CS61B Lecture #19

Administrative:

- Review session today 4–6PM in 2 LeConte.
- HKN CS61B review session Saturday 1–3PM in the Woz.
- Need alternative test time? Make sure you send me mail today.

Today:

- Maps
- Generic Implementation
- Array vs. linked: tradeoffs
- Sentinels
- Specialized sequences: stacks, queues, deques
- Circular buffering
- Recursion and stacks
- Adapters

Readings: *Data Structures*, Chapter 3, 4 (for today), and 5 (next).

Simple Banking I: Accounts

Problem: Want a simple banking system. Can look up accounts by name or number, deposit or withdraw, print.

Account Structure

```
class Account {
  Account (String name, String number, int init) {
     this.name = name; this.number = number;
     this.balance = init;
  }
  /** Account-holder's name */
  final String name;
  /** Account number */
  final String number;
  /** Current balance */
  int balance;

  /** Print THIS on STR in some useful format. */
  void print (PrintWriter str) { ... }
}
```

Simple Banking II: Banks

```
class Bank {
  /* These variables maintain mappings of String -> Account.  They keep
   * the set of keys (Strings) in "compareTo" order, and the set of
   * values (Accounts) is ordered according to the corresponding keys. */
  SortedMap<String,Account> accounts = new TreeMap<String,Account> ();
  SortedMap<String,Account> names = new TreeMap<String,Account> ();

  void openAccount (String name, int initBalance) {
     Account acc =
       new Account (name, chooseNumber (), initBalance);
     accounts.put (acc.number, acc);
     names.put (name, acc);
  }

  void deposit (String number, int amount) {
    Account acc = accounts.get (number);
    if (acc == null) ERROR(...);
    acc.balance += amount;
  }
  // Likewise for withdraw.
```

Banks (continued): Iterating

Printing out Account Data

```
/** Print out all accounts sorted by number on STR. */
void printByAccount (PrintStream str) {
   // accounts.values () is the set of mapped-to values.  Its
   // iterator produces elements in order of the corresponding keys.
   for (Account account : accounts.values ())
     account.print (str);
}

/** Print out all bank acconts sorted by name on STR. */
void printByName (PrintStream str) {
   for (Account account : names.values ())
     account.print (str);
}
```

A Design Question: What would be an appropriate representation for keeping a record of all transactions (deposits and withdrawals) against each account?

Partial Implementations

- Besides interfaces (like `List`) and concrete types (like `LinkedList`), Java library provides abstract classes such as `AbstractList`.
- Idea is to take advantage of the fact that operations are related to each other.
- Example: once you know how to do `get(k)` and `size()` for an implementation of `List`, you can implement all the other methods needed for a *read-only* list (and its iterators).
- Now throw in `add(k,x)` and you have all you need for the additional operations of a growable list.
- Add `set(k,x)` and `remove(k)` and you can implement everything else.

Example: The java.util.AbstractList helper class

```
public abstract class AbstractList<Item> implements List<Item> {
   /** Inherited from List */
   // public abstract int size ();
   // public abstract Item get (int k);
   public boolean contains (Object x) {
      for (int i = 0; i < size (); i += 1) {
        if ((x == null && get (i) == null) ||
            (x != null && x.equals (get (i))))
          return true;
      }
      return false;
   }
   /* OPTIONAL: By default, throw exception; override to do more. */
   void add (int k, Item x) {
     throw new UnsupportedOperationException ();
   }
```

Likewise for remove, set

Example, continued: AListIterator

```
// Continuing abstract class AbstractList<Item>:
   public Iterator<Item> iterator () { return listIterator (); }
   public ListIterator<Item> listIterator () { return new AListIterator (this); }

   private static class AListIterator implements ListIterator<Item> {
     AbstractList<Item> myList;
     AListIterator (AbstractList<Item> L) { myList = L; }
     /** Current position in our list. */
     int where = 0;

     public boolean hasNext () { return where < myList.size (); }
     public Item next () {  where += 1; return myList.get (where-1); }
     public void add (Item x) { myList.add (where, x); where += 1; }
     ... previous, remove, set, etc.
   }
   ...
}
```

