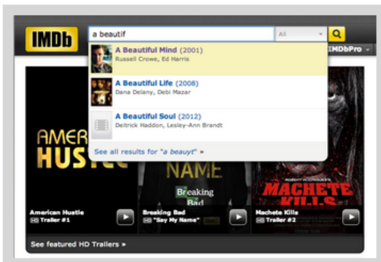
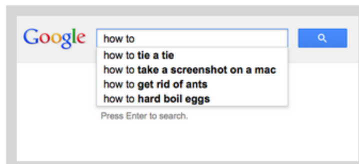
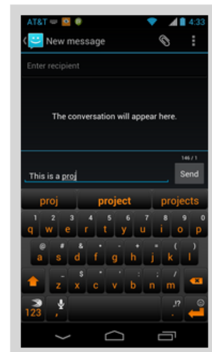
Goal The purpose of this assignment is to write a program to implement *autocomplete* for a given set of n strings and nonnegative weights. That is, given a prefix, find all strings in the set that start with the prefix, in descending order of weight.

Autocomplete is an important feature of many modern applications. As the user types, the program predicts the complete *query* (typically a word or phrase) that the user intends to type. Autocomplete is most effective when there are a limited number of likely queries. For example, the Internet Movie Database uses it to display the names of movies as the user types; search engines use it to display suggestions as the user enters web search queries; cell phones use it to speed up text input.







In these examples, the application predicts how likely it is that the user is typing each query and presents to the user a list of the top-matching queries, in descending order of weight. These weights are determined by historical data, such as box office revenue for movies, frequencies of search queries from other Google users, or the typing history of a cell phone user. For the purposes of this assignment, you will have access to a set of all possible queries and associated weights (and these queries and weights will not change).

The performance of autocomplete functionality is critical in many systems. For example, consider a search engine which runs an autocomplete application on a server farm. According to one study, the application has only about 50ms to return a list of suggestions for it to be useful to the user. Moreover, in principle, it must perform this computation *for every keystroke typed into the search bar* and *for every user*!

In this assignment, you will implement autocomplete by sorting the queries in lexicographic order; using binary search to find the set of queries that start with a given prefix; and sorting the matching queries in descending order by weight.

Problem 1. (*Autocomplete Term*) Implement an immutable comparable data type called `Term` that represents an autocomplete term: a string query and an associated real-valued weight. You must implement the following API, which supports comparing terms by three different orders: lexicographic order by query; in descending order by weight; and lexicographic order by query but using only the first r characters. The last order may seem a bit odd, but you will use it in Problem 3 to find all terms that start with a given prefix (of length r).

☰ `Term`	
`Term(String query)`	constructs a term given the associated query string, having weight 0
`Term(String query, long weight)`	constructs a term given the associated query string and weight
`String toString()`	returns a string representation of this term
`int compareTo(Term that)`	returns a comparison of this term and `other` by query
`static Comparator<Term> byReverseWeightOrder()`	returns a comparator for comparing two terms in reverse order of their weights
`static Comparator<Term> byPrefixOrder(int r)`	returns a comparator for comparing two terms by their prefixes of length `r`

Corner Cases

- The constructor should throw a `NullPointerException("query is null")` if *query* is `null` and an `IllegalArgumentException("Illegal weight")` if $weight < 0$.

- The `byPrefixOrder()` method should throw an `IllegalArgumentException("Illegal r")` if $r < 0$.

Performance Requirements

- The string comparison methods should run in time $T(n) \sim n$, where n is number of characters needed to resolve the comparison.

```
>_ ~/workspace/project3

$ java Term data/baby-names.txt 5
Top 5 by lexicographic order:
11      Aaban
5       Aabha
11      Aadam
11      Aadan
12      Aadarsh
Top 5 by reverse-weight order:
22175   Sophia
20811   Emma
18949   Isabella
18936   Mason
18925   Jacob
```

Directions:

- Instance variables:
  - Query string, `String query`.
  - Query weight, `long weight`.
- `Term(String query)` and `Term(String query, long weight)`
  - Initialize instance variables to appropriate values.
- `String toString()`
  - Return a string containing the weight and query separated by a tab.
- `int compareTo(Term other)`
  - Return a negative, zero, or positive integer based on whether `this.query` is less than, equal to, or greater than `other.query`.
- `static Comparator<Term> byReverseWeightOrder()`
  - Return an object of type `ReverseWeightOrder`.
- `static Comparator<Term> byPrefixOrder(int r)`
  - Return an object of type `PrefixOrder`.
- `Term` :: `ReverseWeightOrder`
  - `int compare(Term v, Term w)`
    - Return a negative, zero, or positive integer based on whether `v.weight` is less than, equal to, or greater than `w.weight`.
- `Term` :: `PrefixOrder`
  - Instance variable:
    - Prefix length, `int r`.
  - `PrefixOrder(int r)`
    - Initialize instance variable appropriately.
  - `int compare(Term v, Term w)`

    * Return a negative, zero, or positive integer based on whether `a` is less than, equal to, or greater than `b`, where `a` is a substring of `v` of length `min(r, v.query.length())` and `b` is a substring of `w` of length `min(r, w.query.length())`.

Problem 2. (*Binary Search Deluxe*) When binary searching a sorted array that contains more than one key equal to the search key, the client may want to know the index of either the first or the last such key. Accordingly, implement a library called `BinarySearchDeluxe` with the following API:

BinarySearchDeluxe	
`static int firstIndexOf(Key[] a, Key key, Comparator<Key> c)`	returns the index of the first key in `a` that equals the search `key`, or -1, according to the order induced by the comparator `c`
`static int lastIndexOf(Key[] a, Key key, Comparator<Key> c)`	returns the index of the last key in `a` that equals the search `key`, or -1, according to the order induced by the comparator `c`

Corner Cases

- Each method should throw a `NullPointerException("a, key, or c is null")` if any of the arguments is `null`. You may assume that the array `a` is sorted (with respect to the comparator `c`).

Performance Requirements

- Each method should should run in time $T(n) \sim \log n$, where n is the length of the array `a`.

```
~/workspace/project3
$ java BinarySearchDeluxe data/wiktionary.txt love
firstIndexOf(love) = 5318
lastIndexOf(love)  = 5324
frequency(love)    = 7
$ java BinarySearchDeluxe data/wiktionary.txt coffee
firstIndexOf(coffee) = 1628
lastIndexOf(coffee)  = 1628
frequency(coffee)    = 1
$ java BinarySearchDeluxe data/wiktionary.txt java
firstIndexOf(java) = -1
lastIndexOf(java)  = -1
frequency(java)    = 0
```

Directions:

- `static int firstIndexOf(Key[] a, Key key, Comparator<Key> c)`
  - Modify the standard binary search such that when `a[mid]` matches `key`, instead of returning `mid`, remember it in, say `index` (initialized to -1), and adjust `hi` appropriately.
  - Return `index`.
- `static int lastIndexOf(Key[] a, Key key, Comparator<Key> c)` can be implemented similarly.

Problem 3. (*Autocomplete*) In this part, you will implement a data type that provides autocomplete functionality for a given set of string and weights, using `Term` and `BinarySearchDeluxe`. To do so, *sort* the terms in lexicographic order; use *binary search* to find the set of terms that start with a given prefix; and sort the matching terms in descending order by weight. Organize your program by creating an immutable data type called `Autocomplete` with the following API:

Autocomplete	
`Autocomplete(Term[] terms)`	constructs an autocomplete data structure from an array of `terms`
`Term[] allMatches(String prefix)`	returns all terms that start with `prefix`, in descending order of their weights.
`int numberOfMatches(String prefix)`	returns the number of terms that start with `prefix`

Corner Cases

- The constructor should throw a `NullPointerException("terms is null")` if $terms$ is `null`.
- Each method should throw a `NullPointerException("prefix is null)"` if $prefix$ is `null`.

