CSE 143
Lecture 12

Maps/Sets; Grammars

reading: 11.2 - 11.3

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Exercise

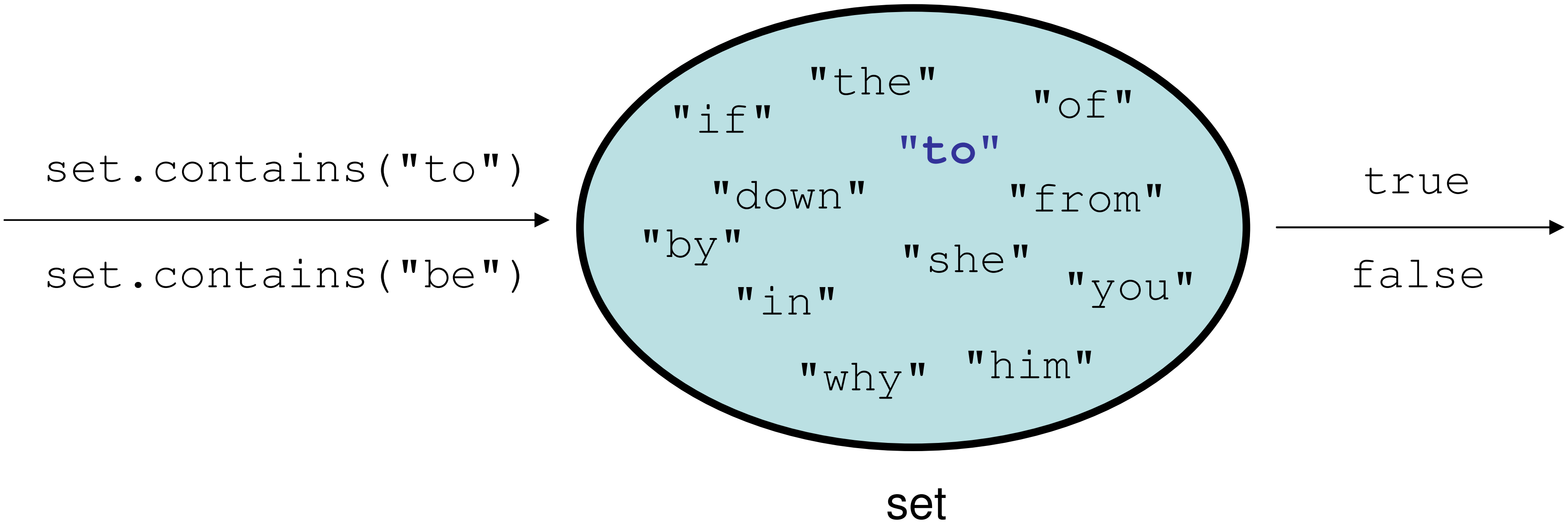
- Write a program that counts the number of unique words in a large text file (say, *Moby Dick* or the King James Bible).
  - Store the words in a collection and report the # of unique words.
  - Once you've created this collection, allow the user to search it to see whether various words appear in the text file.

- What collection is appropriate for this problem?

Sets (11.2)

- **set**: A collection of unique values (no duplicates allowed) that can perform the following operations efficiently:
  - add, remove, search (contains)

  - We don't think of a set as having indexes; we just add things to the set in general and don't worry about order



`Set` implementation

- in Java, sets are represented by `Set` type in `java.util`
- `Set` is implemented by `HashSet` and `TreeSet` classes
  - `HashSet`: implemented using a "hash table" array;
    very fast: **O(1)** for all operations
    elements are stored in unpredictable order
  - `TreeSet`: implemented using a "binary search tree";
    pretty fast: **O(log N)** for all operations
    elements are stored in sorted order
  - `LinkedHashSet`: **O(1)** but stores in order of insertion;
    slightly slower than `HashSet` because of extra info stored

Set methods

```
List<String> list = new ArrayList<String>();
...
Set<Integer> set = new TreeSet<Integer>();      // empty
Set<String> set2 = new HashSet<String>(list);
```

– can construct an empty set, or one based on a given collection

`add(`**value**`)`	adds the given value to the set
`contains(`**value**`)`	returns `true` if the given value is found in this set
`remove(`**value**`)`	removes the given value from the set
`clear()`	removes all elements of the set
`size()`	returns the number of elements in list
`isEmpty()`	returns `true` if the set's size is 0
`toString()`	returns a string such as `"[3, 42, -7, 15]"`

