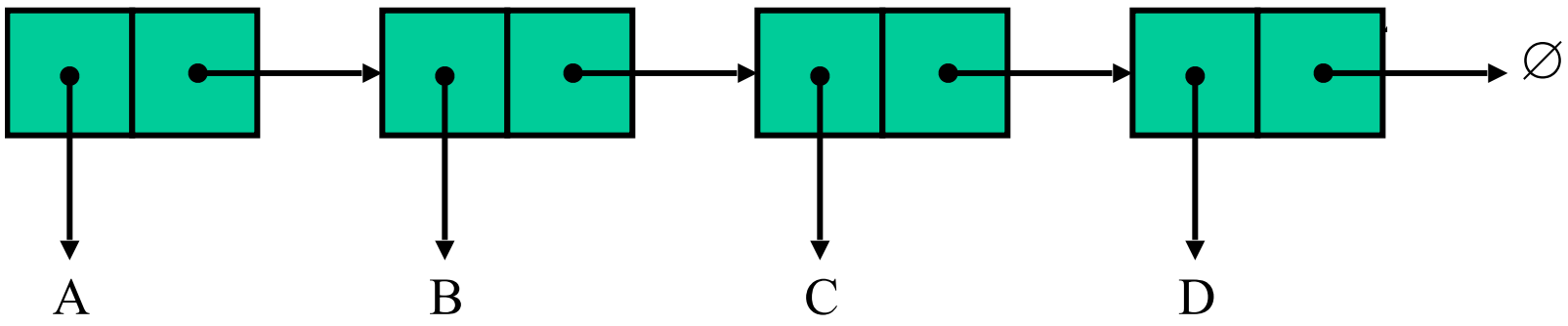
Linked Lists

Linked List

- A linked list is a lists of objects.
- The objects form a linear sequence.
- The sequence is unbounded in length.
- Each object leads to the next



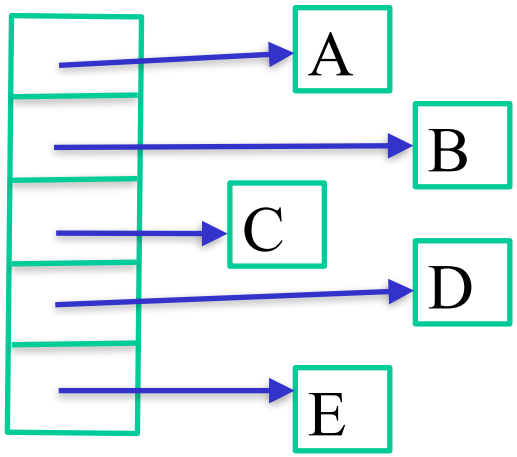
Linked List, Array and ArrayList

- An array is a single consecutive piece of memory, a linked list is made of many disjoint pieces (the linked objects).
- ArrayList is between(ish)

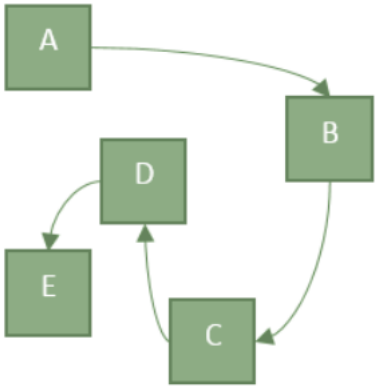
Array

Picture correct for primitive types

ArrayList



Linked List



Linked List versus Array

- Array
  - quick access to any element
  - slow insertion, deletion and reordering (shifting required in general)
- Linked list
  - quick insertion, deletion and reordering of the elements
  - slow access (must traverse list)

Linked List Core

- the essential part of a linked list is a "self-referential" structure.
- That is, a class with an instance variable that holds a "reference" to another member of that same class
- For linked lists, this structure is usually called a Node

```
private class Node<J> {
  public J data;
  public Node<J> next;
  public Node(J data, Node<J> nx) {
    this.data = data;
    this.next = nx;
  }}
```

References in Java (Review)

- A reference variable holds a memory address to where the referenced object is stored (not the object itself)
- Reference types
  - Anything that inherits from Object (including `String`, `Integer`, `Double`, etc)
    - convention — initial capital letter
  - "primitive" types: int, float, etc are NOT reference types (value variables)
- A reference is `null` when it doesn't refer/point to any object