Example: Using AbstractList

Problem: Want to create a *reversed view* of an existing `List` (same elements in reverse order).

```
public class ReverseList<Item> extends AbstractList<Item> {
  private final List<Item> L;

  public ReverseList (List<Item> L) { this.L = L; }

  public int size () { return L.size (); }

  public Item get (int k) { return L.get (L.size ()-k-1); }

  public void add (int k, Item x)
    { L.add (L.size ()-k, x); }

  public Item set (int k, Item x)
    { return L.set (L.size ()-k-1, x); }

  public Item remove (int k)
    { return L.remove (L.size () - k - 1); }
}
```

Aside: Another way to do AListIterator

It's also possible to make the nested class non-static:

```
  public Iterator<Item> iterator () { return listIterator (); }
  public ListIterator<Item> listIterator () { return this.new AListIterator (); }

  private class AListIterator implements ListIterator<Item> {
    /** Current position in our list. */
    int where = 0;

    public boolean hasNext () { return where < AbstractList.this.size (); }
    public Item next () {  where += 1; return AbstractList.this.get (where-1); }
    public void add (Item x) { AbstractList.this.add (where, x); where += 1; }
    ... previous, remove, set, etc.
  }
  ...
}
```

- Here, `AbstractList.this` means "the `AbstractList` I am attached to" and X`.new AListIterator` means "create a new `AListIterator` that is attached to X."
- In this case you can abbreviate `this.new` as `new` and can leave off the `AbstractList.this` parts, since meaning is unambiguous.

Getting a View: Sublists

Problem: `L.sublist(start, end)` is a full-blown `List` that *gives* a view of part of an existing list. Changes in one must affect the other. How? Here's part of `AbstractList`:

```
List sublist (int start, int end) {
  return new this.Sublist (start, end);
}

private class Sublist extends AbstractList<Item> {
  // NOTE: Error checks not shown
  private int start, end;
  Sublist (int start, int end) { obvious }

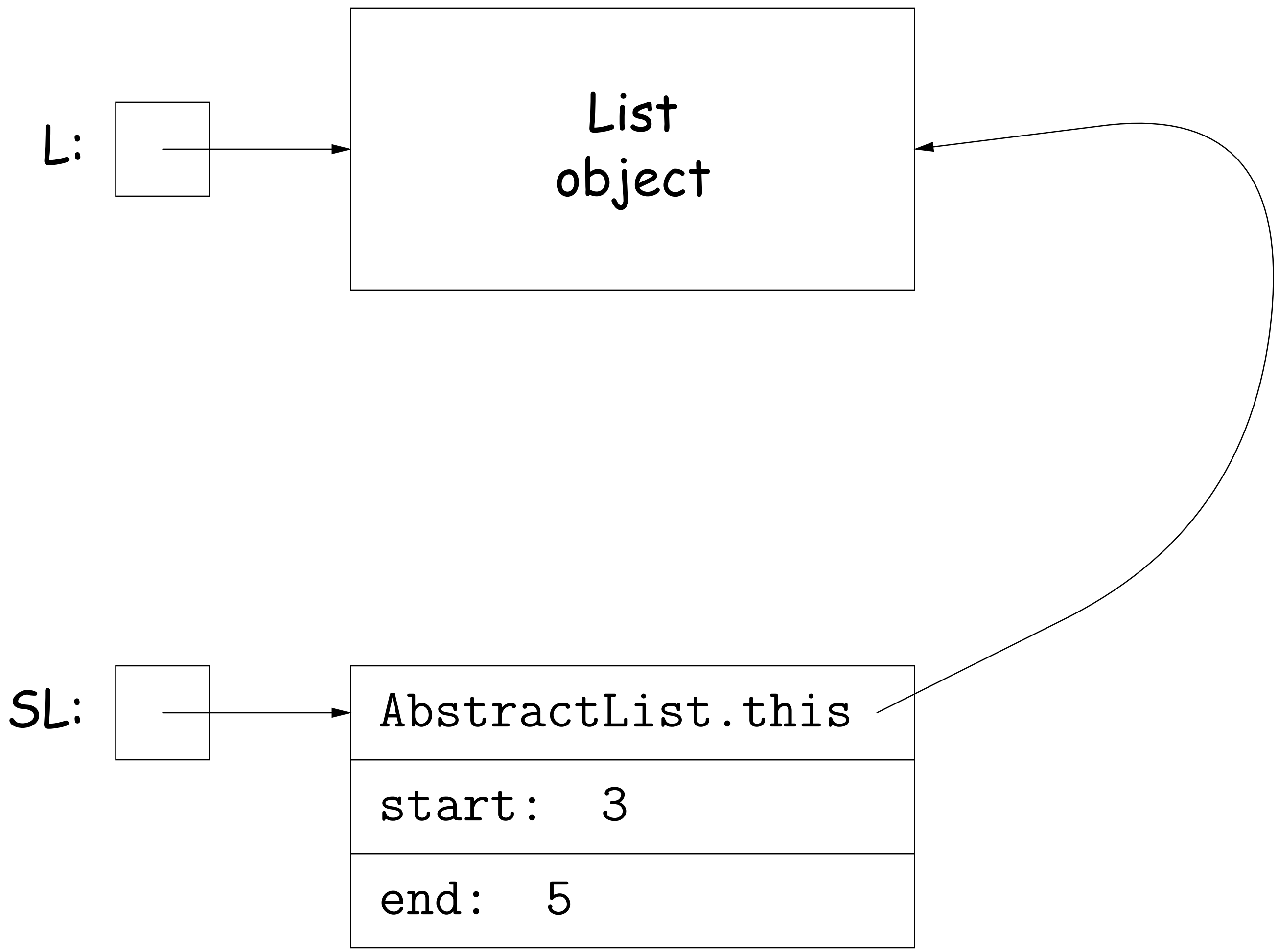
  public int size () { return end-start; }

  public Item get (int k)
    { return AbstractList.this.get (start+k); }

  public void add (int k, Item x) {
    { AbstractList.this.add (start+k, x); end += 1; }
  ...
}
```