The "for each" loop (7.1)

```
for (type name : collection) {
    statements;
}
```

- Provides a clean syntax for looping over the elements of a `Set`, `List`, array, or other collection

```
Set<Double> grades = new HashSet<Double>();
...

for (double grade : grades) {
    System.out.println("Student's grade: " + grade);
}
```

  - needed because sets have no indexes; can't `get` element `i`

Exercise

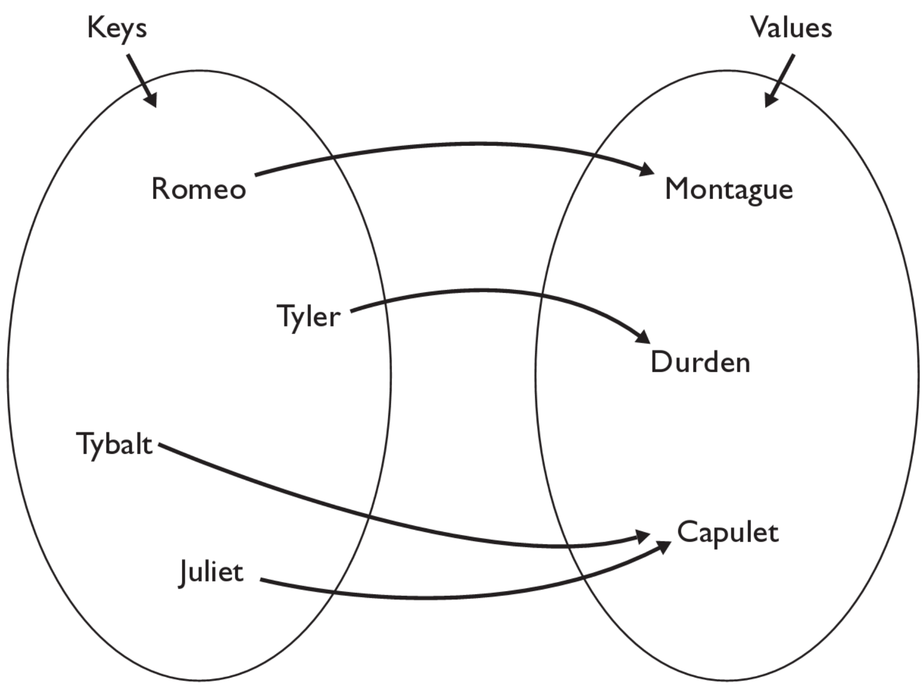
- Write a program to <u>count the number of occurrences</u> of each unique word in a large text file (e.g. *Moby Dick*).
  - Allow the user to type a word and report how many times that word appeared in the book.
  - Report all words that appeared in the book at least 500 times, in alphabetical order.

- What collection is appropriate for this problem?

Maps (11.3)

- **map**: Holds a set of unique *keys* and a collection of *values*, where each key is associated with one value.
  - a.k.a. "dictionary", "associative array", "hash"

- basic map operations:
  - **put**(*key*, *value*): Adds a mapping from a key to a value.
  - **get**(*key*): Retrieves the value mapped to the key.
  - **remove**(*key*): Removes the given key and its mapped value.



`myMap.get("Juliet")` returns `"Capulet"`

`Map` implementation

- in Java, maps are represented by `Map` type in `java.util`
- `Map` is implemented by the `HashMap` and `TreeMap` classes
  - `HashMap`: implemented using an array called a "hash table"; extremely fast: **O(1)** ; keys are stored in unpredictable order
  - `TreeMap`: implemented as a linked "binary tree" structure; very fast: **O(log N)** ; keys are stored in sorted order
  - `LinkedHashMap`: O(1) ; keys are stored in order of insertion
- A map requires 2 type params: one for keys, one for values.

```
// maps from String keys to Integer values
Map<String, Integer> votes = new HashMap<String, Integer>();
```

