- Interfaces. *(cf "The Java Programming Language" book, ch 4.)* These provide a very natural way to design a specification for code to solve a problem, think of them as being contracts for classes. Effectively, cracking a problem can be broken down into designing the solution and then implementing it; the design stage being stipulated by listing 'skeletal' classes having methods (but no definitions), and the implementation stage being split between implementing the contracts (classes) and writing code which uses them to actually solve the problem. Hence a programming team could be divided into these three groups, allowing them to work largely in parallel once the design has been set.

- Imagine building a spec sheet for a queue ... folk join at the back and are served (and leave) from the front. Being aggressive, we could insist that after joining a queue, the only way to leave is from the front. This might lead to ...

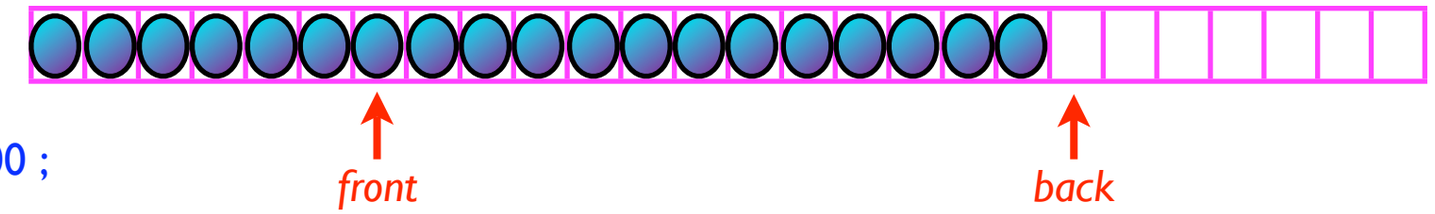
everything in an interface is presumed public

```
public interface Queue {  // note that there aren't even hints of method definitions below, save for the comments!!!
    void joinQ ( Person p ) ;  // the person p gets added to the back of the queue
    Person leaveQ ( ) ;  // to return the person at the front, and then dump them in favour of the next person in line
    int getLength ( ) ;  // to return the number of people in the queue
    boolean isFull ( ) ;  // to return true if there's no room left in the queue
    boolean isEmpty ( ) ;  // to return true if there's no-one in the queue
}  // end interface Queue
```

- Note that promising to implement an interface forces (via the compiler) an implementation of *every* method listed in that interface *(but doesn't insist on the method definitions being sensible!)* ...

```
public class Q1 implements Queue {
    void joinQ ( Person p ) { return ;}
    Person leaveQ ( ) { return new Person ( "anonymous" ) ;}
    int getLength ( ) { return Integer.MAX_VALUE ;}
    boolean isFull ( ) { return true ;}
    boolean isEmpty ( ) { return true ;}
    public Q1 ( int n ) { System.out.println ( "This queue is so efficient it takes up almost no space!!!" ) ;}  // constructor
    public Q1 ( ) {  this ( -47 ) ;  }  //  equally silly default constructor
 }  // end interface Queue
```

Sadly, the compiler will be perfectly happy with this! Perhaps rather better might be ...




```
public class Q2 implements Queue {
    private Person [ ] storage ;
    private int length , front , back , size ;
    private final int DEFAULT_SIZE = 100 ;

    void joinQ ( Person p ) { if ( ! isFull( ) ) { storage [ back++ ] = p ;    length++ ;}
                              else               System.out.println ( "Sorry, full up" ) ;   } // end joinQ method
    Person leaveQ ( ) { Person temp ;
                        if ( ! isEmpty( ) ) { temp = storage [ front++ ] ;    length-- ;    return temp ;}
                        else                System.out.println ( "Sorry, queue is empty" ) ;   } // end leaveQ method
    int getLength ( ) { return this.length ;}
    boolean isFull ( ) { return ( this.back == size ) ;}
    boolean isEmpty ( ) { return ( length == 0 ) ;}

    public Q2 ( int n ) { size = n ;   storage = new Person [ n ] ;   length = 0 ;   front = 0 ;   back = 0 ;}  // hopefully n > 0 !
    public Q2 ( ) {  this ( DEFAULT_SIZE ) ;  }  // or some such default value
}  // end class Q2
```

- Interfaces make no presumption about implementations - indeed, there can be multiple strikingly different implementations of any given interface. As further examples *(cf the Weiss textbook, ch 3)* ...