What Does a Sublist Look Like?

- Consider `SL = L.sublist (3, 5);`



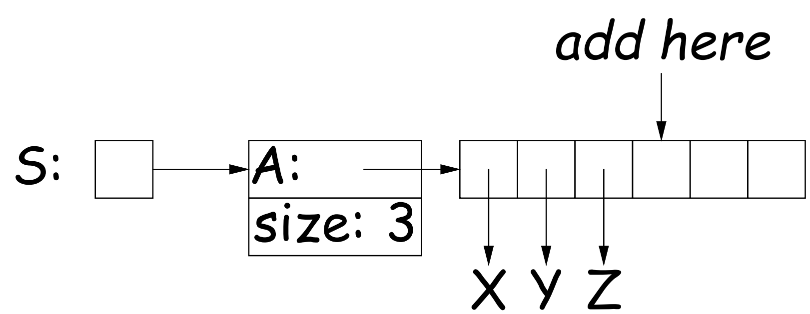
Arrays and Links

- Two main ways to represent a sequence: array and linked list
- In Java Library: `ArrayList` and `Vector` vs. `LinkedList`.
- Array:
  - Advantages: compact, fast ($\Theta(1)$) *random access* (indexing).
  - Disadvantages: insertion, deletion can be slow ($\Theta(N)$)
- Linked list:
  - Advantages: insertion, deletion fast once position found.
  - Disadvantages: space (link overhead), random access slow.

