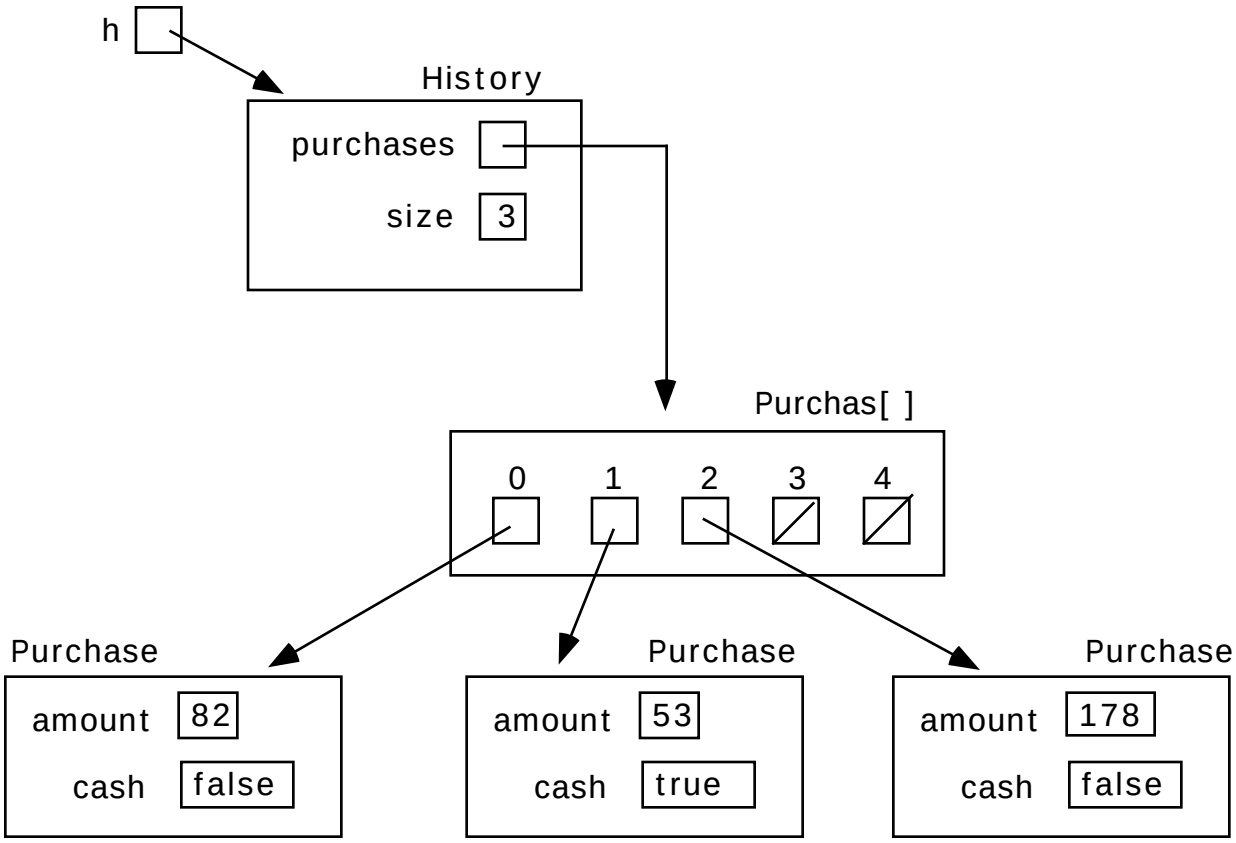
Wellesley College ◊ CS111 Computer Programming and Problem Solving ◊ Spring 2002

FINAL EXAM REVIEW SOLUTIONS

This final draft contains solutions to all problems.

Problem 1: Sales Statistics *(Data Abstraction, Arrays, Lists, Objects, Object Diagrams)*

Part a.