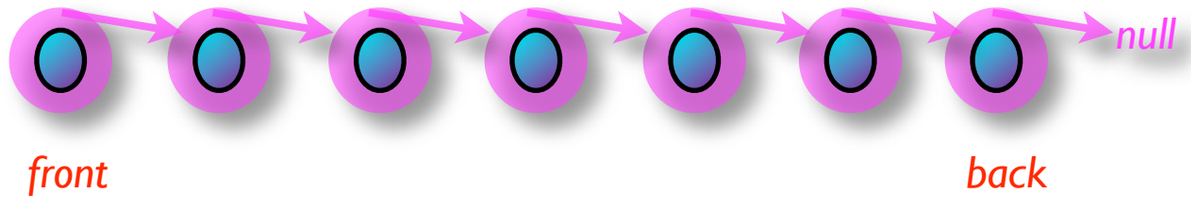
```
public class Q3 implements Queue {
    private Person [ ] storage ;
    private int length , front , back , size ;
    private final int DEFAULT_SIZE = 100 ;

    void joinQ ( Person p ) { if ( ! isFull( ) ) { storage [ ( back++ ) % size] = p ;    length++ ;}
                              else               System.out.println ( "Sorry, full up" ) ;   } // end joinQ method
    Person leaveQ ( ) { if ( ! isEmpty( ) ) { Person temp = storage [ ( front++ ) % size ] ;    length-- ;    return temp ;}
                        else                  System.out.println ( "Sorry, queue is empty" ) ;   } // end leaveQ method
    int getLength ( ) { return this.length ;}
    boolean isFull ( ) { return ( this.length == size ) ;}
    boolean isEmpty ( ) { return ( length == 0 ) ;}

    public Q3 ( int n ) { size = n ;  storage = new Person [ size ] ;  length = 0 ;  front = 0 ;  back = 0 ;}  // hopefully n > 0 !
    public Q3 ( ) {  this ( DEFAULT_SIZE ) ;  }
} // end class Q3
```

The difference between the Q2 and Q3 implementations is that for Q2 we stored the data in a linear array (wasting space as it emptied, and losing queue re-usability), whereas for Q3 the storage was in a 'quasi-circular' array (allowing continual use). It's worth noting that Q2 might be well-suited in a situation having limited resource (eg queueing for food or for concert tickets) whereas Q3 would be a better match for a renewable resource (eg printing or processor access, or customer service).

- Thinking more structurally about a queue, we could build a more elegant flavour ...

```
public class Q4 implements Queue {
   private Node front , back ;     private int length ;

   public void joinQ ( Person p ) {
      if ( isEmpty ( ) )  { back = new Node ( p ) ;   front = back ; }
      else { back.setNext ( new Node ( p ) ) ; back=back.getNext( ) ; }
      length++ ;
   } // end joinQ method
   public Person leaveQ ( ) {
      if ( ! isEmpty( ) ) { Person temp = front.getData ( ) ;
                            front = front.getNext ( ) ;
                            length-- ;    return temp ;}
      else  { System.out.println ( "Sorry, I am empty" ) ; return null ;}
   } // end leaveQ method
   public int getLength ( ) { return this.length ;}
   public boolean isFull ( ) { return false ;}
   public boolean isEmpty ( ) { return ( length == 0 ) ;}

   public Q4 ( int n ) { length = 0 ;}  // n is irrelevant here
   public Q4 ( ) {  this ( 0 ) ; }
} // end class Q4
```

```
public class Node {
   private Person data ;  // holds the data
   private Node next ;  // points to next in line

   public Person getData ( ) { return data ;}
   public void setData ( Person p ) { data = p ;}
   public Node getNext ( ) { return next ;}
   public void setNext ( Node n ) { next = n ;}

   public Node ( Person p , Node n ) {
         data = p ;  next = n ;}
   public Node ( Person p ) { this ( p , null ) ;}
   public Node ( ) ( this ( null ) ;}
}  // end class Node
```