References and equality (review)

```
public class ReferenceCheck {
    public static void main(String[] args) {
        String s1 = new String("abc");
        String s2 = new String("abc");
        String s3 = s2;
        String s4 = “abc";
        String s5 = “abc”;

        System.out.println(“s1.equals(s2) " + s1.equals(s2));
        System.out.println("s1==s2 " + (s1 == s2));
        System.out.println("s1==s3 " + (s1 == s3));
        System.out.println("s1==s4 " + (s1 == s4));
        System.out.println("s2==s3 " + (s2 == s3));
        System.out.println("s2==s3 " + (s2 == s4));
        System.out.println("s3==s4 " + (s3 == s4));
    }
}
```

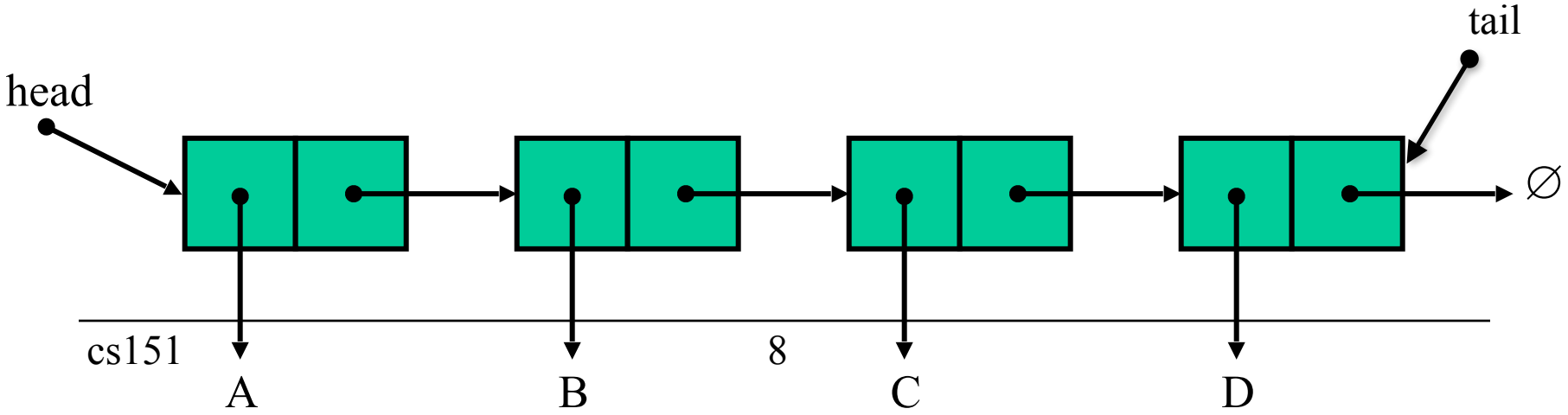
The “new” operator returns a reference to an object of the given type

equals ***should*** compare content!
default equals compares location
compareTo should compare content!

== compares memory location

Heads and Tails

- Given that one thing leads to another in a LL, need a place to start
  - referred to as "head"
- If you know where the head is, you can get to everything in LL
  - So, when working with LL there is almost always a value called head (or front, or …)
- Often it is useful to also have a value tail
  - not required, just really useful
- Q: How do you know when at end of LL?



Linked List interface

```
public interface LinkedListInterface<J>
{
    int size();
    boolean isEmpty();
    J first();
    J last();
    void addLast(J c);
    void addFirst(J c);
    J removeFirst();
    J removeLast();
    boolean remove(J r);
}
```

No mention of nodes — they are not public!!
But this still egregiously violates encapsulation (why?)!!

Starting Point

an Abstract Class

```
public abstract class AbstractLinkedList<J>
{
    protected class Node<H>
    {
        public H data;
        public Node<H> next;
        public Node(H data)
        {
           this.data = data;
           this.next = null;
        }
    }

    protected Node<J> head = null;
```

Why doesn't this class implement LinkedListInterface?

Or, why have both abstract class and interface?

isEmpty() and first()

Size — in AbstractLinkedList

```
public int size() {
    int siz=0;
    Node<J> n = head;
    while (n!=null)  {
        siz++;
        n= n.next;
    }
return siz;
}
```

- Algorithmic Complexity (Big-O)?
- Can we improve? (yes, but you have to cheat)

toString() for Linked List

again in AbstractLinkedList

```
public String toString() {
    StringBuffer sb = new StringBuffer();
    for (Node<J> node = head; node != null; node = node.next) {
        sb.append(node.data.toString());
        sb.append("\n");
    }
    return sb.toString();
}
```