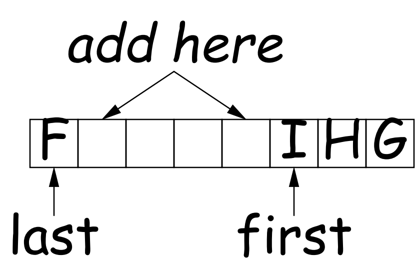
Implementing with Arrays

- Biggest problem using arrays is insertion/deletion in the *middle* of a list (must shove things over).
- Adding/deleting from ends can be made fast:
  - Double array size to grow; amortized cost constant (Lecture #15).
  - Growth at one end really easy; classical stack implementation:

```
S.push ("X");
S.push ("Y");
S.push ("Z");
```



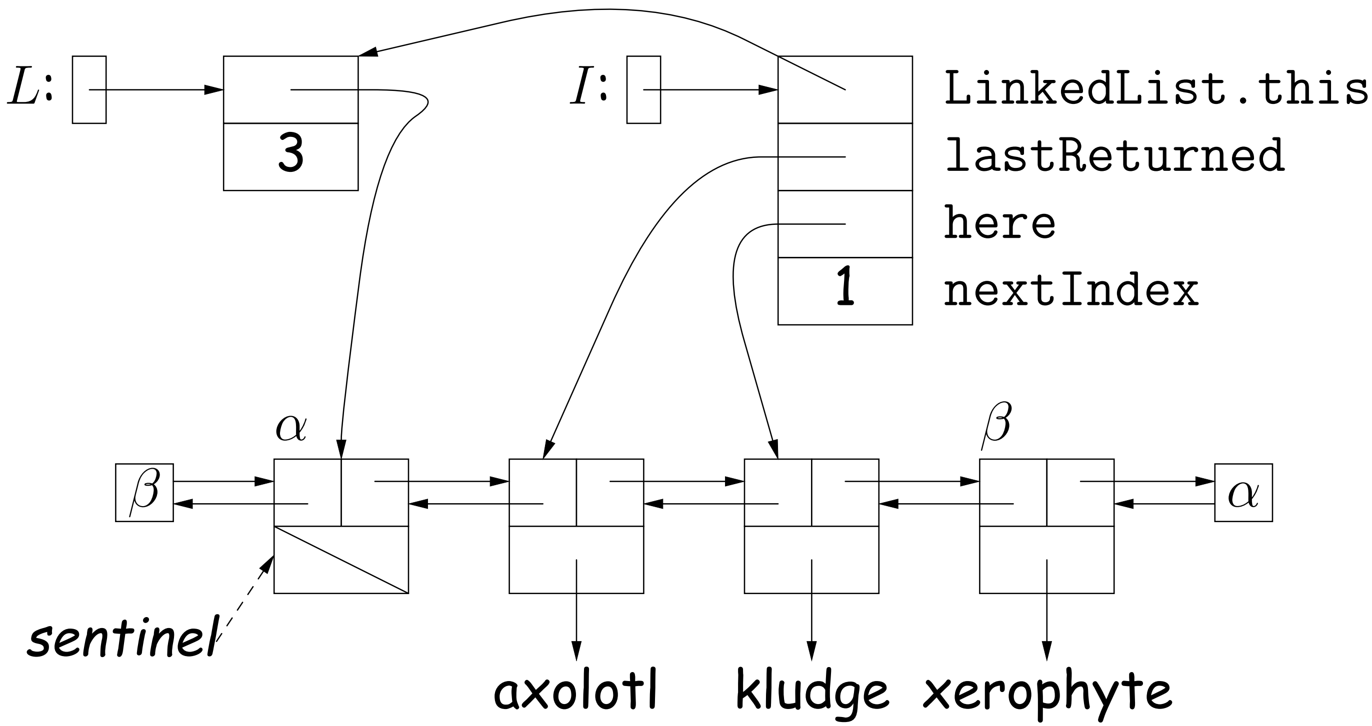
  - To allow growth at either end, use *circular buffering:*



  - Random access still fast.

