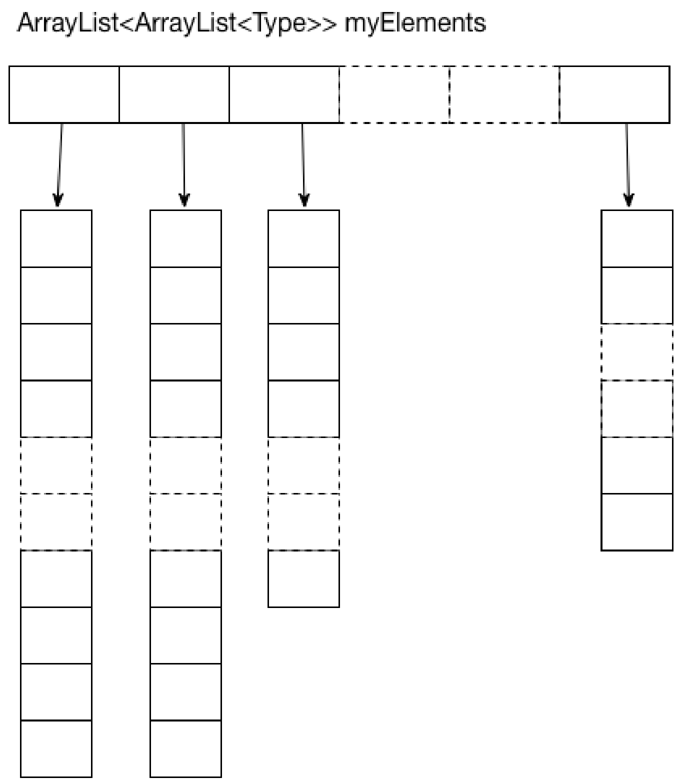
Compsci 201
Maps and Midterms

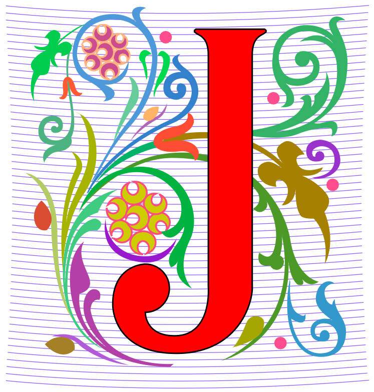


Susan Rodger

February 12, 2020

`J` is for …

- **Java**
  - A simple, object-oriented, distributed, interpreted, robust, secure, architecture-neutral, portable, high performance, multi-threaded, and dynamic language.
- **Just in Time Teaching**
  - Introduce concepts when needed, in context of solving problems. WOTO style



Announcements

- Exam 1 Friday, Feb 14!
- Assignment P2 due tomorrow, Feb 13
  - Get it done early, great practice for exam
  - Grace period is extended
- Assignment P3 will build on Assignment P2
- APT-Quiz coming next week
  - Do by yourself
- Discussion 6 on Feb 17

PFTDBE1

- Maps: API and Problem Solving
  - Keys and Values
- Toward Hashing DIYAD
  - From locker analogies to code
- Midterm details and review
  - What to do, bring, think about