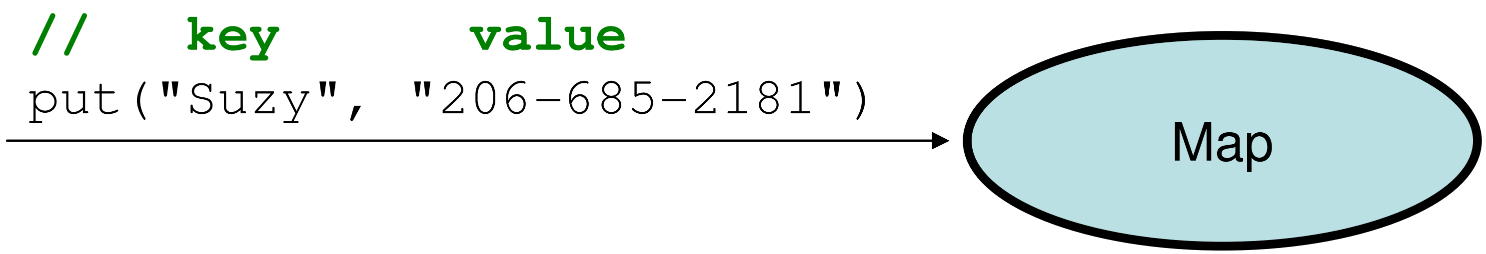
Map methods

put(**key**, **value**)	adds a mapping from the given key to the given value; if the key already exists, replaces its value with the given one
get(**key**)	returns the value mapped to the given key (null if not found)
containsKey(**key**)	returns true if the map contains a mapping for the given key
remove(**key**)	removes any existing mapping for the given key
clear()	removes all key/value pairs from the map
size()	returns the number of key/value pairs in the map
isEmpty()	returns true if the map's size is 0
toString()	returns a string such as "{a=90, d=60, c=70}"

keySet()	returns a set of all keys in the map
values()	returns a collection of all values in the map
putAll(**map**)	adds all key/value pairs from the given map to this map
equals(**map**)	returns true if given map has the same mappings as this one

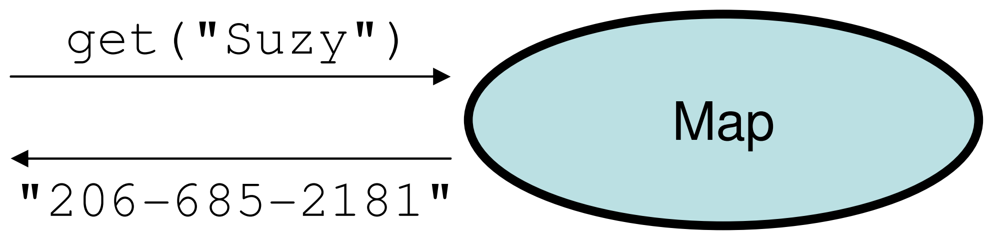
Using maps

- A map allows you to get from one half of a pair to the other.
  - Remembers one piece of information about every index (key).



  - Later, we can supply only the key and get back the related value:

    Allows us to ask: *What is Suzy's phone number?*



Maps and tallying

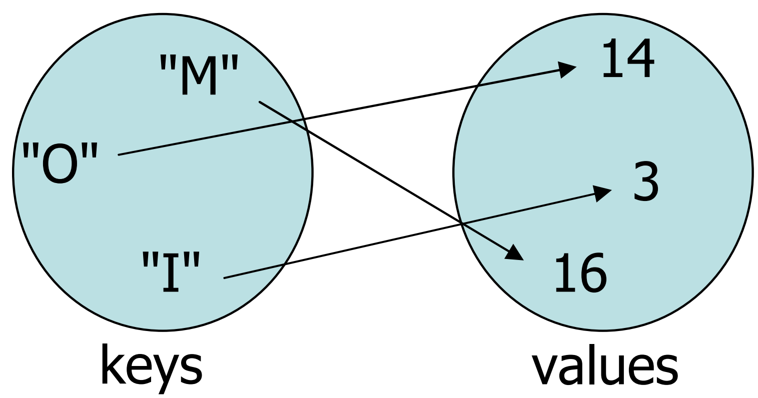
- a map can be thought of as generalization of a tallying array
  - the "index" (key) doesn't have to be an `int`
  - count digits: `22092310907`

index	0	1	2	3	4	5	6	7	8	9
value	3	1	3	0	0	0	0	1	0	2

```
// (M)cCain, (O)bama, (I)ndependent
```