Linking

- Essentials of linking should now be familiar
- Used in Java `LinkedList`. One possible representation:



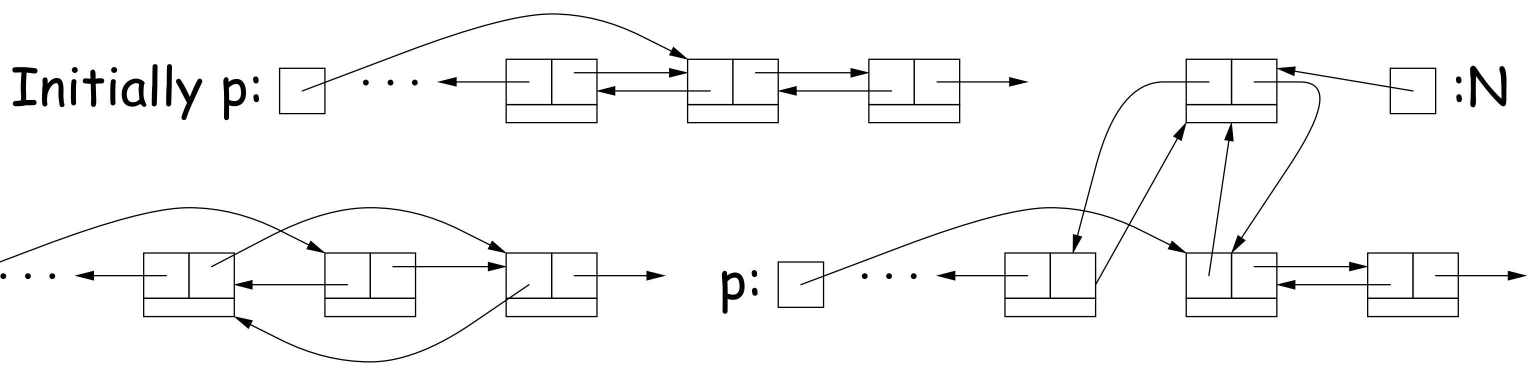

```
L = new LinkedList<String>();
L.add("axolotl");
L.add("kludge");
L.add("xerophyte");
I = L.listIterator();
I.next();
```

Clever trick: Sentinels

- A *sentinel* is a dummy object containing no useful data except links.
- Used to eliminate special cases and to provide a fixed object to point to in order to access a data structure.
- Avoids special cases ('**if**' statements) by ensuring that the first and last item of a list always have (non-null) nodes—possibly sentinels—before and after them:
-

```
// To delete list node at p:
p.next.prev = p.prev;
p.prev.next = p.next;
```

```
// To add new node N before p:
N.prev = p.prev; N.next = p;
p.prev.next = N;
p.prev = N;
```



Specialization

- Traditional special cases of general list:
  - **Stack**: Add and delete from one end (LIFO).
  - **Queue**: Add at end, delete from front (FIFO).
  - **Dequeue**: Add or delete at either end.
- All of these easily representable by either array (with circular buffering for queue or deque) or linked list.
- Java has the `List` types, which can act like any of these (although with non-traditional names for some of the operations).
- Also has `java.util.Stack`, a subtype of `List`, which gives traditional names ("push", "pop") to its operations. There is, however, no "stack" interface.

Stacks and Recursion

- Stacks related to *recursion*. In fact, can convert any recursive algorithm to stack-based (however, generally no great performance benefit):
  - Calls become "push current variables and parameters, set parameters to new values, and loop."
  - Return becomes "pop to restore variables and parameters."