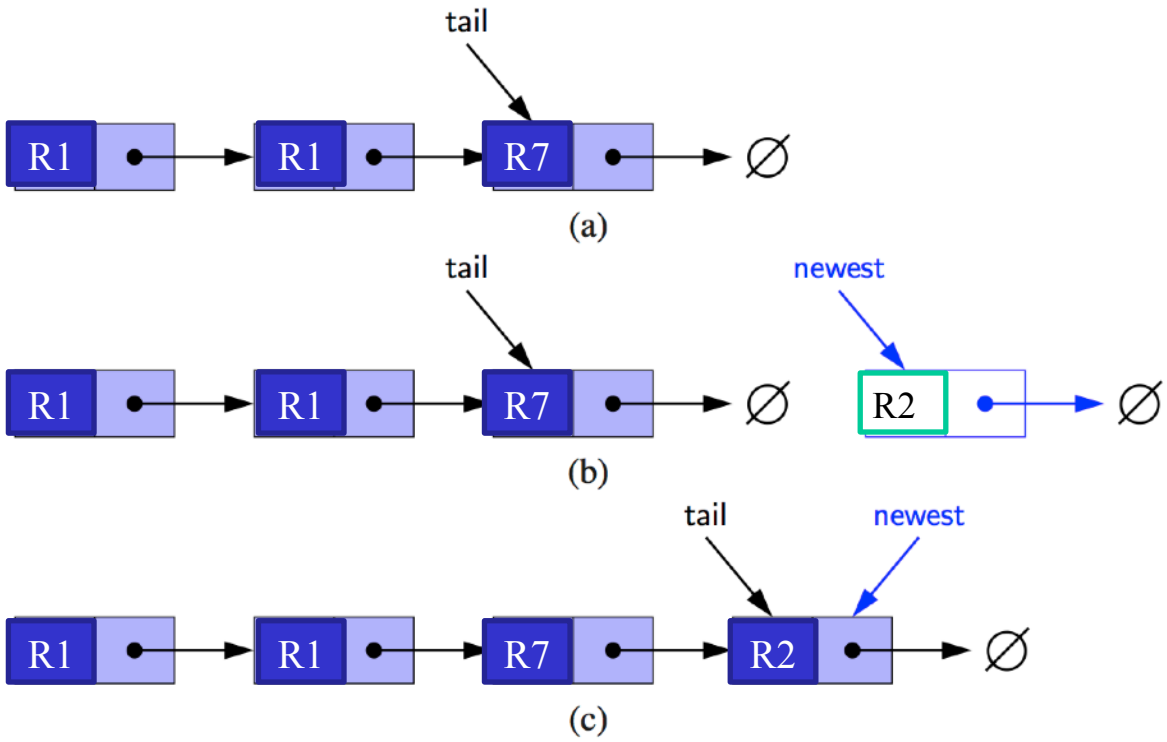
public J last()