Part b. Finishing the instance methods of the History class:

```
public class History {

  // Instance Variables:
  private Purchase [ ] purchases;
  private int size;

  // Constructor Method:
  public History (int maxEntries) {
    purchases = new Purchase[maxEntries];
    size = 0;
  }

  // Instance Methods:
  public void add (int amount, boolean cash) {
    if (size < purchases.length) {
      purchases[size] = new Purchase(amount, cash);
      size = size + 1;
    }
  }
```

```
    public int size(){
      return size;
    }

    public int min(boolean cash){
      int minVal = Integer.MAX_VALUE;
      for (int i = 0; i < size; i ++){
        if (purchases[i].getCash() == cash){
          if(purchases[i].getAmount() < minVal){
            minVal = purchases[i].getAmount();
          }
        }
      }
      return minVal;
    }

    public int max(boolean cash){
      int maxVal = Integer.MIN_VALUE;
      for (int i = 0; i < size; i ++){
        if (purchases[i].getCash() == cash){
          if(purchases[i].getAmount() > maxVal){
            maxVal = purchases[i].getAmount();
          }
        }
      }
      return maxVal;
    }

    public int average(boolean cash){
      int sum = 0;
      int count = 0;
      for (int i = 0; i < size; i++){
        if(purchases[i].getCash() == cash){
          sum = sum + purchases[i].getAmount();
          count = count + 1;
        }
      }
      if (count == 0){
        return 0;

      } else {
        return sum/count;
      }
    }

    public int number (boolean cash){
      int count = 0;
      for (int i = 0; i < size; i ++) {
        if(purchases[i].getCash() == cash){
          count = count + 1;
        }
      }
      return count;
    }

    public int percentage (boolean cash){
      if (size > 0){
        return (number(cash) * 100)/size;
      }else{
        return 0;
      }
    }
}
```

Part c. You cannot write the constructor method as either of:

```
public Purchase (int amount, boolean cash) {
    amount = amount;
    cash = cash;
  }

public Purchase (int a, boolean c) {
    int amount = a;
    int cash = c;
  }
```

In both cases, the variables `amount` and `cash` refer to *local* variables in the execution frame, not the instance variables in the instance. If there is a local variable with the same name as the instance variable, the instance variable must be referred to as **this**.amount.

Part d.

1) Implement the Purchase class with the instance variable as an array of two integers:

```
public class Purchase {

  // Instance Variables
  private int [] sale;

  // Constructor Method
  public Purchase (int i, boolean b) {
    sale = new int [2];
    sale[0] = i;
    sale[1] = intToBool(b);
  }

  // Instance Methods
  public int getAmount () {return sale[0];}

  public void setAmount (int newAmount) {sale[0] = newAmount;}

  public boolean getCash () {return (sale[1] == 1);}

  public void setCash (boolean newCash) {
    sale[1] = intToBool(newCash);
  }

  // Useful helper method
  private bool boolToInt (boolean b) {
    if(b){
      return 1;
    } else {
      return 0;
    }
  }
```

2) Implement `Purchase` class with an integer list:

```
public class Purchase {

  // Instance Variables
  private IntList sale;

  // Constructor Method
  public Purchase (int i, boolean b) {
    sale = prepend(i, prepend(intToBool(b), empty()));
  }

  // Instance Methods
  public int getAmount () {
    return head(sale);
  }

  public void setAmount (int newAmount) {
    sale = prepend(newAmount, tail(sale));
  }

  public boolean getCash () {
    return (head(tail(sale)) == 1);
  }

  public void setCash (boolean newCash) {
    sale = prepend(head(sale), prepend(intToBool(newCash), empty()));
  }

  // Useful helper method
  private bool boolToInt (boolean b) {
    if(b){
      return 1;
    } else {
      return 0;
    }
  }
}
```

3) Implement `Purchase` class as a single positive or negative integer:

```
public class Purchase {

  // Instance Variables
  private int sale;

  // Constructor Method
  public Purchase (int i, boolean b) {
    sale = (sign(b)) * i
  }

  // Instance Methods
  public int getAmount () {
    return Math.abs(sale);
  }

  public void setAmount (int newAmount) {
    sale = sign(sale) * Math.abs(newAmount);
  }

  public boolean getCash () {
    return (sale > 0);
  }

  public void setCash (boolean newCash) {
    sale = sign(newCash) * Math.Abs(sale);
  }

  // Useful helper method
  public int sign (boolean b) {
    if (b) {
      return 1;
    } else {
      return –1;
    }
  }
}
```

