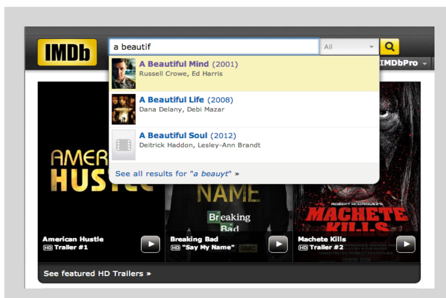
Autocomplete Assignment

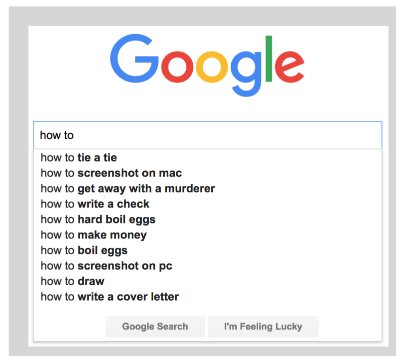
Web Clip

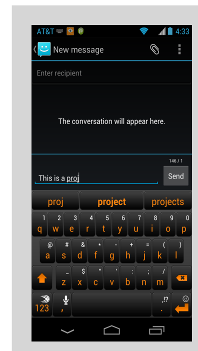
Partnering is permitted on this assignment. Before partnering, read the [COS 226 collaboration policy](#).

Write a program to implement *autocomplete* for a given set of *n terms*, where a term is a query string and an associated non-negative weight. That is, given a prefix, find all queries that start with the given prefix, in descending order of weight.

Autocomplete is pervasive in 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 50*ms* 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 terms by query string; *binary searching* to find all query strings that start with a given prefix; and *sorting* the matching terms by weight.

Part 1: autocomplete term. Write an immutable data type `Term.java` that represents an autocomplete *term*—a query string and an associated integer weight. You must implement the following API, which supports comparing terms by three different orders: [lexicographic order](#) by query string (the natural order); in descending order by weight (an alternate order); and lexicographic order by query string but using only the first *r* characters (a family of alternate orderings). The last order may seem a bit odd, but you will use it in *Part 3* to find all query strings that start with a given prefix (of length *r*).

```
public class Term implements Comparable<Term> {

  // Initializes a term with the given query string and weight.
  public Term(String query, long weight)

  // Compares the two terms in descending order by weight.
  public static Comparator<Term> byReverseWeightOrder()

  // Compares the two terms in lexicographic order,
  // but using only the first r characters of each query.
  public static Comparator<Term> byPrefixOrder(int r)

  // Compares the two terms in lexicographic order by query.
  public int compareTo(Term that)

  // Returns a string representation of this term in the following format:
  // the weight, followed by a tab, followed by the query.
  public String toString()

  // unit testing (required)
  public static void main(String[] args)

}
```

Corner cases. Throw an `IllegalArgumentException` in the constructor if either `query` is `null` or `weight` is negative. Throw an `IllegalArgumentException` in `byPrefixOrder()` if `r` is negative.

Unit testing. Your `main()` method must call each public constructor and method directly and help verify that they work as prescribed (e.g., by printing results to standard output).

Performance requirements. The string comparison functions must take time proportional to the number of characters needed to resolve the comparison.

Part 2: binary search. 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 the following API:

```
public class BinarySearchDeluxe {

 // Returns the index of the first key in the sorted array a[]
 // that is equal to the search key, or -1 if no such key.
 public static <Key> int firstIndexOf(Key[] a, Key key, Comparator<Key> comparator)

 // Returns the index of the last key in the sorted array a[]
 // that is equal to the search key, or -1 if no such key.
 public static <Key> int lastIndexOf(Key[] a, Key key, Comparator<Key> comparator)

 // unit testing (required)
 public static void main(String[] args)
}
```