Go over – WOTO from last time

http://bit.ly/201spring20-0207-2

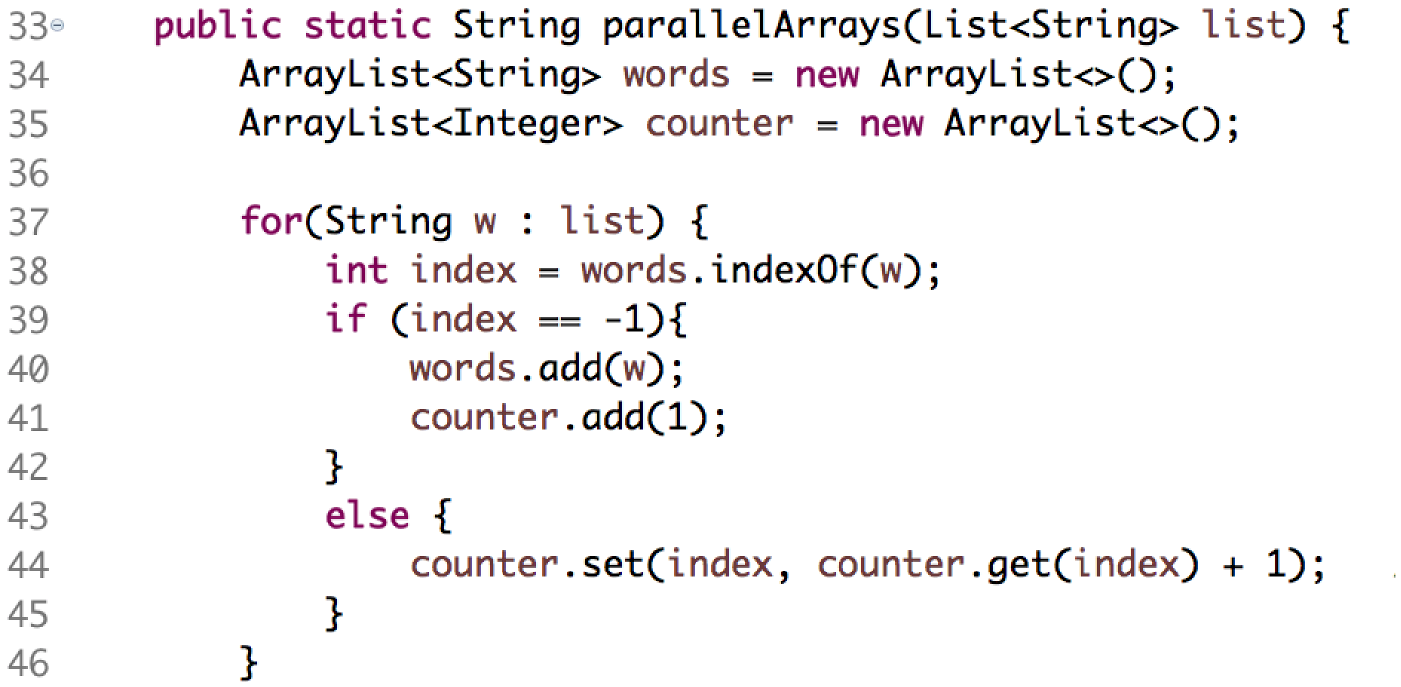
Problems and Solutions

- String that occurs most in a list of strings?
  - CountingStringsBenchmark.java, two ideas
    - See also CountingStringsFile for same ideas
    - https://coursework.cs.duke.edu/201spring20/classcode
  - Parallel arrays: word[k] occurs count[k] times
  - Use ArrayLists: 2 “the”, 3 “fat”, 4 “fox”

the	**fox**	**cried**	**fat**	**tears**
0	*1*	*2*	*3*	*4*
2	**4**	**1**	**3**	**5**

How does the code work?

- Process each string s
  - First time **`words.add(s),counter.add(1)`**
  - Otherwise, increment count corresponding to s
  - **`c[s] += 1 ?`**

