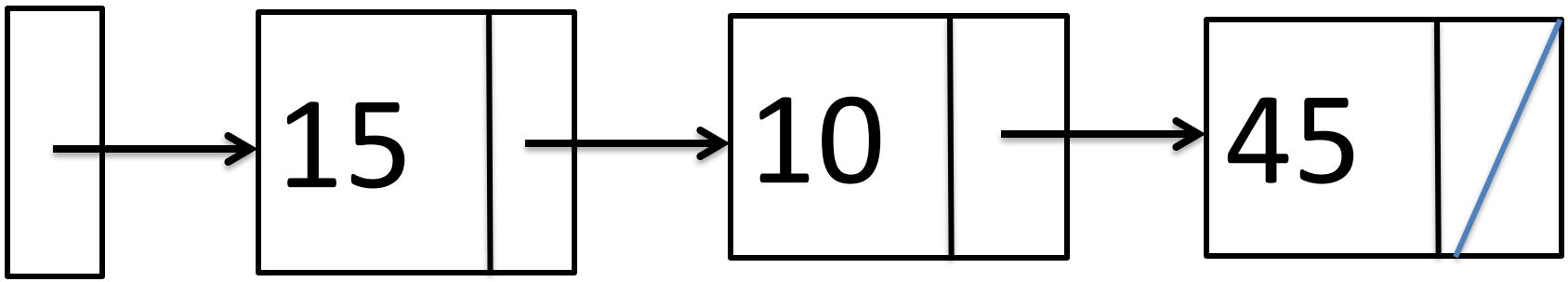
 public static int lastValue(Node  l){
     //  your code goes here
  }

  public static void main(String[]  args){
              Node root; //the head node
              Node currentNode  = root;
              int lastNumber  = last(currentNode);
              System.out.println(lastNumber);
}
```

Exercise:

Make recursive version to get the last element of linked list

Demo in Eclipse



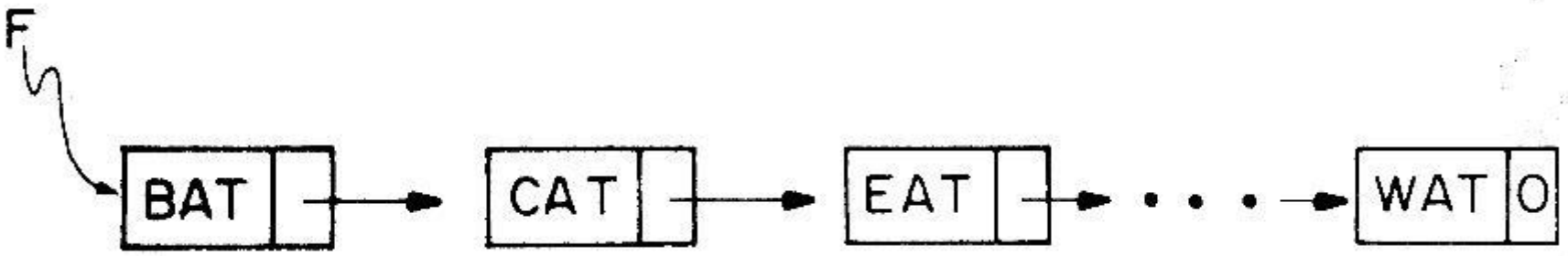
Exercise

Given the linked list: { A , B , C , E , F }

1. Insert D between elements C and E

2. Remove element E

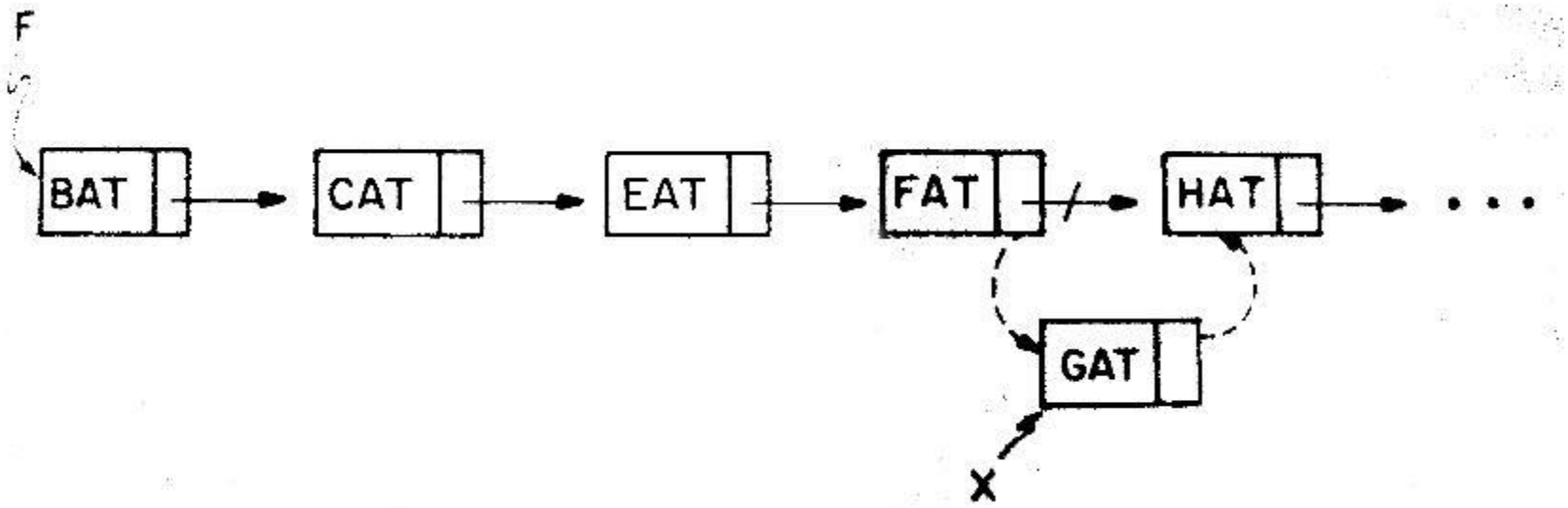
Linked List Operations



Fundamentals of Data Structures, E Horowitz & S Sohni, 2007.

Linked List Operations

Insertion:



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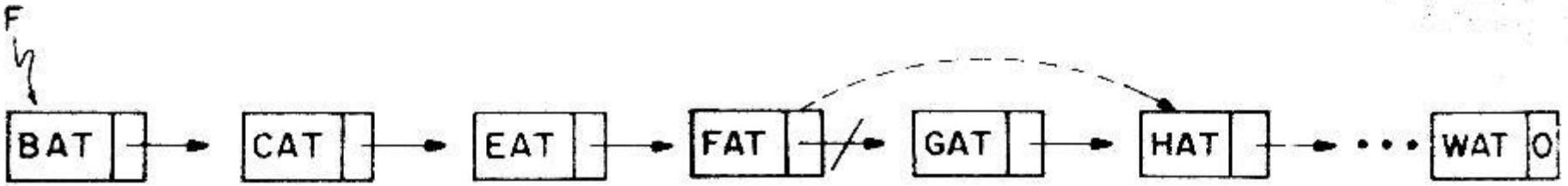
Linked List Operations

Deletion:



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Linked Lists Space Race

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Summary

- Dynamic Data Structures
  - Can grow and contract
  - Are efficient in shuffling data around
- DDS also have some limitations
  - Not randomly accessible
  - Need to step through in order
- Attendance sheet
- **Next lecture:** operations on dynamic linked lists