Corner cases. Throw an `IllegalArgumentException` if any argument to either `firstIndexOf()` or `lastIndexOf()` is `null`.
Preconditions. Assume that the argument array is in sorted order (with respect to the supplied comparator).
Unit testing. Your `main()` method must call each public method directly and help verify that they work as prescribed (e.g., by printing results to standard output).
Performance requirements. The `firstIndexOf()` and `lastIndexOf()` methods must make at most $1 + \lceil \log_2 n \rceil$ compares in the worst case, where *n* is the length of the array. In this context, a *compare* is one call to `comparator.compare()`.
Part 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 all query strings 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 `Autocomplete` with the following API:

```
public class Autocomplete {

 // Initializes the data structure from the given array of terms.
 public Autocomplete(Term[] terms)

 // Returns all terms that start with the given prefix, in descending order of weight.
 public Term[] allMatches(String prefix)

 // Returns the number of terms that start with the given prefix.
```

```
public int numberOfMatches(String prefix)

// unit testing (required)
public static void main(String[] args)

}
```

Corner cases. Throw an `IllegalArgumentException` in the constructor if either its argument array is `null` or any entry is `null`. Throw an `IllegalArgumentException` in `allMatches()` and `numberOfMatches()` if its argument is `null`.

Unit testing. Your `main()` method call each public constructor and method directly and help verify that they work as prescribed (e.g., by printing results to standard output).

Performance requirements. Your implementation must achieve each of the following worst-case performance requirements:

- The constructor must make $O(n \log n)$ compares where *n* is the number of terms.
- The `allMatches()` method must make $O(m \log m + \log n)$ compares, where *m* is the number of matching terms.
- The `numberOfMatches()` method must make $O(\log n)$ compares.

In this context, a *compare* is one call to any of the `compare()` or `compareTo()` methods defined in `Term`.

Input format. We provide a number of sample input files for testing. Each file consists of an integer *n* followed by *n* pairs of query strings and non-negative weights. There is one pair per line, with the weight and string separated by a tab. A weight can be any integer between 0 and $2^{63} - 1$. A query string can be any sequence of Unicode characters, including spaces (but not newlines).

- The file wiktionary.txt contains the 10,000 most common words in Project Gutenberg, with weights proportional to their frequencies.
- The file cities.txt contains 93,827 cities, with weights equal to their populations.

```
~/Desktop/autocomplete> more wiktionary.txt
10000
 5627187200    the
 3395006400    of
 2994418400    and
 2595609600    to
 1742063600    in
 1176479700    i
 1107331800    that
 1007824500    was
 879975500    his
 ...
 392323    calves
```

```
~/Desktop/autocomplete> more cities.txt
93827
 14608512    Shanghai, China
 13076300    Buenos Aires, Argentina
 12691836    Mumbai, India
 12294193    Mexico City, Distrito Federal, Mexico
 11624219    Karachi, Pakistan
 11174257    İstanbul, Turkey
 10927986    Delhi, India
 10444527    Manila, Philippines
 10381222    Moscow, Russia
 ...
 2    Al Khāniq, Yemen
```

Below is a sample client that takes the name of an input file and an integer *k* as command-line arguments. It reads the data from the file; then it repeatedly reads autocomplete queries from standard input, and prints the top *k* matching terms in descending order of weight.

```
public static void main(String[] args) {
```

```
public static void main(String[] args) {

// read in the terms from a file
String filename = args[0];
In in = new In(filename);
int n = in.readInt();
Term[] terms = new Term[n];
for (int i = 0; i < n; i++) {
long weight = in.readLong(); // read the next weight
in.readChar(); // scan past the tab
String query = in.readLine(); // read the next query
terms[i] = new Term(query, weight); // construct the term
}

// read in queries from standard input and print the top k matching terms
int k = Integer.parseInt(args[1]);
Autocomplete autocomplete = new Autocomplete(terms);
while (StdIn.hasNextLine()) {
String prefix = StdIn.readLine();
Term[] results = autocomplete.allMatches(prefix);
StdOut.printf("%d matches\n", autocomplete.numberOfMatches(prefix));
for (int i = 0; i < Math.min(k, results.length); i++)
StdOut.println(results[i]);
}
}
```