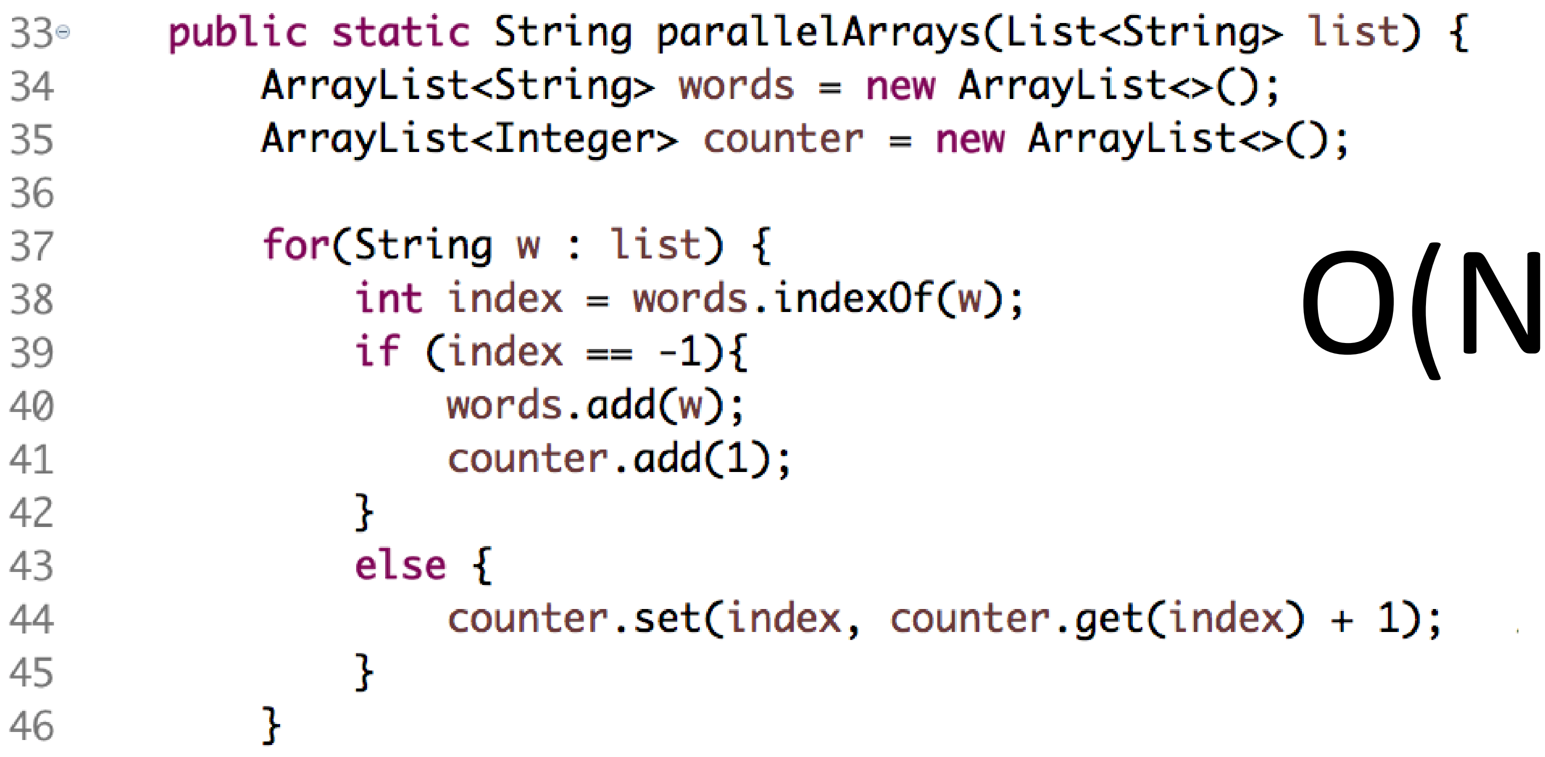


```java
    public static String parallelArrays(List<String> list) {
        ArrayList<String> words = new ArrayList<>();
        ArrayList<Integer> counter = new ArrayList<>();

        for(String w : list) {
            int index = words.indexOf(w);
            if (index == -1){
                words.add(w);
                counter.add(1);
            }
            else {
                counter.set(index, counter.get(index) + 1);
            }
        }
```

Tracking N strings

- Complexity of search? O(M) for M different words
  - Complexity of **`words.indexOf(..)`** is O(M)
  - what about all calls? 1 + 2 + … N is N(N+1)/2



