Problem. Print out the command-line arguments in lexicographic order:

% java sort the quick brown fox jumped over the lazy dog
brown dog fox jumped lazy over quick the the

Plan.

```java
public class Sort {
    /** Sort and print WORDS lexicographically. */
    public static void main(String[] words) {
        sort(words, 0, words.length-1);
        print(words);
    }

    /** Sort items A[L..U], with all others unchanged. */
    static void sort(String[] A, int L, int U) {
        /* "TOMORROW" */
    }

    /** Print A on one line, separated by blanks. */
    static void print(String[] A) {
        /* "TOMORROW" */
    }
}
```

How do We Know If It Works?

- **Unit testing** refers to the testing of individual units (methods) within a program, rather than the whole program.
- **Module testing** refers to testing of classes or other groupings of methods and data.
- **System testing** (or **acceptance testing**) refers to the testing of the functionality of an entire program.
- **Integration testing** is sort of intermediate between unit and system testing, and tests that modules work correctly together.
- **Regression testing** refers to testing with the specific goal of checking that fixes, enhancements, or other changes have not introduced faults (regressions).

- In this class, we mainly use the JUnit tool for unit testing.
- Example: AGTestYear.java in lab #1.
- Our system testing is somewhat more ad hoc, and customized to the program. At its simplest, one might just run specific input files through the program and compare with precomputed outputs.
Test-Driven Development

• Idea: write tests first.
• Implement unit at a time, run tests, fix and refactor until it works.
• We’re only going to push is fairly lightly in this course, but it is useful and has quite a following.
• You’ll see a lot more of it in CS169.
Testing sort

- This is pretty easy: just give a bunch of arrays to sort and then make sure they each get sorted properly.

- Have to make sure we cover the necessary cases:
  - Corner cases. E.g., empty array, one-element, all elements the same.
  - Representative “middle” cases. E.g., elements reversed, elements in order, one pair of elements reversed, ....
Simple JUnit

- The JUnit package provides some handy tools for unit testing.
- The Java annotation `@Test` on a method tells the JUnit machinery to call that method.
- (An *annotation* in Java provides information about a method, class, etc., that can be examined within Java itself.)
- A collection of methods with names beginning with `assert` then allow your test cases to check conditions and report failures.
- [See example in the code link for lecture 6.]
Selection Sort

/** Sort items A[L..U], with all others unchanged. */
static void sort(String[] A, int L, int U) {
    if (L < U) {
        int k = /*( Index s.t. A[k] is largest in A[L],...,A[U] )*/;
        /*{ Sort items L to U-1 of A. }*/;
    }
}

And we're done! Well, OK, not quite.
Selection Sort

/** Sort items A[L..U], with all others unchanged. */
static void sort(String[] A, int L, int U) {
    if (L < U) {
        int k = indexOfLargest(A, L, U);
        /*{ Sort items L to U-1 of A. }*/;
    }
}

/** Index k, I0<=k<=I1, such that V[k] is largest element among
 *  V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    ...
}
Selection Sort

/** Sort items A[L..U], with all others unchanged. */
static void sort(String[] A, int L, int U) {
    if (L < U) {
        int k = indexOfLargest(A, L, U);
        sort(A, L, U-1);      // Sort items L to U-1 of A
    }
}

/** Index k, I0<=k<=I1, such that V[k] is largest element among
 * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    ...
}
Selection Sort

/** Sort items A[L..U], with all others unchanged. */
static void sort(String[] A, int L, int U) {
    if (L < U) {
        int k = indexOfLargest(A, L, U);
        sort(A, L, U-1);  // Sort items L to U-1 of A
    }
}

/** Index k, I0<=k<=I1, such that V[k] is largest element among
 * V[I0], ... V[I1]. Requires I0<I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    ...
}
Selection Sort

/** Sort items A[L..U], with all others unchanged. */
static void sort(String[] A, int L, int U) {
    if (L < U) {
        int k = indexOfLargest(A, L, U);
        sort(A, L, U-1); // Sort items L to U-1 of A
    }
}

What would an iterative version look like?

    while (?) {
        ?
    }
Selection Sort

/** Sort items A[L..U], with all others unchanged. */
static void sort(String[] A, int L, int U) {
    if (L < U) {
        int k = indexOfLargest(A, L, U);
        sort(A, L, U-1); // Sort items L to U-1 of A
    }
}

Iterative version:

    while (L < U) {
        int k = indexOfLargest(A, L, U);
        U -= 1;
    }
/** Index k, I0<=k<=I1, such that V[k] is largest element among * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (?)
        return i1;
    else {
        
    }
}
Find Largest

/** Index k, I0<=k<=I1, such that V[k] is largest element among
 * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        
    }
}
/** Index k, I0<=k<=I1, such that V[k] is largest element among
 * V[I0], ... V[I1]. Requires I0<=I1. */

static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        int k = /*( index of largest value in V[i0 + 1..i1] )*/;
        return /*( whichever of i0 and k has larger value )*/;
    }
}
Find Largest

