CS61B Lecture #18

Announcements:

- **Programming Contest Saturday, October 14.** See

  `http://inst.eecs.berkeley.edu/~ctest/contest/`

  for details and registration.

- Starting next week, some of the TAs will be holding 20 minute one-on-one advising sessions. If you would like to talk about how you're doing in this course, get some advice about study strategies, or just would like someone to talk to, feel free to sign up! *Please do not treat these as private office hours or ask the TA to debug your code.*

  Times and locations will be available at

  http://tinyurl.com/cs61b-advising.

  When you sign up for an advising session, make sure to include some topics you'd like to talk about during the session in the description box. If the location is not listed, it will be emailed to you before your session.

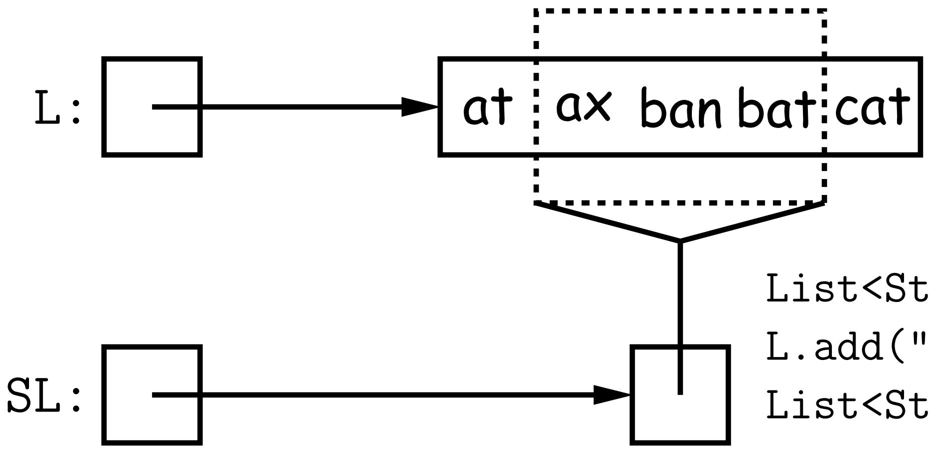
Topics

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

Views

New Concept: *A view* is an alternative presentation of (interface to) an existing object.

- For example, the `sublist` method is supposed to yield a "view of" part of an existing list:




```
List<String> L = new ArrayList<String>();
L.add("at"); L.add("ax"); ...
List<String> SL = L.sublist(1,4);
```

- Example: after `L.set(2, "bag")`, value of `SL.get(1)` is `"bag"`, and after `SL.set(1,"bad")`, value of `L.get(2)` is `"bad"`.
- Example: after `SL.clear()`, `L` will contain only `"at"` and `"cat"`.
- Small challenge: "How do they *do* that?!"

Maps

- A `Map` is a kind of "modifiable function:"

```
package java.util;
public interface Map<Key,Value> {
  Value get(Object key);              // Value at KEY.
  Object put(Key key, Value value);   // Set get(KEY) -> VALUE
  ...
}
-------------------------------------------------------
Map<String,String> f = new TreeMap<String,String>();
f.put("Paul", "George"); f.put("George", "Martin");
f.put("Dana", "John");
// Now f.get("Paul").equals("George")
//     f.get("Dana").equals("John")
//     f.get("Tom") == null
```

Map Views

```
public interface Map<Key,Value> { // Continuation

           /* Views of Maps */

  /** The set of all keys. */
  Set<Key> keySet();

  /** The multiset of all values that can be returned by get.
   *  (A multiset is a collection that may have duplicates). */
  Collection<Value> values();

  /** The set of all(key, value) pairs */
  Set<Map.Entry<Key,Value>> entrySet();
}
```

View Examples

Using example from a previous slide:

```
Map<String,String> f = new TreeMap<String,String>();
f.put("Paul", "George"); f.put("George", "Martin");
f.put("Dana", "John");
```

we can take various views of `f`:

```
for (Iterator<String> i = f.keySet().iterator(); i.hasNext();)
   i.next()  ===>  Dana, George, Paul
// or, more succinctly:
for (String name : f.keySet())
   name  ===>  Dana, George, Paul

for (String parent : f.values())
   parent  ===>   John, Martin, George

for (Map.Entry<String,String> pair : f.entrySet())
   pair   ===>   (Dana,John), (George,Martin), (Paul,George)

f.keySet().remove("Dana");   // Now f.get("Dana") == null
```