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            counter.add(1);
        }
        else {
            counter.set(index, counter.get(index) + 1);
        }
    }
```

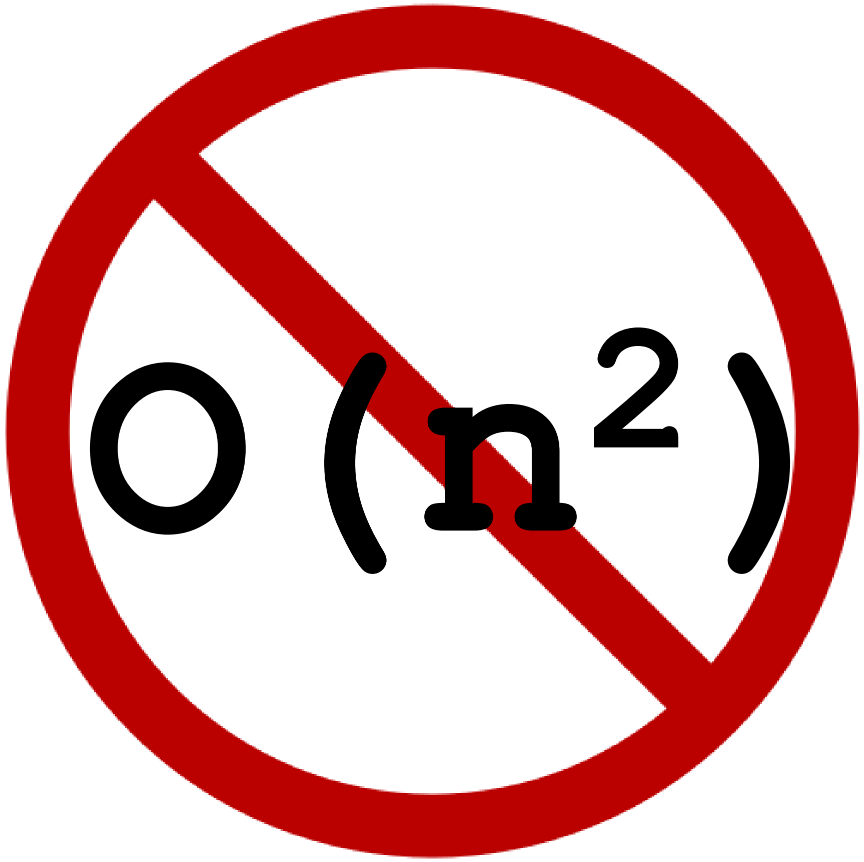
$O(N^2)$

Understanding O-notation

- This is an upper bound and in the limit
  - Coefficients don't matter, *order of* growth
  - N + N + N + N = 4N is O(N) --- why?
  - 100*N*N is O(N^2) – why?
  - O(1) means independent of N, constant time

- In analyzing code and code fragments
  - Account for each statement
  - How many times is each statement executed?

Just Say No.. When you can



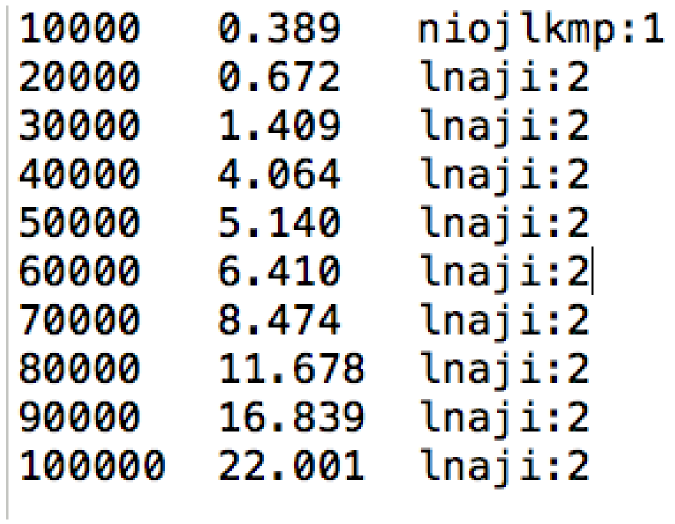
CountingStringsFile.java

- Generate an ArrayList of Strings
  - Find the word that occurs the most often
    - See three different methods

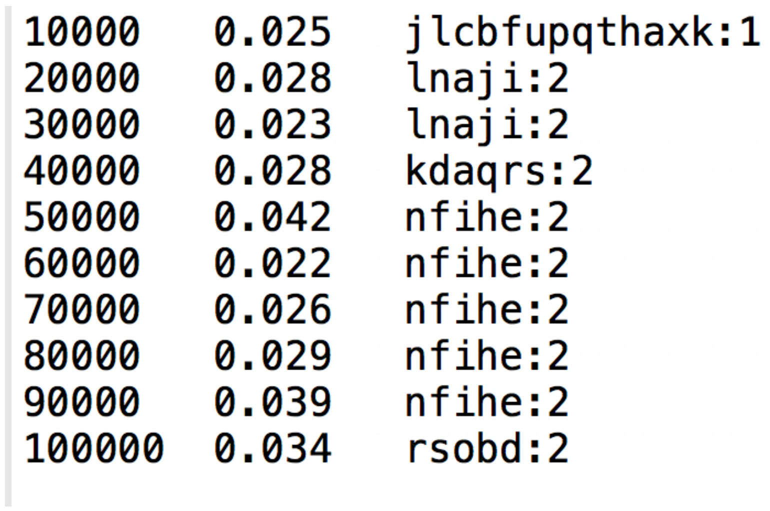
LIVE CODING

O(N^2) too slow, solution?

- Rather than parallel arrays, where search is O(N)
  - Use hashing, where search is **`O(1)`** – wow!
  - (String,Integer) stored together in *map*
    - *Different than parallel arrays, here stored together*