Here are a few sample executions:

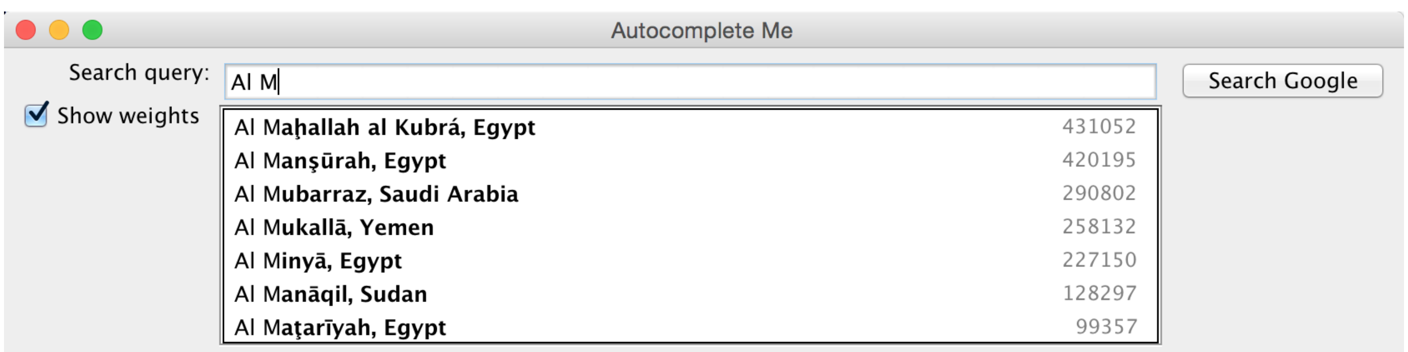
```
~/Desktop/autocomplete> java-algs4 Autocomplete wiktionary.txt 5
auto
2 matches
 619695    automobile
 424997    automatic
comp
52 matches
 13315900    company
 7803980    complete
 6038490    companion
 5205030    completely
 4481770    comply
the
38 matches
 5627187200    the
 334039800    they
```

```
 282026500    their
 250991700    them
 196120000    there

~/Desktop/autocomplete> java-algs4 Autocomplete cities.txt 7
M
7211 matches
 12691836 Mumbai, India
 12294193 Mexico City, Distrito Federal, Mexico
 10444527 Manila, Philippines
 10381222 Moscow, Russia
 3730206 Melbourne, Victoria, Australia
 3268513 Montréal, Quebec, Canada
 3255944 Madrid, Spain
Al M
39 matches
 431052 Al Maḩallah al Kubrá, Egypt
 420195 Al Manşūrah, Egypt
 290802 Al Mubarraz, Saudi Arabia
 258132 Al Mukallā, Yemen
 227150 Al Minyā, Egypt
 128297 Al Manāqil, Sudan
 99357 Al Maţarīyah, Egypt
```

Interactive GUI (optional, but fun and no extra work). Download and compile AutocompleteGUI.java . The program takes the name of a file and an integer *k* as command-line arguments and provides a GUI for the user to enter queries. It presents the top *k* matching terms in real time. When the user selects a term, the GUI opens up the results from a Google search for that term in a browser.

```
~/Desktop/autocomplete> java-algs4 AutocompleteGUI cities.txt 7
```



Deliverables. Submit `Autocomplete.java`, `BinarySearchDeluxe.java`, and `Term.java`. Do not call any library functions other than those in `java.lang`, `java.util`, and `algs4.jar`. Finally, submit a readme.txt file and answer the questions.

Grading.

file	*points*
`Term.java`	13
`BinarySearchDeluxe.java`	10
`Autocomplete.java`	12
`readme.txt`	5
	40

Reminder: You can lose up to 4 points for poor style and up to 4 points for inadequate unit testing.

This assignment was developed by Matthew Drabick and Kevin Wayne.