“True Fun is the confluence of playfulness, connection, and flow. Whenever these three states occur at the same time, we experience True Fun.”

“By playfulness I mean a spirit of lightheartedness and freedom - of doing an activity just for the sake of doing the activity and not caring too much about the outcome.”

“True Fun always involves a sense of connection - the feeling of having a special, shared experience with someone (or something) else.”

“Flow is a term used in psychology to describe when you are fully engrossed and engaged in your present experience to the point that you lose track of the passage of time.”

-- The Power of Fun: How to Feel Alive Again by Price

# CSCI 136:<br>Data Structures<br>and<br>Advanced Programming

## Lecture 14

## Sorting, part 2

Instructor: Kelly Shaw

Williams

## Topics

- Association
- Bubble sort complexity
- How do we sort data of any type?
- Other sorts

## Your to-dos

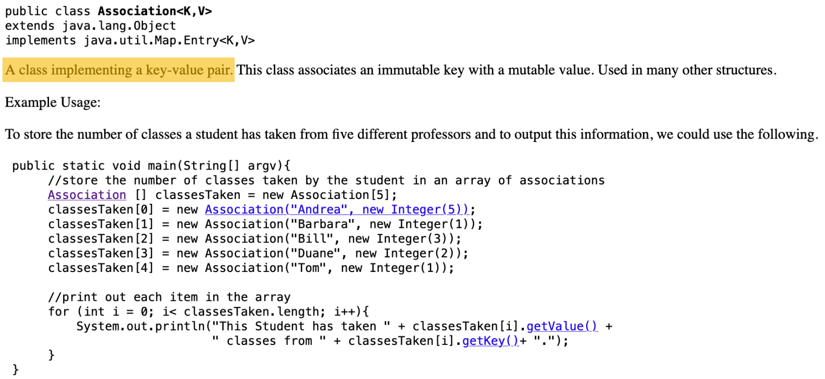
1. Read **before Fri**: Bailey, Ch 6.5-6.6.
2. Quiz 5, **due Saturday by 6pm**.
3. Lab 5, **due Tuesday 10/18 by 10pm**.

# Announcements

1. Midterm: **in lab** two weeks from now:
   **Wed, October 26** and
   **Thu, October 27** and
2. Midterm review: **Mon, October 24** **in class**.
3. No class: **Fri, October 28**.

# Simple data structure for Lab 5…

# Association



```
public class Association<K,V>
extends java.lang.Object
implements java.util.Map.Entry<K,V>
```

A class implementing a key-value pair. This class associates an immutable key with a mutable value. Used in many other structures.

Example Usage:

To store the number of classes a student has taken from five different professors and to output this information, we could use the following.

```
 public static void main(String[] argv){
      //store the number of classes taken by the student in an array of associations
      Association [] classesTaken = new Association[5];
      classesTaken[0] = new Association("Andrea", new Integer(5));
      classesTaken[1] = new Association("Barbara", new Integer(1));
      classesTaken[2] = new Association("Bill", new Integer(3));
      classesTaken[3] = new Association("Duane", new Integer(2));
      classesTaken[4] = new Association("Tom", new Integer(1));

      //print out each item in the array
      for (int i = 0; i< classesTaken.length; i++){
          System.out.println("This Student has taken " + classesTaken[i].getValue() +
                             " classes from " + classesTaken[i].getKey()+ ".");
      }
 }
```

You will need to use `Association` in **Lab 5**.

# Sorting

# Recall: bubble sort

```
public static void bubbleSort(int data[], int n)
// pre: 0 <= n <= data.length
// post: values in data[0..n-1] in ascending order
{
    int numSorted = 0;      // number of values in order
    int index;              // general index
    while (numSorted < n)
    {
        // bubble a large element to higher array index
        for (index = 1; index < n-numSorted; index++)
        {
            if (data[index-1] > data[index])
                swap(data,index-1,index);
        }
        // at least one more value in place
        numSorted++;
    }
}
```

(demo)

# Bubble sort complexity

Bubble sort is an **$O(n^2)$** sorting algorithm in the **worst case**. The naive algorithm is also **$O(n^2)$** in the **best case**. With a small modification, bubble sort is **$O(n)$** in the best case (i.e., where the array is already sorted).

Bubble sort's performance is bad enough that there are few practical uses for it (other than for teaching!).

# What if…

… you wanted to sort **data that isn't just a bunch of ints**?

What's **problematic** with our bubble sort implementation?

## Where is the problem?

```
public static void bubbleSort(int data[], int n)
// pre: 0 <= n <= data.length
// post: values in data[0..n-1] in ascending order
{
    int numSorted = 0;      // number of values in order
    int index;              // general index
    while (numSorted < n)
    {
        // bubble a large element to higher array index
        for (index = 1; index < n-numSorted; index++)
        {
            if (data[index-1] > data[index])
                swap(data,index-1,index);
        }
        // at least one more value in place
        numSorted++;
    }
}
```

## Comparators

## Comparators

We frequently have to sort data that is **more complex** than simple numbers.

For example, suppose we need to sort objects, like a **`People[]`**.

How do we define an order so that we can easily sort this?

**`compare`** to the rescue.

## Comparator interface

The **`Comparator`** **interface** defines the method **`compare`** that lets us compare **two elements** of the same type.

```
public int compare(T o1, T o2)
```

Returns any **`int < 0`** when `o1` is “less than” `o2`.

Returns any **`int > 0`** when `o2` is “less than” `o1`.

Returns **`0`** otherwise.

# Let’s modify this algorithm

```
public static void bubbleSort(int data[], int n)
// pre: 0 <= n <= data.length
// post: values in data[0..n-1] in ascending order
{
    int numSorted = 0;      // number of values in order
    int index;              // general index
    while (numSorted < n)
    {
        // bubble a large element to higher array index
        for (index = 1; index < n-numSorted; index++)
        {
            if (data[index-1] > data[index])
                swap(data,index-1,index);
        }
        // at least one more value in place
        numSorted++;
    }
}
```

(code)

# Better comparison sorts

# Insertion sort

6 5 3 1 8 7 2 4

# Insertion sort

**Insertion sort** is a **sorting algorithm** in which the next element is **“inserted”** into a sorted array during each step. Insertion sort makes **n-1** passes through the sorted data, performing pairwise comparisons of elements using **<**.

Insertion sort maintains the **invariant** that the leftmost **n-numSorted** elements are sorted.

I.e., insertion sort builds a sorted order to the left.

# Insertion sort complexity

Insertion sort is an **$O(n^2)$** sorting algorithm in the **worst case**. Insertion sort is **O(n)** in the best case.

# Insertion sort algorithm

```
public static void insertionSort(int data[], int n)
// pre: 0 <= n <= data.length
// post: values in data[0..n-1] are in ascending order
{
    int numSorted = 1;      // number of values in place
    int index;              // general index
    while (numSorted < n)
    {
        // take the first unsorted value
        int temp = data[numSorted];
        // ...and insert it among the sorted:
        for (index = numSorted; index > 0; index--)
        {
            if (temp < data[index-1])
            {
                data[index] = data[index-1];
            } else {
                break;
            }
        }
        // reinsert value
        data[index] = temp;
        numSorted++;
    }
}
```

## On your own…

Read about **selection sort** from the book.

## Recap & Next Class

### Today:

- Association
- Sort complexity
- Comparators

### Next class:

- Very fast comparison sorts