```
10000    0.389    niojlkmp:1
20000    0.672    lnaji:2
30000    1.409    lnaji:2
40000    4.064    lnaji:2
50000    5.140    lnaji:2
60000    6.410    lnaji:2
70000    8.474    lnaji:2
80000    11.678   lnaji:2
90000    16.839   lnaji:2
100000   22.001   lnaji:2
```

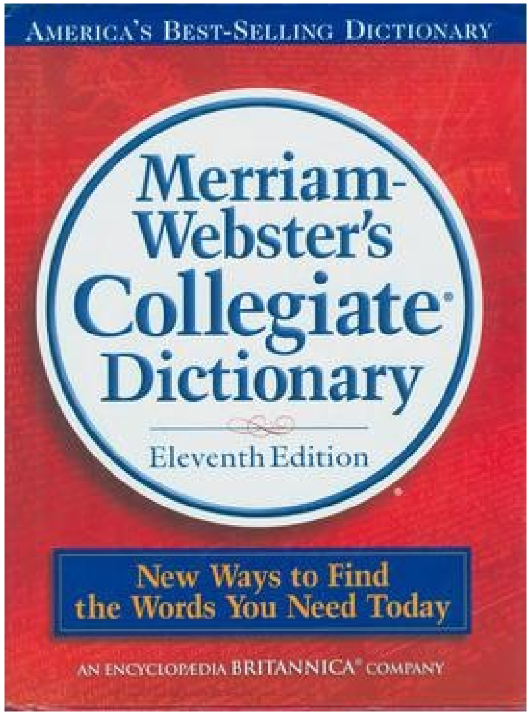


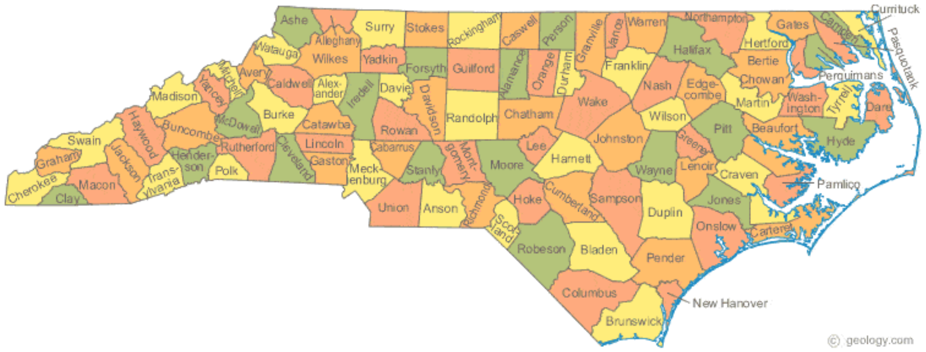
```
10000    0.025    jlcbfupqthaxk:1
20000    0.028    lnaji:2
30000    0.023    lnaji:2
40000    0.028    kdaqrs:2
50000    0.042    nfihe:2
60000    0.022    nfihe:2
70000    0.026    nfihe:2
80000    0.029    nfihe:2
90000    0.039    nfihe:2
100000   0.034    rsobd:2
```

Map conceptually (key,value)

- **Search engine: (K,V) is (query, list of web pages)**
  - Key is word or phrase, Value: list of pages
  - Maps query to list of web pages/URLs
- **Internet: URL -> IP address**
- **Color Name/RGB triple: (K,V) is (name, (r,g,b))**
  - Duke Blue maps to (0,48, 135)
  - NCSU Wolfpack red maps to (204, 0, 0)
  - Purdue Boilermakers gold maps to (194,142, 12)

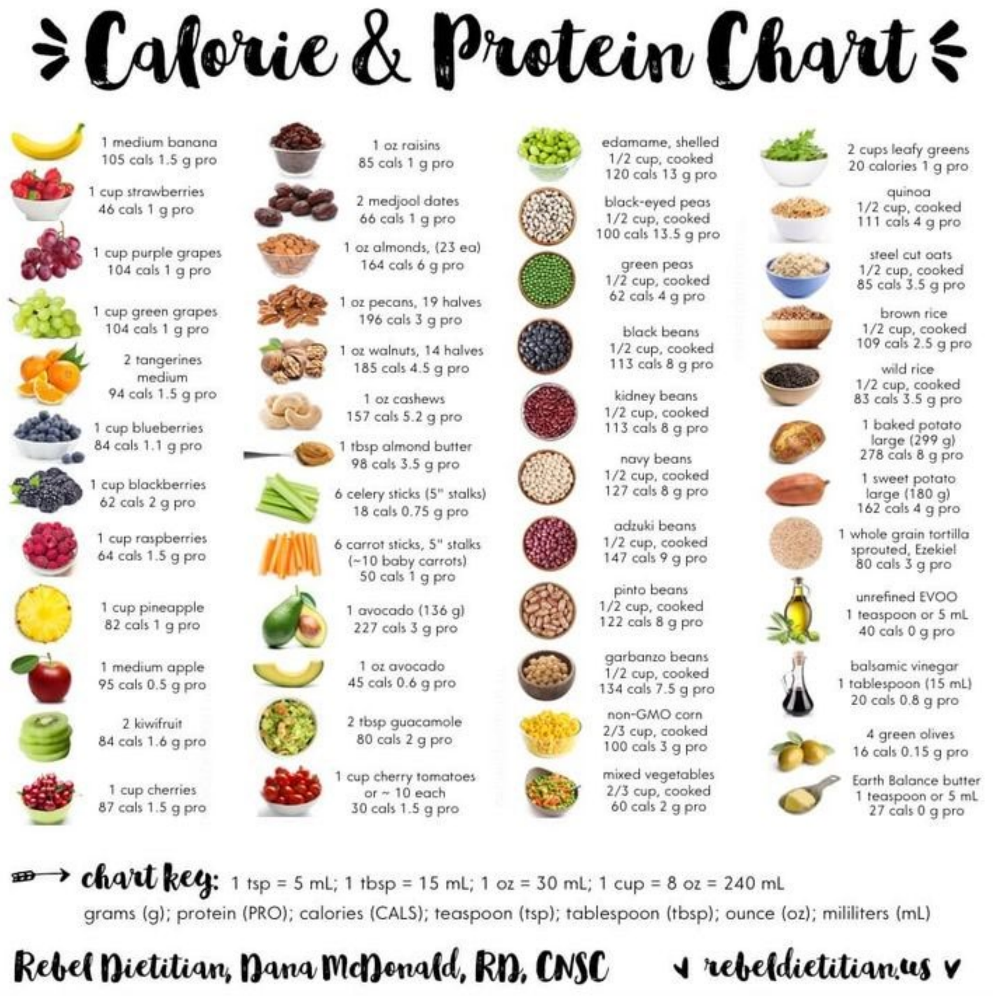