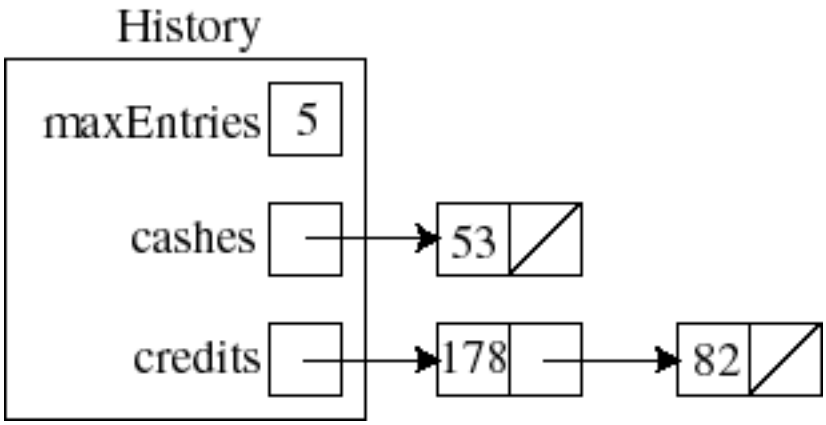
4) Implement `Purchase` class as a single integer where (i) amount is one half of integer (via integer division) and (ii) even is cash, odd is credit.

```
public class Purchase {

  // Instance Variables
  private int sale;

  // Constructor Method
  public Purchase (int i, boolean b) {
    sale = 2*i + intToBool(b);
  }

  // Instance Methods
  public int getAmount () {
    return sale/2; // integer division
  }

  public void setAmount (int newAmount) {
    sale = (newAmount*2) + (sale%2);
  }

  public boolean getCash () {
    return (sale%2) == 1;
  }

  public void setCash (boolean newCash) {
    sale = 2*(sale/2) + intToBool(newCash);
  }


  // Useful helper method
  private bool boolToInt (boolean b) {
    if(b){
      return 1;
    } else {
      return 0;
    }
  }
}
```

Part e. Silly Bud! Making the instance variables of the `Purchase` class `public` would tie the hands of the implementer, making it more difficult to change the representation of `Purchase`.

Part f. Implement history with 3 instance variables: maxEntries, and two IntLists:

i.



ii. Implementation

```
public class History {

  // Instance Variables:
  private int maxEntries;
  private IntList cashes;
  private IntList credits;

  // Constructor Method:
  public History (int maxEntries) {
    this.maxEntries = maxEntries;
    cashes = empty();
    credits = empty();
  }

  // Instance Methods:
  public void add (int amount, boolean cash) {
    if (length(cashes) + length(credits) < maxEntries) {
      if (cash){
        cashes = prepend(amount, cashes);
      } else {
        credits = prepend(amount, credits);
      }
    }
  }

public int min(boolean cash){
    if (cash){
      return minOfList(cashes);
    } else {
      return minOfList(credits);
    }
  }

  public int minOfList(IntList L){
    if(isempty(L)){
      return Integer.MAX_VALUE;
    } else {
      int minVal = minOfList(tail(L));
      if(head(L) < minVal){
        return head(L);
      } else {
        return minVal;
      }
    }
  }
```

```
public int size(){return length(cashes) + length(credits);}

public int max(boolean cash){ //similar to min--left as exercise.}

  public int average(boolean cash){
    if(cash){
      if(isempty(cashes){
        return 0;
      } else {
        return sum(cashes)/length(cashes);
      }
    }else {
      if(isempty(credits){
        return 0;
      } else {
        return sum(credits)/length(cashes);
      }
    }
  }

  private int sum (IntList L) {
    if(isempty(L)){
      return 0;
    } else {
      return head(L) + sum(tail(L));
    }
  }

  private int length (IntList L) {
    if(isempty(L)){
      return 0;
    } else {
      return 1 + length(tail(L));
    }
  }

  public int number (boolean cash){
    if(cash){
      return length(cashes);
    } else {
      return length(credits);
    }
  }


public int percentage (boolean cash){
    if (size() != 0){
      if (cashes){
        return length(cashes) * 100/size();
      }else{
        return length(credits) * 100/size();
      }
    } else {
      return 0;
    }
  }
}
```

Part g. Left as exercise for the student.