- Write in groups

Show my last with private utility function

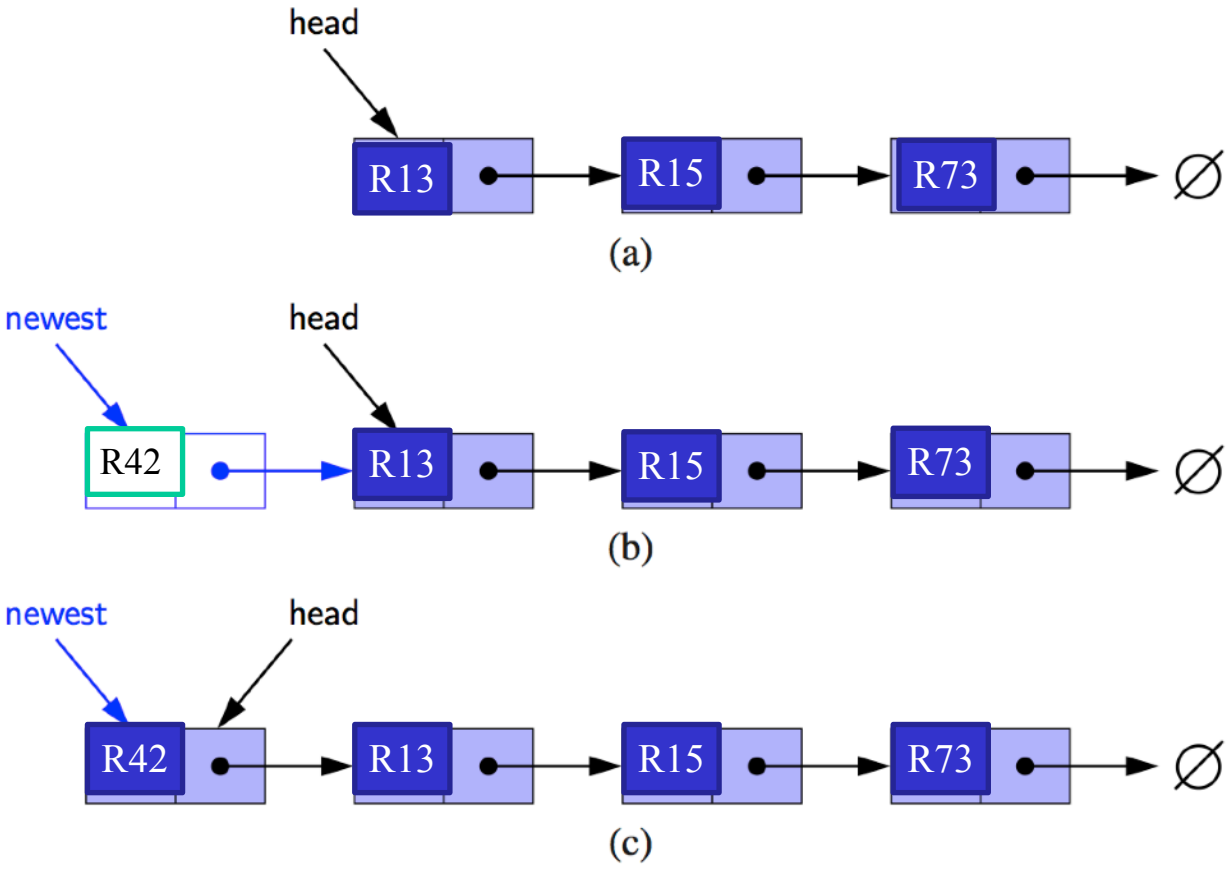
Inserting at the Tail

1. Get to the end
   1. O(n)
   2. Save time, add an instance variable "tail"
2. Create a new node
3. Have new node point to null
4. have old last node point to new node
5. update tail to point to new node



Inserting at the Head

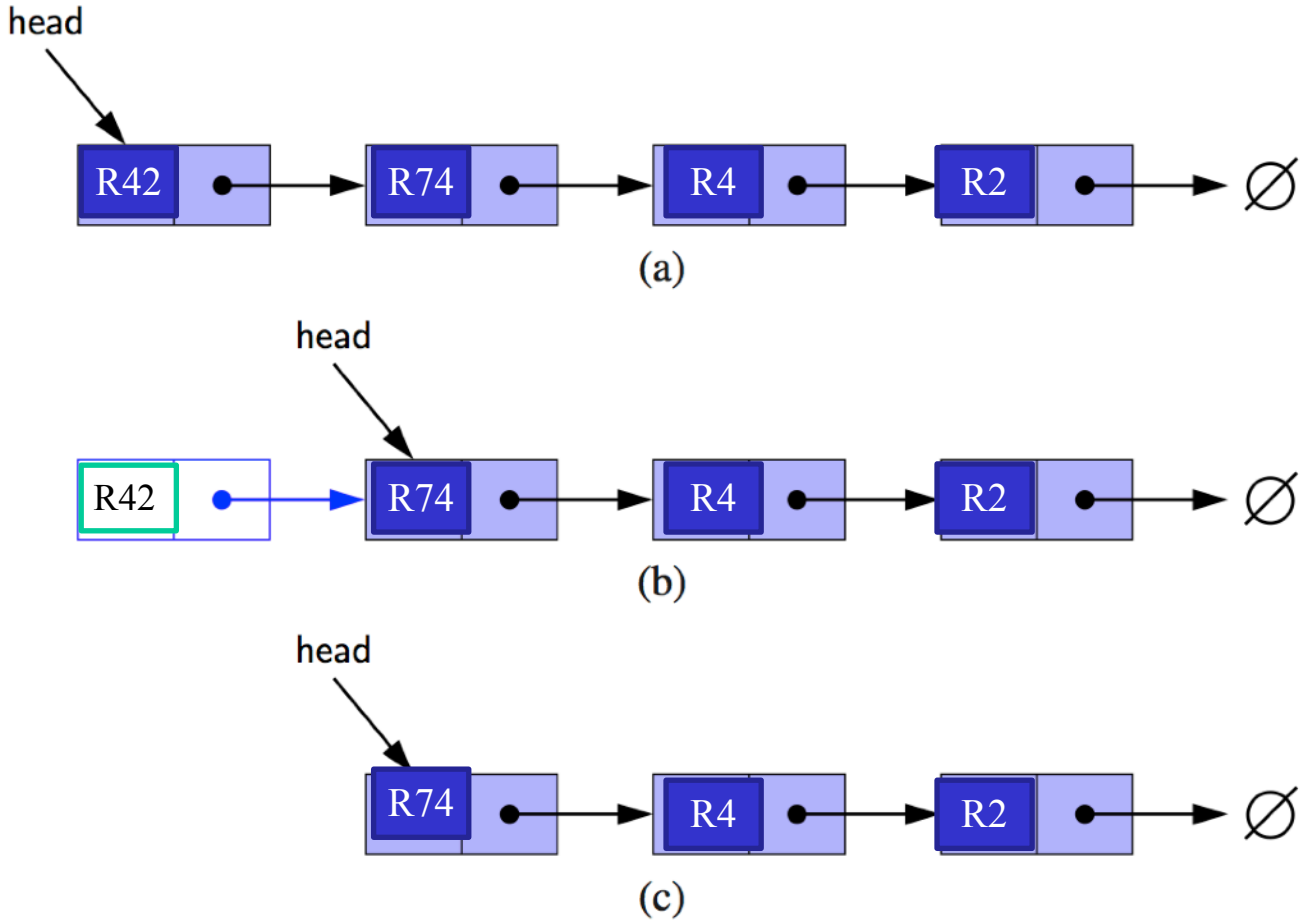
1. create a new node
2. have new node point to old head
3. update head to point to new node