A Rose by Any Other Name…


America's Best-Selling Dictionary
Merriam-Webster's Collegiate Dictionary
Eleventh Edition
New Ways to Find the Words You Need Today
An Encyclopædia Britannica Company



Map: Keys and Values

- I’m looking for the value associated with a key
  - The key is a string, a Point, almost anything
  - Given a food, find calories and protein
  - *Key*: food, *Value*: (calorie, protein) pair



Calorie & Protein Chart

1 medium banana
105 cals 1.5 g pro

1 cup strawberries
46 cals 1 g pro

1 cup purple grapes
104 cals 1 g pro

1 cup green grapes
104 cals 1 g pro

2 tangerines
medium
94 cals 1.5 g pro

1 cup blueberries
84 cals 1.1 g pro

1 cup blackberries
62 cals 2 g pro

1 cup raspberries
64 cals 1.5 g pro

1 cup pineapple
82 cals 1 g pro

1 medium apple
95 cals 0.5 g pro

2 kiwifruit
84 cals 1.6 g pro

1 cup cherries
87 cals 1.5 g pro

1 oz raisins
85 cals 1 g pro

2 medjool dates
66 cals 1 g pro

1 oz almonds, (23 ea)
164 cals 6 g pro

1 oz pecans, 19 halves
196 cals 3 g pro