  - count votes: `"MOOOOOOMMMMMOOOOOOMOMMIMOMMIMOMMIO"`

key	"M"	"O"	"I"
value	16	14	3



`keySet` and `values`

- `keySet` method returns a `Set` of all keys in the map
  - can loop over the keys in a foreach loop
  - can get each key's associated value by calling `get` on the map

```
Map<String, Integer> ages = new TreeMap<String, Integer>();
ages.put("Marty", 19);
ages.put("Geneva", 2);   // ages.keySet() returns Set<String>
ages.put("Vicki", 57);
for (String name : ages.keySet()) {            // Geneva -> 2
    int age = ages.get(name);                  // Marty -> 19
    System.out.println(name + " -> " + age);   // Vicki -> 57
}
```

- `values` method returns a collection of all values in the map
  - can loop over the values in a foreach loop
  - no easy way to get from a value to its associated key(s)

Languages and Grammars

Languages and grammars

- (formal) **language**: A set of words or symbols.

- **grammar**: A description of a language that describes which sequences of symbols are allowed in that language.
  - describes language *syntax* (rules) but not *semantics* (meaning)
  - can be used to generate strings from a language, or to determine whether a given string belongs to a given language

Backus-Naur (BNF)

- **Backus-Naur Form (BNF)**: A syntax for describing language grammars in terms of transformation *rules*, of the form:

  <**symbol**> ::= <**expression**> | <**expression**> ... | <**expression**>

  – **terminal**: A fundamental symbol of the language.
  – **non-terminal**: A high-level symbol describing language syntax, which can be transformed into other non-terminal or terminal symbol(s) based on the rules of the grammar.

  – developed by two Turing-award-winning computer scientists in 1960 to describe their new ALGOL programming language

An example BNF grammar

```
<s>::=<n> <v>
<n>::=Marty | Victoria | Stuart | Jessica
<v>::=cried | slept | belched
```

- Some sentences that could be generated from this grammar:

```
Marty slept
Jessica belched
Stuart cried
```

BNF grammar version 2

<s>::=<np> <v>
<np>::=<pn> | <dp> <n>
<pn>::=Marty | Victoria | Stuart | Jessica
<dp>::=a | the
<n>::=ball | hamster | carrot | computer
<v>::=cried | slept | belched

- Some sentences that could be generated from this grammar:

```
the carrot cried
Jessica belched
a computer slept
```

BNF grammar version 3

```
<s>::=<np> <v>
<np>::=<pn> | <dp> <adj> <n>
<pn>::=Marty | Victoria | Stuart | Jessica
<dp>::=a | the
<adj>::=silly | invisible | loud | romantic
<n>::=ball | hamster | carrot | computer
<v>::=cried | slept | belched
```

- Some sentences that could be generated from this grammar:

```
the invisible carrot cried
Jessica belched
a computer slept
a romantic ball belched
```

Grammars and recursion

```
<s>::=<np> <v>
<np>::=<pn> | <dp> <adjp> <n>
<pn>::=Marty | Victoria | Stuart | Jessica
<dp>::=a | the
<adjp>::=<adj> <adjp> | <adj>
<adj>::=silly | invisible | loud | romantic
<n>::=ball | hamster | carrot | computer
<v>::=cried | slept | belched
```

- Grammar rules can be defined *recursively*, so that the expansion of a symbol can contain that same symbol.
  - There must also be expressions that expand the symbol into something non-recursive, so that the recursion eventually ends.

Grammar, final version

```
<s>::=<np> <vp>
<np>::=<dp> <adjp> <n>|<pn>
<dp>::=the|a
<adjp>::=<adj>|<adj> <adjp>
<adj>::=big|fat|green|wonderful|faulty|subliminal
<n>::=dog|cat|man|university|father|mother|child
<pn>::=John|Jane|Sally|Spot|Fred|Elmo
<vp>::=<tv> <np>|<iv>
<tv>::=hit|honored|kissed|helped
<iv>::=died|collapsed|laughed|wept
```

- Could this grammar generate the following sentences?

```
Fred honored the green wonderful child
big Jane wept the fat man fat
```

- Generate a random sentence using this grammar.

Sentence generation