Problem 2: List Partitioning *(Iteration, Recursion, Lists)*

Part a. Below is the iteration table for `partition(5,A)` where `A` is the list with printed representation `[7,2,3,5,8,6]`. Each row of an iteration table represents one call to the tail-recursive method `partitionTail`. The values of each state variable in the iteration table represent the values of the parameters of `partitionTail` each time it is invoked.

pivot	list	lesses	greaters
5	[7,2,3,5,8,6]	[]	[]
5	[2,3,5,8,6]	[]	[7]
5	[3,5,8,6]	[2]	[7]
5	[5,8,6]	[3,2]	[7]
5	[8,6]	[5,3,2]	[7]
5	[6]	[5,3,2]	[8,7]
5	[]	[5,3,2]	[6,8,7]

Part b. Here is the **`while`** loop implementation of the partition algorithm:

```
public static IntList [] partitionWhile (int pivot, IntList L) {
  // initialize state variables
  IntList lesses = IL.empty();
  IntList greaters = IL.empty();
  while (!isEmpty(L)) { // continuation condition
    if (IL.head(L) <= pivot) { // update lesses
      lesses = IL.prepend(IL.head(L), lesses);
    } else { // update greaters
      greaters = IL.prepend(IL.head(L), greaters);
    }
    L = IL.tail(L); // always update L, and it needs to be done after the updates
  } // end of iteration via while loop
  return twoLists(lesses, greaters); // put together our answer
}
```

Part c. The *tail-recursive* implementation was given to us in the problem set. For this problem, we want to implement the partition algorithm using recursion which is not tail-recursive. In other words, pending operations are ok and there should not be any auxiliary methods.

```
public static IntList [] partitionNonTail (int pivot, IntList L) {
  if (isEmpty(L)) { // base case for recursion
    return twoLists(IL.empty(), IL.empty());
  } else{ // general case
    // solve the smaller problem via wishful thinking<
    IntList [] subresult = partitionNonTail(pivot, IL.tail(L));

    // break the subresult into its two components
    IntList lesses = (IntList)subresult[0];
    IntList greaters = (IntList)subresult[1];

    // add the first element of the list to the appropriate component
    if (IL.head(L) <= pivot) { // update lesses
      lesses = IL.prepend(IL.head(L), lesses);
    } else { // update greaters
      greaters = IL.prepend(IL.head(L), greaters);
    }
    return twoLists(lesses, greaters); // put together our answer
  } // end general case
}
```

An alternative solution can be written using the fact that the slots of subresult can be modified directly rather than returning a freshly allocated array. This implementation is shown below:

```
public static IntList [] partitionNonTail (int pivot, IntList L) {
  if (isEmpty(L)) { // base case for recursion
    return twoLists (empty(), empty());
  } else{ // general case
    // solve the smaller problem via wishful thinking
    IntList [] subresult = partitionNonTail(pivot, IL.tail(L));

    // add the first element of the list to the appropriate component
    if (IL.head(L) <= pivot) { // update lesses
      subresult[0] = IL.prepend(IL.head(L), subresult[0]);
    } else { // update greaters
      subresult[1] = IL.prepend(IL.head(L), subresult[1]);
    }

    return subresult;
  } // end general case
}
```

Part d. Quicksort is one method to sort a list of numbers into numerical order. Quicksort works recursively and its algorithm was described in the problem set description. To implement quicksort, we need to figure out what is its base case and what is its general case and what to do in each situation.

- *base case*: a sorted empty list is the empty list (there are no elements to sort!)

- *general case*:

    - partition the elements of the list (except for the first element) into two piles: elements less than the first element, and elements greater than or equal to the first element

    - sort each pile (the lesses and the greaters) using quicksort

    - obtain our final answer by placing the three components in order: the sorted lesses, the first element, the sorted greaters

Code that implements the above quicksort algorithm is shown below:

```
public static IntList quickSort(IntList L) {
  if (IL.isEmpty(L)) { // base case for recursion
    return IL.empty();
  } else { // general case
    IntList [] partitions = partition(IL.head(L), IL.tail(L));
    IntList lesses = partitions[0];
    IntList greaters = partitions[1];
    return IL.append(quickSort(lesses), IL.prepend(IL.head(L), quickSort(greaters)));
  } // end general case
}
```

Problem 3: Squares *(Recursion, Iteration, TurtleWorld, BuggleWorld, PictureWorld, Java Graphics)*

Part a. *Turtle World*

```
public void squares(int n, int len) {
  if (n > 0) {
    drawSquare(len);
    fd(len);
    squares(n - 1, len/2);
    bd(len);
  }
}

public void drawSquare(int length) {
  for (int i = 0; i < 4; i++) {
    fd(length);
    lt(90);
  }
}
```