write addFirst at chalkboard

Removing at the Head

1. update head to point to next node in the list
2. allow "garbage collector" to reclaim the former first node



void addLast(J c);
void addFirst(J c);

```
private Node<J> lastNode() {









}

public void addLast(J c) {
    Node<J> n = lastNode();
    Node<J> newnode = new Node<>(c);
    if (n == null) {
        head = newnode;
        return;
    }
    n.next = newnode;
}
```

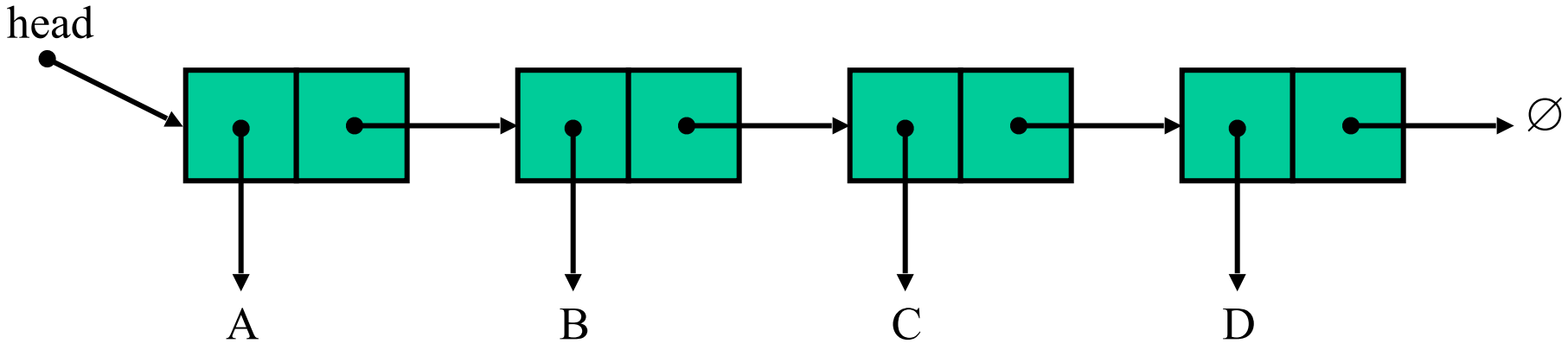
```
public void addFirst(J c) {

}
```

Deletion

```
public J removeFirst() {
    if (head == null)
        return;
    Node<J> tmp = head;
    head = head.next;
    return tmp.data;
}
```

removeLast()

- Problem
  - How do you remove the last
  - Can we use the lastNode utility function?
    - Not exactly, because to remove D we need to do things to C
    - Cannot go backwards!!
- So, need to search forward in list to find the node before the last node



Remove Last

- To find the node before last use two vars: prev and here
- each time in loop
  - prev=here
  - here=here.next

```
public J removeLast() {

}
```