/** Index k, I0<=k<=I1, such that V[k] is largest element among
 * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        int k = indexOfLargest(V, i0 + 1, i1);
        return /*( whichever of i0 and k has larger value )*/;
    }
}
/** Index k, I0<=k<=I1, such that V[k] is largest element among * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        int k = indexOfLargest(V, i0 + 1, i1);
        return (V[i0].compareTo(V[k]) > 0) ? i0 : k;
        // if (V[i0].compareTo(V[k]) > 0) return i0; else return k;
    }
}

• Turning this into an iterative version is tricky: not tail recursive.
• What are the arguments to compareTo the first time it's called?
Iteratively Find Largest

/** Value k, I0<=k<=I1, such that V[k] is largest element among * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        int k = indexOfLargest(V, i0 + 1, i1);
        return (V[i0].compareTo(V[k]) > 0) ? i0 : k;
        // if (V[i0].compareTo(V[k]) > 0) return i0; else return k;
    }
}

Iterative:

int i, k;

k = ?;  // Deepest iteration
for (i = ?; ...?; i ...?)
   k = ?;
return k;
Iteratively Find Largest

/** Value k, I0<=k<=I1, such that V[k] is largest element among * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        int k = indexOfLargest(V, i0 + 1, i1);
        return (V[i0].compareTo(V[k]) > 0) ? i0 : k;
        // if (V[i0].compareTo(V[k]) > 0) return i0; else return k;
    }
}

Iterative:

int i, k;

k = i1; // Deepest iteration
for (i = ?; ...?; i ...?)
    k = ?;
return k;
Iteratively Find Largest

/** Value k, I0<=k<=I1, such that V[k] is largest element among * V[I0], ... V[I1]. Requires I0<=I1. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        int k = indexOfLargest(V, i0 + 1, i1);
        return (V[i0].compareTo(V[k]) > 0) ? i0 : k;
        // if (V[i0].compareTo(V[k]) > 0) return i0; else return k;
    }
}

Iterative:

int i, k;
    k = i1;  // Deepest iteration
for (i = i1 - 1; i >= i0; i -= 1)
    k = ?;
return k;
Iteratively Find Largest

/** Value $k$, $I_0 \leq k \leq I_1$, such that $V[k]$ is largest element among
 * $V[I_0]$, ..., $V[I_1]$. Requires $I_0 \leq I_1$. */
static int indexOfLargest(String[] V, int i0, int i1) {
    if (i0 >= i1)
        return i1;
    else /* if (i0 < i1) */ {
        int k = indexOfLargest(V, i0 + 1, i1);
        return (V[i0].compareTo(V[k]) > 0) ? i0 : k;
        // if (V[i0].compareTo(V[k]) > 0) return i0; else return k;
    }
}

Iterative:

int i, k;

k = i1; // Deepest iteration
for (i = i1 - 1; i >= i0; i -= 1)

    k = (V[i].compareTo(V[k]) > 0) ? i : k;
return k;
Finally, Printing

/** Print A on one line, separated by blanks. */
static void print(String[] A) {
    for (int i = 0; i < A.length; i += 1)
        System.out.print(A[i] + " ");
    System.out.println();
}

/* Java also provides a simple, specialized syntax for looping
 * through an entire array: */
for (String s : A)
    System.out.print(s + " ");
Another Problem

Given an array of integers, \( A \), of length \( N > 0 \), find the smallest index, \( k \), such that all elements at indices \( \geq k \) and \( < N - 1 \) are greater than \( A[N - 1] \). Then rotate elements \( k \) to \( N - 1 \) right by one. For example, if \( A \) starts out as

{ 1, 9, 4, 3, 0, 12, 11, 9, 15, 22, 12 }

then it ends up as

{ 1, 9, 4, 3, 0, 12, 11, 9, 12, 15, 22 }

As another example,

{ 1, 9, 4, 3, 0, 12, 11, 9, 15, 22, -2 }

would become

{ -2, 1, 9, 4, 3, 0, 12, 11, 9, 15, 22 }

What if \( A \) starts like this?

{ 1, 9, 4, 3, 0, 12, 11, 9, 12, 15, 22 }
Another Problem

Given an array of integers, $A$, of length $N > 0$, find the smallest index, $k$, such that all elements at indices $\geq k$ and $< N - 1$ are greater than $A[N - 1]$. Then rotate elements $k$ to $N - 1$ right by one. For example, if $A$ starts out as

\[
\{ 1, 9, 4, 3, 0, 12, 11, 9, 15, 22, 12 \}
\]

then it ends up as

\[
\{ 1, 9, 4, 3, 0, 12, 11, 9, 12, 15, 22 \}
\]

As another example,

\[
\{ 1, 9, 4, 3, 0, 12, 11, 9, 15, 22, -2 \}
\]

would become

\[
\{ -2, 1, 9, 4, 3, 0, 12, 11, 9, 15, 22 \}
\]

What if $A$ starts like this?

\[
\{ 1, 9, 4, 3, 0, 12, 11, 9, 12, 15, 22 \}
\]

Answer: It’s unchanged. (No, the spec is not ambiguous.)
public class Shove {

    /** Rotate elements $A[k]$ to $A[A.length-1]$ one element to the right, where $k$ is the smallest index such that elements $k$ through $A.length-2$ are all larger than $A[A.length-1]$. */
    static void moveOver(int[] A) {
        // FILL IN
    }
}

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