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(PrintStream 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 accounts 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: Throws 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 some `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<Item> sublist(int start, int end) {
  return new this.Sublist(start, end);
}

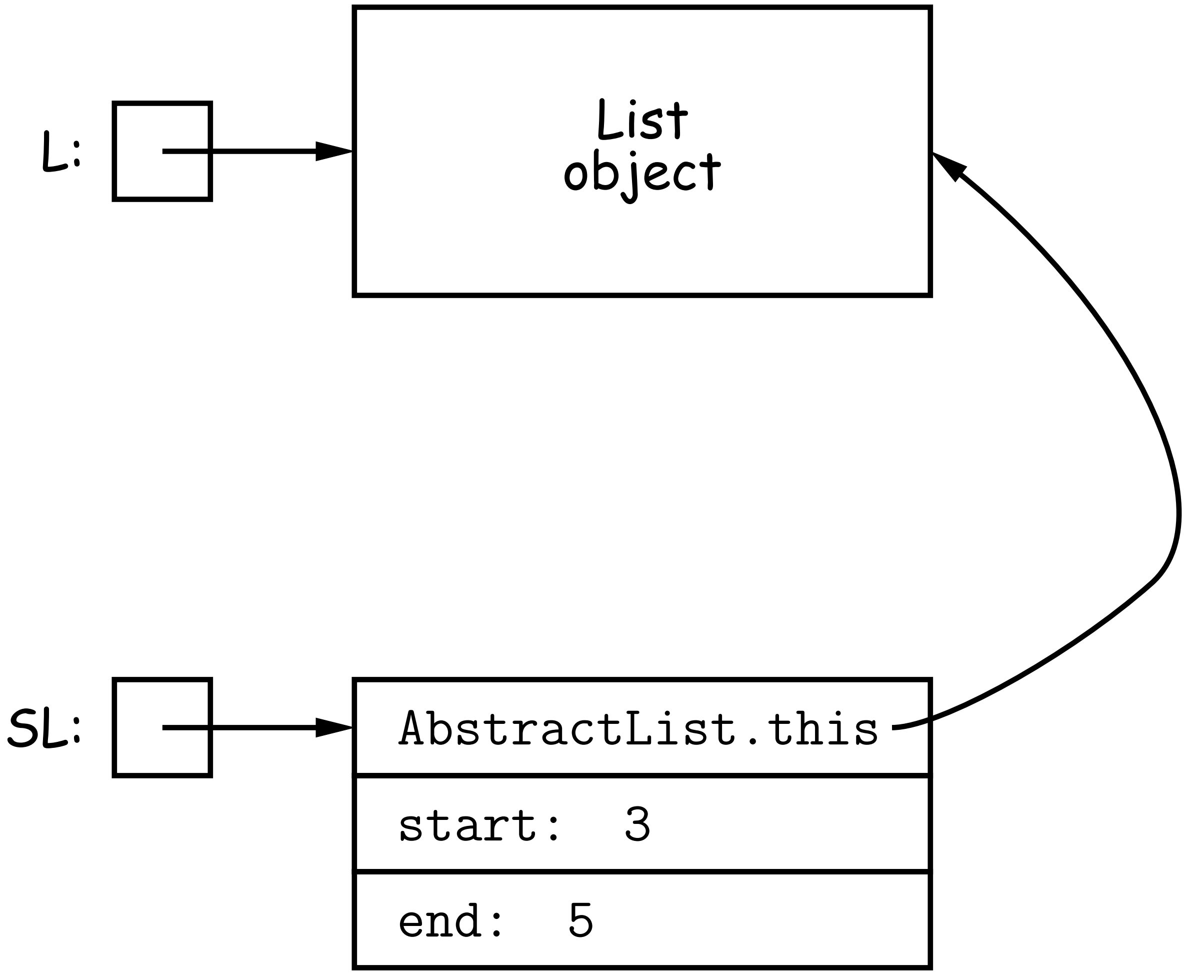
private class Sublist extends AbstractList<Item> {
  // NOTE: Error checks not shown
  private int start, end;
  Sublist(int start, int end) { obvious }