Part b. *Buggle World*

```
public void squares(int n, int len) {
  if (n > 0) {
    bagelRect(len,len);
    forward(len);
    squares(n - 1, len/2);
    backward(len);
  }
}

// Draw a rectangle of bagels with the given width and height.
// The state of the buggle is invariant under this method.
public void bagelRect(int width, int height) {
  if (height > 0) {
    bagelLine(width);
    left();
    forward(1);
    right();
    bagelRect(width, height-1);
    left();
    backward(1);
    right();
}

// Drop a line of width bagels, leaving the state of the buggle invariant
public void bagelLine(int width) {
  if (width > 0) {
    dropBagel();
    forward();
    bagelLine(width-1);
    backward();
}
```

Part c. *Picture World*

```
public Picture squares(int n, Color c1, Color c2) {
  if (n <= 0) {
    return empty();
  }else {
    return fourPics(empty(), empty(), patch(c1),
                    squares(n-1, c2, c1);
  }
}
```

Part d. *Java Graphics*

```
public void squares (Graphics g, int n, int len, Color c1, Color c2) {
  int x = 0;
  int y = len; // Constant throughout iteration
  while (n > 0) {
    g.setColor(c1);
    g.drawRect(x,y,len,len);

    // Update state variables of iteration
    n = n – 1;
    x = x + len;
    len = len/2;
    // swap colors
    Color temp = c1;
    c1 = c2;
    c2 = temp;
  }
}
```

Problem 4: Greatest Common Divisor *(Iteration)*

Part a. Here is the iteration table for the iterative calculation of `GCDTail(95,60)`.

A	B
95	60
60	35
35	25
25	10
10	5
5	0

Part b.

```
public static int GCDWhile (int A, int B) {
  while (B != 0) {
    // Need a temporary variable to perform updates!
    int oldA = A;
    A = B;
    B = oldA % B;
  }
  return A;
}
```

Part c. It is *always* possible to express a **`while`** loop as a **`for`** loop, but the result may not be particularly natural. Indeed, in this case it would not be natural to re-express Wyla's GCDTail program as a **for** loop. For loops best "fit" cases where there is a state variable controlling the number of times through the loop that is independent of other state variables. In the case of GCD, the state variable B controls the number of times through the loop, suggesting the following skeleton:

```
public static int GCDFor (int A, int B) {
  for (; B != 0; B = A % B) { // No initialization of B necessary
    updates
  }
  return A;
}
```

But what should replace *updates*? If we put `A = B` in this position, then the `A` in `A % B` (which is executed after updates) is the value of `A` after the assignment, when we want the value of `A` before the assignment. We need a temporary variable to circumvent this problem, as shown below:

```
public static int GCDFor (int A, int B) {
  int oldA;
  for (; B != 0; B = oldA % B) { // No initialization of B necessary
    oldA = A;
    A = B;
  }
  return A;
}
```

This method is less straightforward than the **`while`** loop, which is much clearer and therefore preferred.

Problem 5: Array Reversal *(Arrays, Iteration)*

Part a.

```
public static int [] copyReverse (int [] a) {
  int len = a.length;
  int [] result = new int[len];
  for (int i = 0; i < len; i++) {
    result[i] = a[(len–1)–i]; // (len–1) is last slot
  }
  return result;
}
```

Part b.

```
public static int [] reverse (int [] a) {
  int len = a.length;
  // Swap first (len/2) slots with last (len/2) slots
  // If len is odd, middle slot stays unchanged
  for (int i = 0; i < len/2; i++) {
    // Swap contents of slot i and (len-1)-i
    int old_a_sub_i  = a[i];
    a[i] = a[(len-1)-i];
    a[(len-1)-i] = old_a_sub_i;
  }
}
```

Problem 6: Inversions (Arrays, Iteration, Lists)

Part a.

```
// Returns the number of inversions in a:
public static int countInversions (int [] a) {
  int invs = 0; // Counts number of inversions
  for (int i = 0; i < a.length; i++) {
    for (int j = i+1; j < a.length; j++) {
      if a[i] > a[j] {
        invs = invs + 1;
      }
    }
  }
  return invs;
}
```

Part b. Suppose that `OL.` is the prefix used for operations on ObjectLists

```
// Returns the inversions in a as a list of points
public static int countInversions (int [] a) {
  ObjectList points = OL.empty(); // Collects inversions as list of points
  for (int i = 0; i < a.length; i++) {
    for (int j = i+1; j < a.length; j++) {
      if a[i] > a[j] {
         points = OL.prepend(new Point(i,j), points);
      }
    }
  }
  return points;
}
```