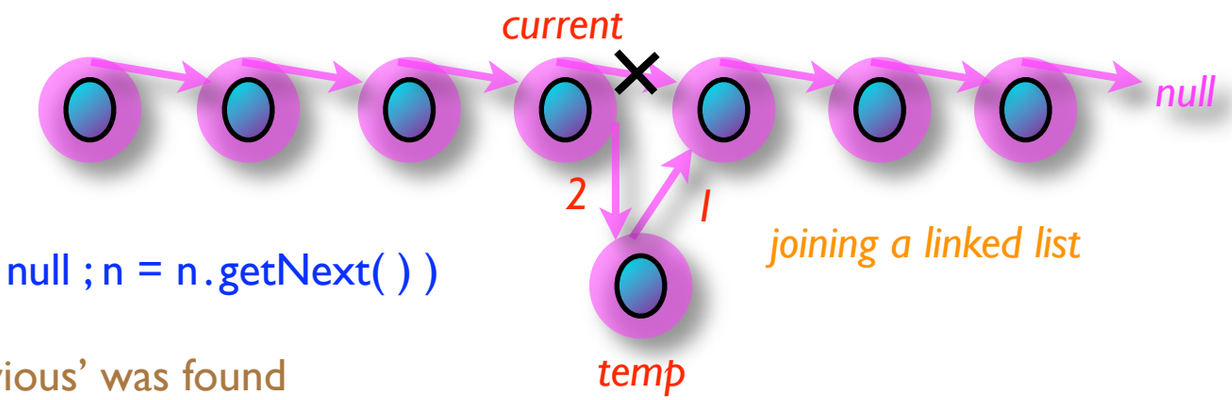


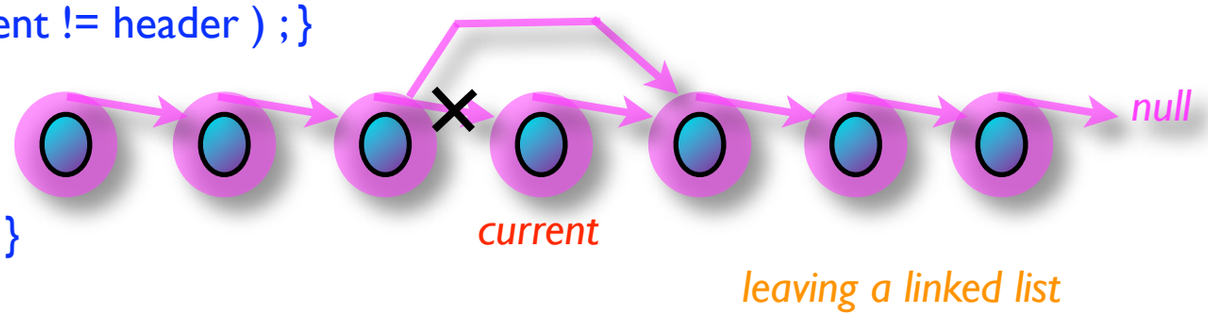
The nifty thing about this approach is that the queue never gets full (until the computer does!), and is always being sized dynamically according to need (so no wasted space). Of course, nothing is ever ideal; so in this case there is some computational overhead in creating each node, so in a situation where the queue size will remain roughly the same it might be better to use an array flavour, but where the size changes frequently and significantly, this pointer-based approach is better. Effectively, each time we add a Person, a Node is created to house them, and it's that Node which is tacked onto the end of the queue. Each time a Person leaves, the pointer (front) advances, so that then nothing is referring to the previous front of the queue, so that it can be garbage-collected, thus allowing reclamation of space.