  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);`



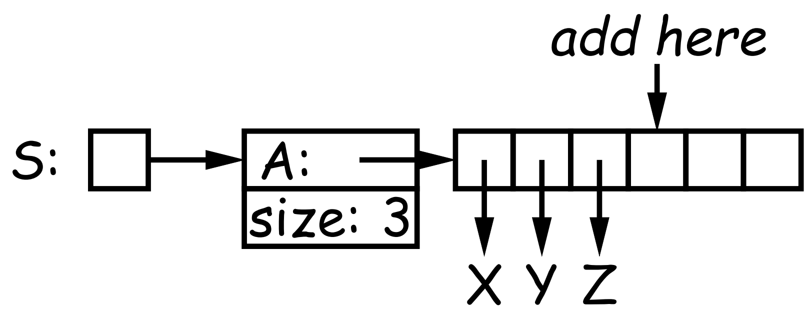
Arrays and Links

- 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.

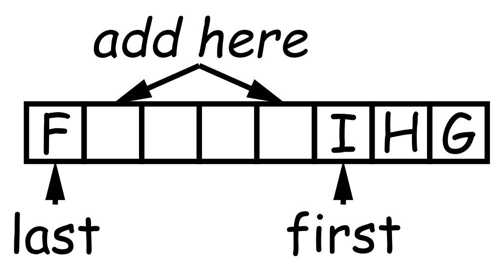
Implementing with Arrays

- 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");
```



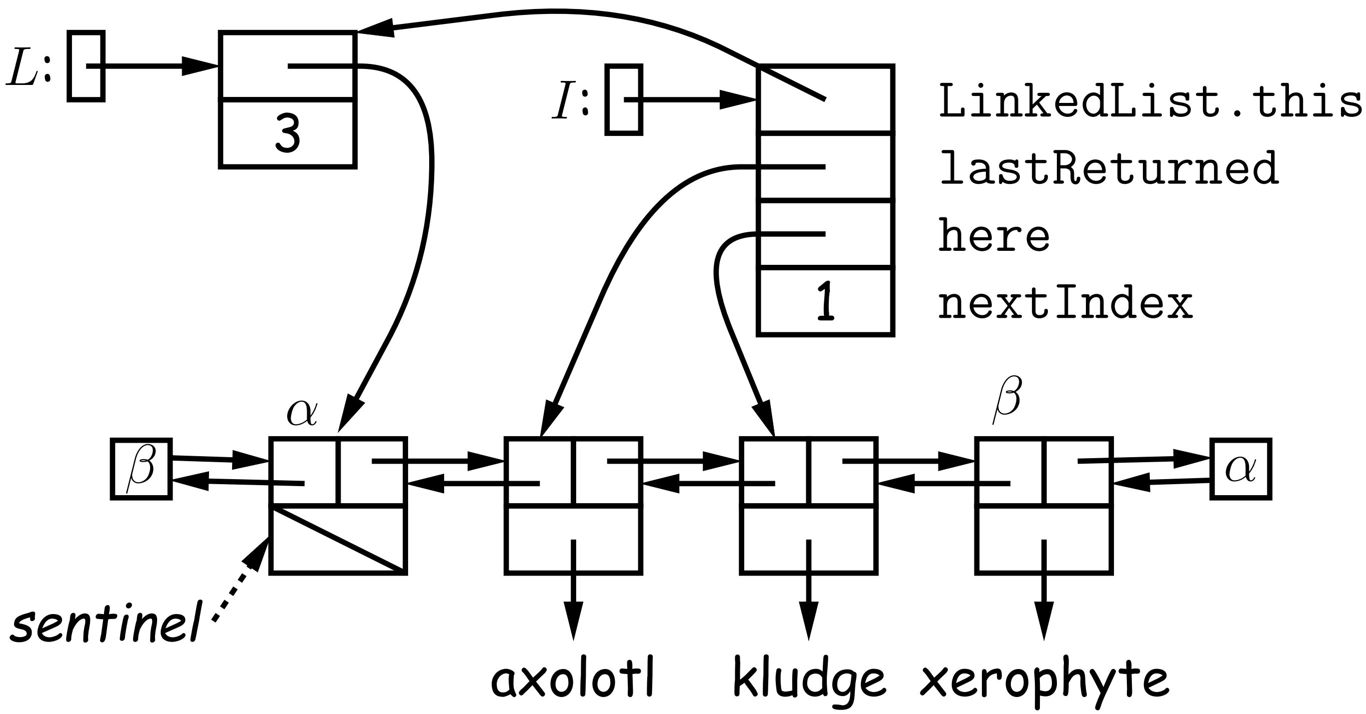
  - To allow growth at either end, use *circular buffering:*



  - Random access still fast.

Linking

- Essentials of linking should now be familiar
- Used in Java `LinkedList`. One possible representation for linked list and an iterator object over it:




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

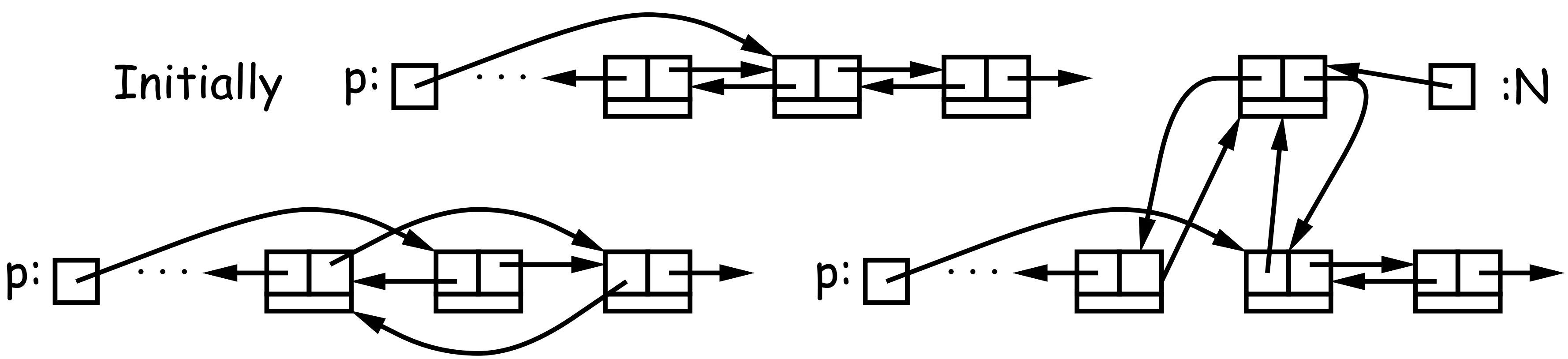
```
I = L.listIterator();
I.next();
```

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."