Problem 7: Inheritance *(Inheritance)*

Statement	Printout on Java Console
`System.out.println((new A()).m1());`	1
`System.out.println((new B()).m1());`	3
`System.out.println((new C()).m1());`	4
`System.out.println((new D()).m1());`	5
`System.out.println((new E()).m1());`	5

Problem 8: Converting Betweeen Different Forms of Iteration *(Lists, Arrays, Iteration)*

Part a.

```
// Tail Recursion
public static int weightedSum (IntList L) {
  return weightedSumTail (L, 1, 0);
}

public static int weightedSumTail (IntList L, int index, int total) {
  if (isEmpty(L)) {
    return total;
  } else {
    return weightedSumTail(tail(L), index + 1, (index*head(L)) + total);
  }
}

// While loop
public static int weightedSumWhile (IntList L) {
  int index = 1;
  int total = 0;
  while (!isEmpty(L)) {
    total = total + (index*head(L));
    index = index + 1;
    L = tail(L);
  }
}

// For loop
public static int weightedSumFor (IntList L) {
  int index = 1;
  int total = 0;
  for (; !isEmpty(L); L = tail(L);) {
    total = total + (index*head(L));
    index = index + 1;
  }
}
```

Part b.

```
// While loop
public static boolean isMember (int n, int [] a) {
  int i = a.length - 1;
  while ((i >= 0) && (a[i] != n)) {
    i = i - 1;
  }
  return (i >= 0); // Will only be true if n is in a.
}
```

```
// For loop
public static boolean isMemberFor (int n, int [] a) {
  int i = a.length - 1;
  for (int i = a.length – 1; i>=0; i--) {
    if a[i] == n {
      return true;
    }
  }
  return false;
}

// Tail recursion
public static boolean isMemberIter (int n, int [] a) {
  return isMemberTail(n, a, a.length - 1);
}

public static boolean isMemberTail (int n, int [] a, int i) {
    if (i < 0) {
      return false;
    } else if (a[i] == n) {
      return true;
    } else {
      return isMemberTail (n, a, i-1);
    }
}
```

Part c.

```
// For loop
public static void partialSum (int [] a) {
  int sum = 0;
  for (int i = 0; i < a.length; i++) {
    sum = sum + a[i];
    a[i] = sum;
  }
}

// While loop
public static void partialSumWhile (int [] a) {
  int i = 0;
  int sum = 0;
  while (i < a.length) {
   sum = sum + a[i];
    a[i] = sum;
    i++;
  }
}

// Tail recursion
public static void partialSumIter (int [] a) {
  return partialSumTail(a,0, 0);
}

public static void partialSumTail (int [] a, int i, int sum) {
  if (i < a.length) {
    int newsum = sum + a[i];
    a[i] = newsum;
    partialSumTail(a, i+1, newsum);
  }
}
```

Part d.