- A very similar structure, but which allows joining and leaving from anywhere within, is called a 'linked list'. This could be implemented with arrays, but we'll focus on a similar pointer-based approach, using our existing Node class, and thinking of leaving being the deletion of a Person from the 'current' location, and joining as interposing a person right after the current spot ...

```
public class L1 implements List {
    private Node header , current ;    private int length ;
    public void join ( Person p ) throws BadInsertionPoint {
        if ( current == null ) throw new BadInsertionPoint ( ) ;
        Node temp = new Node ( p , current.getNext( ) ) ;
        current.setNext ( temp ) ;    length++ ;
    } // end join method
    public void leave ( ) {
        if ( ! isEmpty( ) && inList ( ) ) {
            getPrevious ( ).setNext ( current.getNext ( ) ) ;
            length-- ; }
        else      System.out.println ("Sorry, list is empty" ) ;
    } // end leave method
    private Node getPrevious ( ) {
        for ( Node n = header ; n != null && n.getNext ( ) != null ; n = n.getNext( ) )
            if ( n.getNext ( ) == current )  return n ;
        return null ; }  // this return is only reached if no 'previous' was found
    public void setCurrent ( Person p ) {
        for ( current = header ;  current != null ; current = current.getNext( ) )
            if ( current.getData ( ).equals ( p ) ) return ; }
    public boolean inList ( ) { return ( current != null && current != header ) ;}
    public int getLength ( ) { return this.length ;}
    public boolean isFull ( ) { return false ;}
    public boolean isEmpty ( ) { return ( length == 0 ) ;}
    public L1 ( int n ) { header = new Node ( ) ;    length = 0 ;}
    public L1 ( ) {  this ( 0 ) ; }
} // end class L1
```

```
public interface List {
    void join ( Person p ) ;  // p inserted after 'current location'
    void leave ( ) ;  // the current locn's content is deleted
    int getLength ( ) ;  // the number of people in the list
    boolean isFull ( ) ;
    boolean isEmpty ( ) ;
    void setCurrent ( Person p ) ;  // set 'cur loc' to where p is
}  // end interface List
```





- Actually this is a poor approach; having just one 'current location' will make it hard to sort a list (we'd need at least two 'currents' for that), and there's some serious awkwardness in the way we manipulated current. Far better would be to divvy up the work between the list and the arrows pointing into the list (iterators) according to where things rightly belong, but we'll delay doing this until we've introduced the other two main data structures.

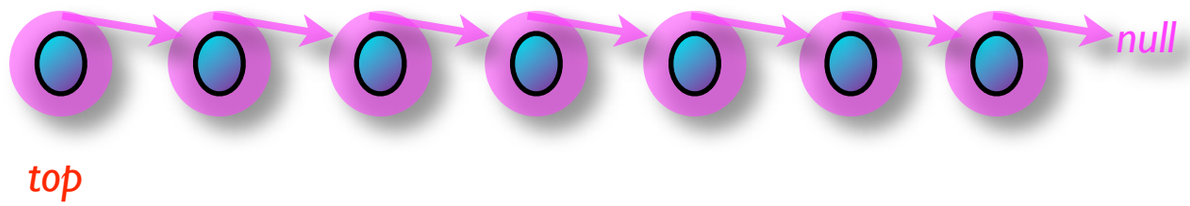
- A stack is another kind of emaciated list, this time only allowing entering and leaving from one end (the 'top') ...

```
public class S1 implements Stack {
    private Node top ;
    private int length ;
    public void join ( Person p ) {
        top = new Node ( p , isEmpty ( ) ? null ; top.getNext ( ) ; ) ;
        length++ ;
    } // end join method
    public Person leave ( ) {
        if ( ! isEmpty( ) ) { Person temp = top.getData ( ) ;
                              top = top.getNext( ) ;   length-- ;   return temp ;}
        else     System.out.println ("Sorry, stack is empty" ) ;
    } // end leave method
    public int getLength ( ) { return this.length ;}
    public boolean isFull ( ) { return false ;}
    public boolean isEmpty ( ) { return ( length == 0 ) ;}

    public S1 ( int n ) { length = 0 ;}  // n is irrelevant here
    public S1 ( ) {  this ( 0 ) ; }
}  // end class S1
```