```
findExit(start):
  if isExit(start)
    FOUND
  else if (!isCrumb(start))
    leave crumb at start;
    for each square, x,
      adjacent to start:
        if legalPlace(x) && !isCrumb(x)
          findExit(x)
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findExit(start):
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Call: findExit(0)
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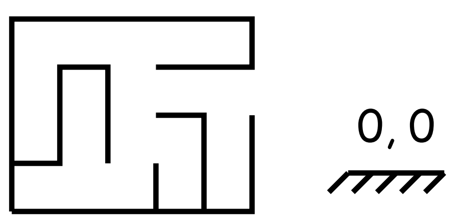

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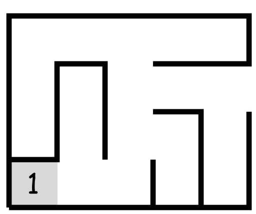

1, 0

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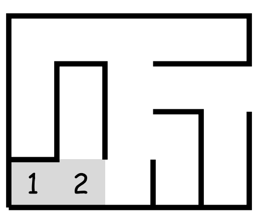

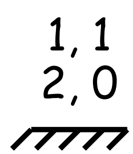

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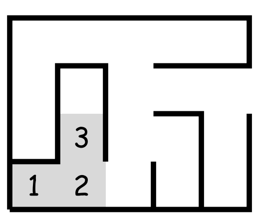

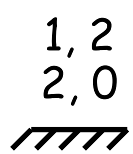

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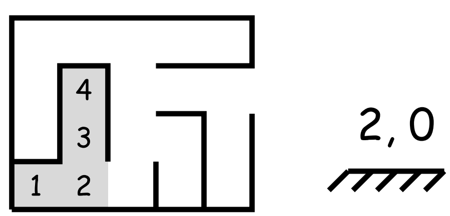