Performance Requirements

- The constructor should run in time $T(n) \sim n \log n$, where n is the number of terms.
- The `allMatches()` method should run in time $T(n) \sim \log n + m \log m$, where m is the number of matching terms.
- The `numberOfMatches()` method should run in time $T(n) \sim \log n$.

```
>_ ~/workspace/project3

$ java Autocomplete data/wiktionary.txt 5
Enter a prefix (or ctrl-d to quit): love
First 5 matches for "love", in descending order by weight:
  49649600      love
  12014500      loved
  5367370       lovely
  4406690       lover
  3641430       loves
Enter a prefix (or ctrl-d to quit): coffee
All matches for "coffee", in descending order by weight:
  2979170       coffee
Enter a prefix (or ctrl-d to quit):
First 5 matches for "", in descending order by weight:
  5627187200    the
  3395006400    of
  2994418400    and
  2595609600    to
  1742063600    in
Enter a prefix (or ctrl-d to quit): <ctrl-d>
```

Directions:

- Instance variable:
  - Array of terms, `Term[] terms`.
- `Autocomplete(Term[] terms)`
  - Initialize `this.terms` to a defensive copy (ie, a fresh copy and not an alias) of. `terms`
  - Sort `this.terms` in lexicographic order.
- `Term[] allMatches(String prefix)`
  - Find the index `i` of the first term in `terms` that starts with `prefix`.
  - Find the number of terms (say `n`) in `terms` that start with `prefix`.
  - Construct an array `matches` containing `n` elements from `terms`, starting at. index `i`
  - Sort `matches` in reverse order of weight and return the sorted array.
- `int numberOfMatches(String prefix)`
  - Find the indices `i` and `j` of the first and last term in `terms` that start with `prefix`.
  - Using the indices, compute the number of terms that start with `prefix`, and return that value.

Data The `data` directory contains sample input files for testing. For example

```
>_ ~/workspace/project3

$ more data/wiktionary.txt
10000
    5627187200  the
    3395006400  of
           ...  ...
```

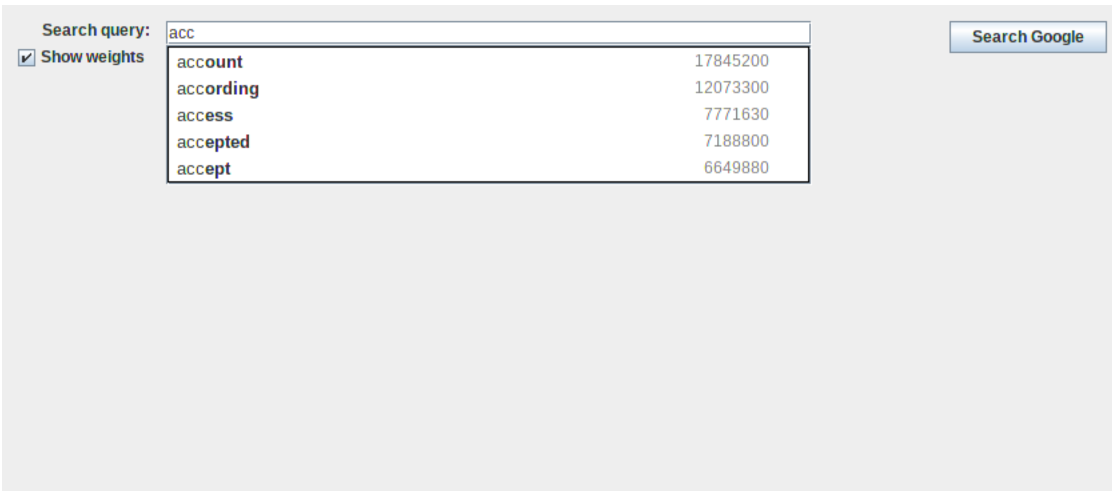
```
        392402   wench
        392323   calves
```

The first line specifies the number of terms and the following lines specify the weight and query string for each of those terms.

Visualization Program The program `AutocompleteVisualizer` accepts the name of a file and an integer k as command-line arguments, provides a GUI for the user to enter queries, and presents the top k matching terms in real time.

```
>_ ~/workspace/project3

$ java AutocompleteVisualizer data/wiktionary.txt 5
```



Acknowledgements This project is an adaptation of the Autocomplete Me assignment developed at Princeton University by Matthew Drabick and Kevin Wayne.

Files to Submit

1. `Term.java`
2. `BinarySearchDeluxe.java`
3. `Autocomplete.java`
4. `notes.txt`

Before you submit your files, make sure:

- You do not use concepts outside of what has been taught in class.
- Your programs meet the style requirements by running the following command in the terminal.

```
>_ ~/workspace/project3

$ check_style src/*.java
```

- Your code is adequately commented, follows good programming principles, and meets any specific requirements such as corner cases and running times.
- You update the `notes.txt` file.