typically called push

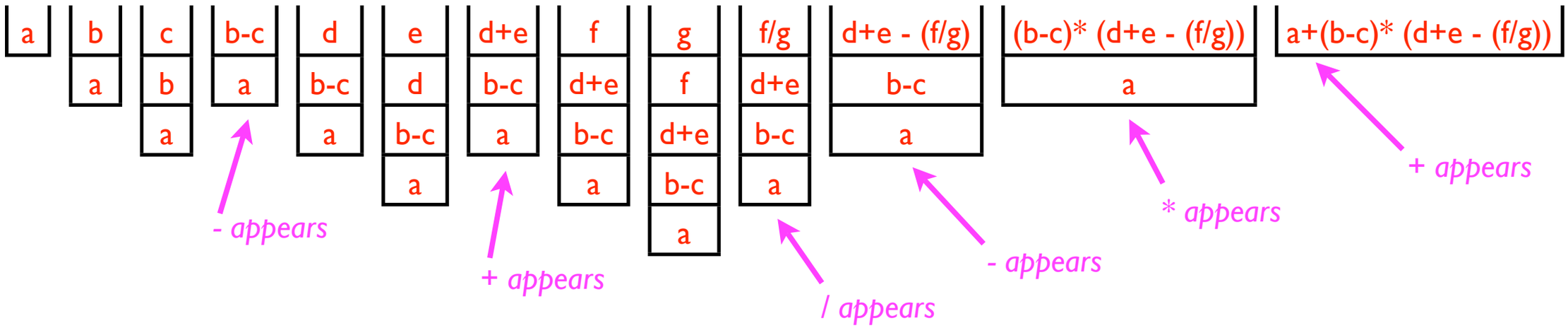
typically called pop

```
public interface Stack {
    void join ( Person p ) ;  // p inserted at the top
    Person leave ( ) ;  // the top is deleted
    int getLength ( ) ;  // # of people in the stack
    boolean isFull ( ) ;
    boolean isEmpty ( ) ;
}  // end interface Stack
```

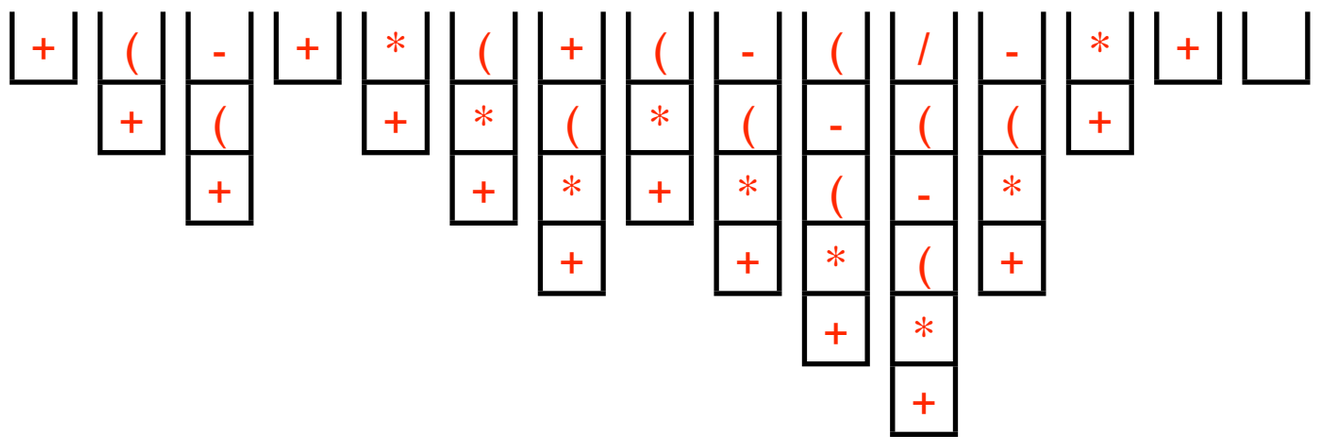


- Stacks are surprisingly powerful animals - much of what goes on in your computer is done via stacks (of commands, of values, etc.). However, as quick examples ...

  (i) Two ways of writing an arithmetic expression are *infix*, as in a + (b-c)*(d+e-(f/g)) and *postfix* (or *reverse Polish*), as in a b c - d e + f g / - * + . To evaluate the latter, we can put the values on a stack, and on seeing an operator, apply it by pulling the top off the stack (twice) and then putting the newly computed value on the stack ...



  (ii) As you might guess from the above, we can also use a stack to convert an infix to a postfix expression, essentially using the stack as a 'storage-until-ready' holding location ...



This will produce the postfix version above from the infix flavour term-by-term under the algorithm:
(i) output non-operands immediately
(ii) rank operands by strength, so + and - are at the bottom, * and / are next, and "(" is the highest
(iii) on reading an operand, pop from the stack (into the output) until seeing a weaker one, then push that operand
(iv) on reading a ")", pop everything from the stack until the "(", which is discarded (popped but not output)
(v) if there's no more input, then pop from the stack until empty (cf 3.6 of the textbook)

- Trees are essentially lists on steroids, with nodes having multiple ‘nexts’, a binary tree having two ‘nexts’ (a left and a right) from each node.