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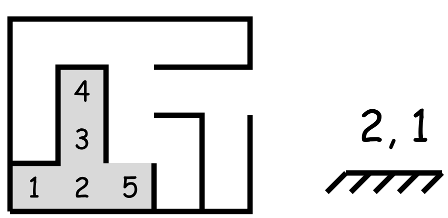

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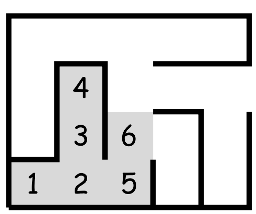

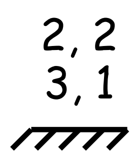

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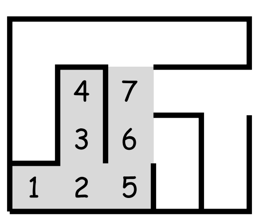

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3, 2
3, 1

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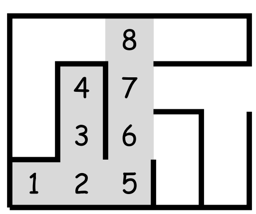

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1, 3
3, 2
3, 1

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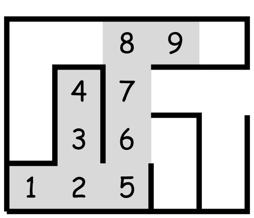

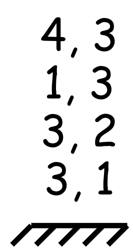

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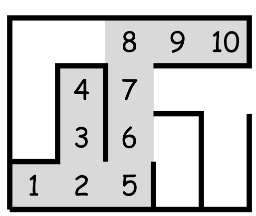

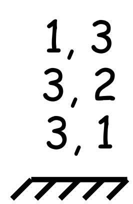

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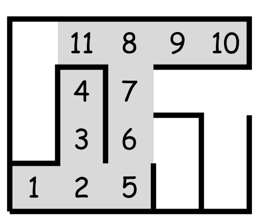

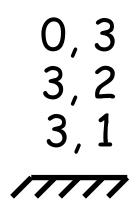

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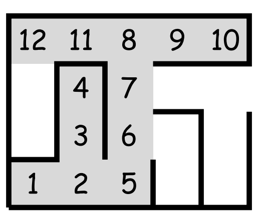

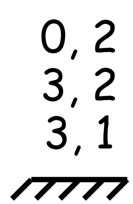


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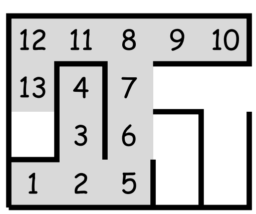

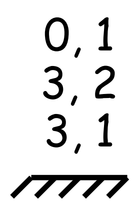


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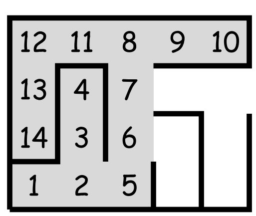

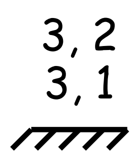

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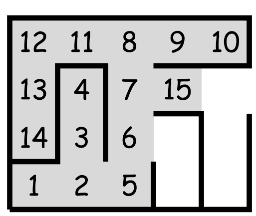

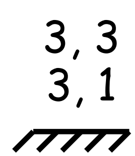

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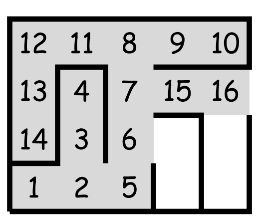

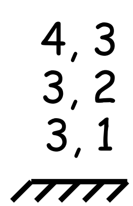

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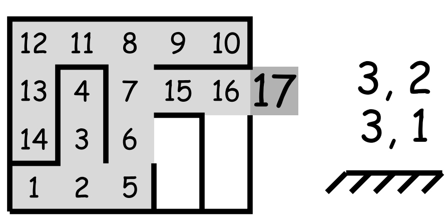

Design Choices: Extension, Delegation, Adaptation

- 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>()); }
}
```