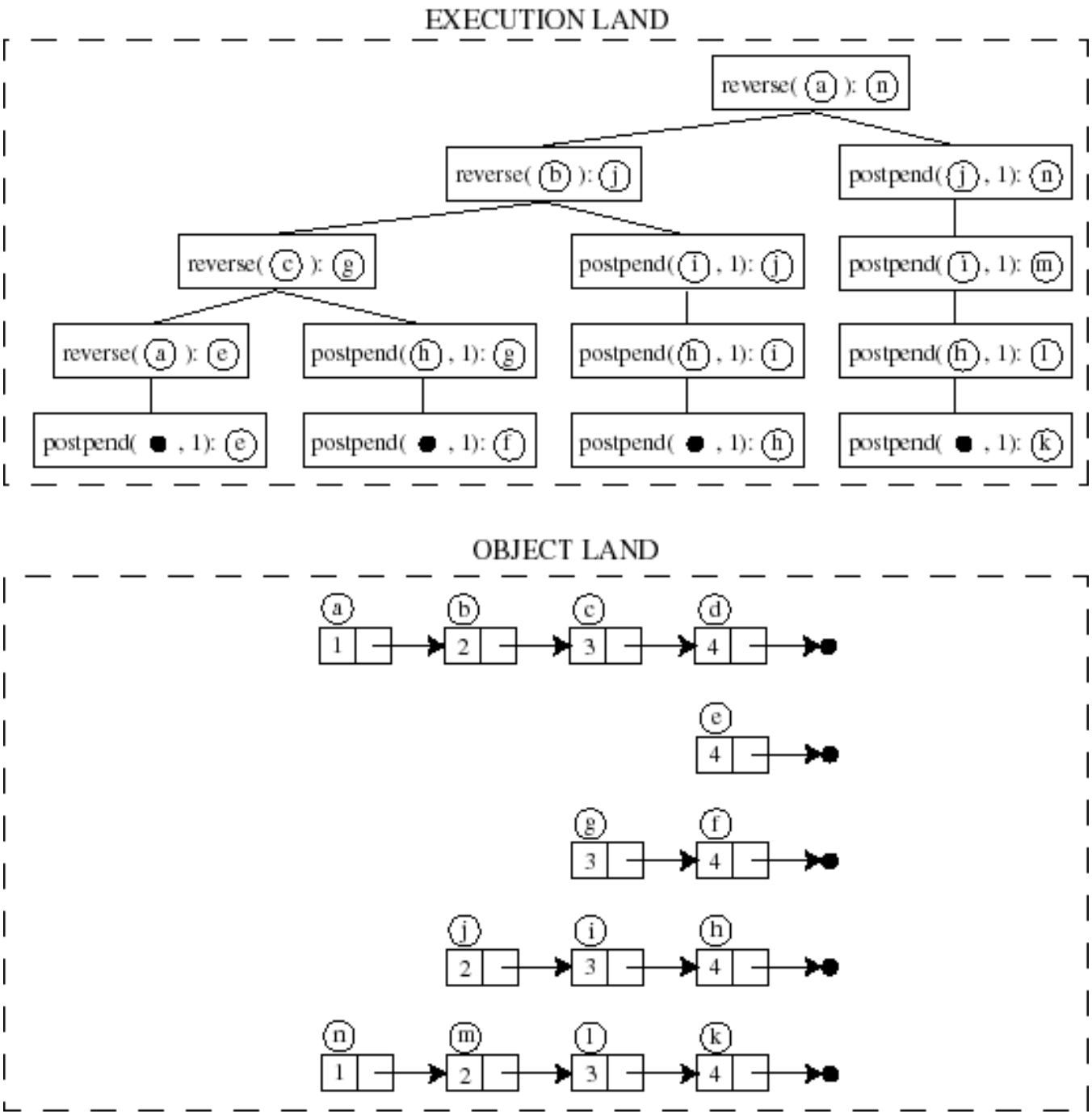
```
// Tail recursion
public static void squiggle (Graphics g, int x1, int y1, int x2, int y2) {
  if ((x1 > 0) || (y1 > 0) || (x2 > 0) || (y2 > 0)) {
    g.drawLine(x1, y1, x2, y2);
    squiggle(g, x2, y2, y1/4, x1*2);
  }
}

// While loop
public static void squiggleWhile (Graphics g, int x1, int y1, int x2, int y2) {
  while ((x1 > 0) || (y1 > 0) || (x2 > 0) || (y2 > 0)) {
    g.drawLine(x1, y1, x2, y2);
    // Introduce temporaries for x1, y1 so don't lose their values!
    old_x1 = x1;
    old_y1 = y1;
    x1 = x2;
    y1 = y2;
    x2 = old_y1/4
    y2 = old_x1*2;
  }
}

// For loop
public static void squiggleFor (Graphics g, int x1, int y1, int x2, int y2) {
  // A particularly uncompelling example of a for loop!
  for (;(x1 > 0) || (y1 > 0) || (x2 > 0) || (y2 > 0);) {
    g.drawLine(x1, y1, x2, y2);
    // Introduce temporaries for x1, y1 so don't lose their values!
    old_x1 = x1;
    old_y1 = y1;
    x1 = x2;
    y1 = y2;
    x2 = old_y1/4
    y2 = old_x1*2;
  }
}
```

Problem 9: Converting Betweeen Arrays and Lists *(Lists, Arrays, Iteration)*

```
public static int [] listToArray (IntList L) {
  int [] result = new int [IL.length(L)];
  int i = 0;
  while (! isEmpty(L)) {
    result[i] = IL.head(L);
    L = IL.tail(L);
    i = i + 1;
  }
  return result;
}

public static IntList arrayToList (int [] a) {
  IntList L = IL.empty();
  // traverse the array from back to front in order
  // to prepend elements in the correct order.
  for (int i = a.length – 1; i >= 0; i--) {
    L = prepend(a[i], L);
  }
  return L;
}
```

Problem 10: Iterative List Reversal *(Invocation Trees, Recursion, Iteration, Lists,)*

Part a.