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findExit(start):
  if isExit(start)
    FOUND
  else if (! isCrumb(start))
    leave crumb at start;
    for each square, x,
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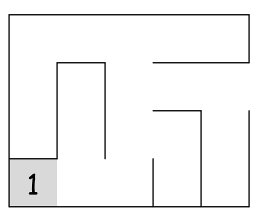
        if legalPlace(x)
          findExit(x)
```

Call: findExit(0)
Exit: 16

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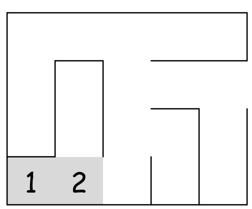

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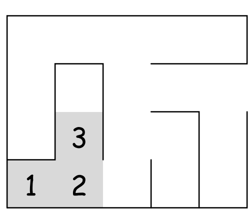

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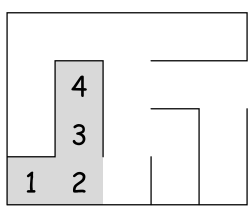

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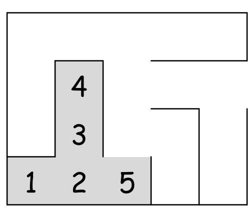


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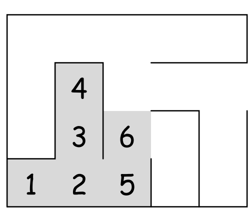

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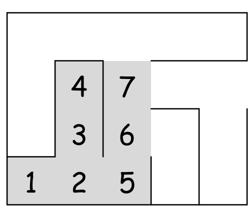

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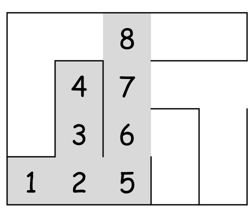


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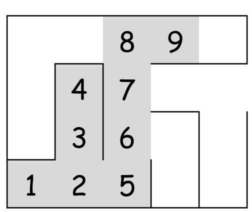


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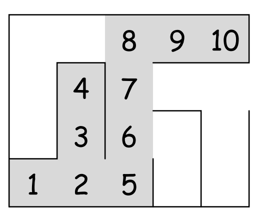

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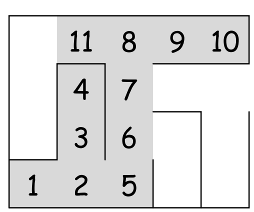


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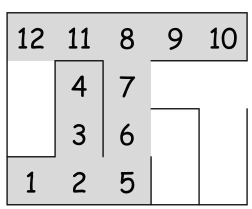


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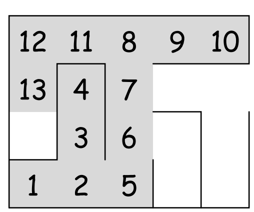
Call: findExit(0)
Exit: 16

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Stacks and Recursion

- Stacks related to *recursion*. In fact, can convert any recursive algorithm to stack-based (however, generally no great performance benefit):
  - Calls become "push current variables and parameters, set parameters to new values, and loop."
  - Return becomes "pop to restore variables and parameters."

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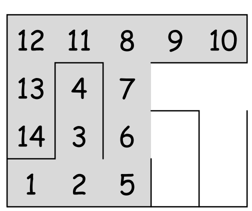


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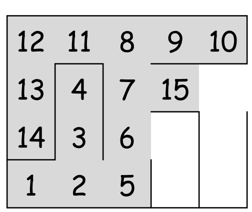


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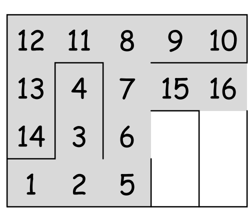


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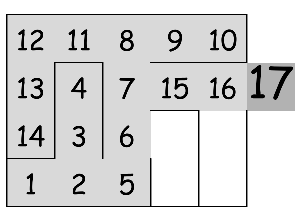


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Design Choices: Extension, Delegation, Adaptation

- The standard `java.util.Stack` type *extends* `Vector`:

```
class Stack<Item> extends Vector<Item> { void push (Item x) { add (x); } ... }
```

- Could instead have *delegated* to a field:

```
class ArrayStack<Item> {
   private ArrayList<Item> repl = new ArrayList<Item> ();
   void push (Item x) { repl.add (x); } ...
}
```

- Or, could *generalize*, and define an *adapter:* a class used to make objects of one kind behave as another:

```
public class StackAdapter<Item> {
   private List repl;
   /** A stack that uses REPL for its storage. */
   public StackAdapter (List<Item> repl) { this.repl = repl; }
   public void push (Item x) { repl.add (x); } ...
}

class ArrayStack<Item> extends StackAdapter<Item> {
  ArrayStack () { super (new ArrayList<Item> ()); }
}
```