Part b.

Tail recursive solution:

```
public static IntList reverseIter (IntList L) {
  return reverseTail(L, IL.empty());
}

public static IntList reverseTail (IntList list, IntList result) {
  if (IL.isEmpty(list)) {
    return result;
  } else {
    return reverseTail(IL.tail(list), IL.prepend(IL.head(list), result));
  }
}
```

While loop solution:

```
public static IntList reverseWhile (IntList L) {
  IntList result = IL.empty();
  while (! IL.isEmpty(L)) {
    result = IL.prepend(IL.head(L), result);
    L = IL.tail(L);
  }
  return result;
}
```

For loop solution:

```
public static IntList reverseWhile (IntList L) {
  IntList result = IL.empty();
  for (; ! IL.isEmpty(L); L = IL.tail(L)) // Note empty initializer
    result = IL.prepend(IL.head(L), result);
  }
  return result;
}
```

Problem 11: Leftist Turtles *(Tests Instance Variables, Class Declarations, Inheritance)*

Part a.

```
public class LeftistTurtle extends Turtle {

  private int leftCount;

  public LeftistTurtle() {
    super();
    leftCount = 0;
  }

  public void lt (double degrees) {
     super.lt(degrees);
     leftCount = leftCount + 1;
  }

  public int numberOfLefts () {
    return leftCount;
  }

}
```

Part b.

The example can print 2 in the case where the `rt()` method of the Turtle class is implemented as follows:

```
public void rt (double degrees) {
   left(-degrees);
}
```

In this case, every call to `rt()` performs an implicit call on `lt()`!

Part c. In the case where the `Turtle` method `rt()` calls `lt()`, we can add a `rt()` method to `LeftistTurtle` that *subtracts* 1 from `leftCount` for each call to `rt()`. This will cancel out the 1 that is added by the implicit call to `lt()`.

```
public void rt (double degrees) {
   super.rt(degrees);
   leftCount = leftCount - 1;
}
```

Suppose we don't know whether the `Turtle rt()` method invokes `lt()` or not – can we still handle `rt()` correctly? Yes! The following version of the `LeftistTurtle rt()` method is more robust than the version above because it makes no assumptions about how the `Turtle rt()` method works:

```
public void rt (double degrees) {
   int oldLeftCount = leftCount;
   super.rt(degrees); // may change leftCount
   leftCount = oldLeftCount; // reset leftCount, in case changed by super.rt()
}
```

Problem 12: Bank Accounts *(Data Abstraction, Lists)*

Part a.

```
class Account {

  private int savings;
  private int total;

  public account () {
    this.savings = 0;
   this.total = 0;
  }

  public int getSavings() {return this.savings;}
  public int getChecking() {return this.total – this.savings;}
  public int getTotal() {return this.total;}

  public void depositToSavings(int amountToAdd) {
    this.savings = this.savings + amountToAdd;
    this.total = this.total + amountToAdd;
  }

  public void transferFromSavingsToChecking(int transferAmount) {
    this.savings = this.savings - transferAmount;
  }

  public void withdrawFromChecking(int withdrawalAmount) {
    this.total = this.total - withdrawalAmount;
  }
}
```

Part b.

```
class Account {

  private IntList accountInfo; // List of savings, checking, total

  public account () {set(0,0,0);}

  // Very useful helper method
  private set (int s, int c, int t) {
    accountInfo = IL.prepend(s, IL.prepend(c, IL.prepend(t IL.empty())));
  }

  public int getSavings() {return IL.head(accountInfo);}
  public int getChecking() {return IL.head(IL.tail(accountInfo));}
  public int getTotal() {return IL.head(IL.tail(IL.tail(accountInfo)));}

  public void depositToSavings(int amount) {
    set(getSavings() + amount, getChecking(),getTotal() + amount);
  }

  public void transferFromSavingsToChecking(int amount) {
    set(getSavings() – amount, getChecking() + ammount, getTotal());
  }

  public void withdrawFromChecking(int amount) {
    set(getSavings(), getChecking() – amount, getTotal() – amount);
  }
}
```