1 oz walnuts, 14 halves
185 cals 4.5 g pro

1 oz cashews
157 cals 5.2 g pro

1 tbsp almond butter
98 cals 3.5 g pro

6 celery sticks (5" stalks)
18 cals 0.75 g pro

6 carrot sticks, 5" stalks
(~10 baby carrots)
50 cals 1 g pro

1 avocado (136 g)
227 cals 3 g pro

1 oz avocado
45 cals 0.6 g pro

2 tbsp guacamole
80 cals 2 g pro

1 cup cherry tomatoes
or ~ 10 each
30 cals 1.5 g pro

edamame, shelled
1/2 cup, cooked
120 cals 13 g pro

black-eyed peas
1/2 cup, cooked
100 cals 13.5 g pro

green peas
1/2 cup, cooked
62 cals 4 g pro

black beans
1/2 cup, cooked
113 cals 8 g pro

kidney beans
1/2 cup, cooked
113 cals 8 g pro

navy beans
1/2 cup, cooked
127 cals 8 g pro

adzuki beans
1/2 cup, cooked
147 cals 9 g pro

pinto beans
1/2 cup, cooked
122 cals 8 g pro

garbanzo beans
1/2 cup, cooked
134 cals 7.5 g pro

non-GMO corn
2/3 cup, cooked
100 cals 3 g pro

mixed vegetables
2/3 cup, cooked
60 cals 2 g pro

2 cups leafy greens
20 calories 1 g pro

quinoa
1/2 cup, cooked
111 cals 4 g pro

steel cut oats
1/2 cup, cooked
85 cals 3.5 g pro

brown rice
1/2 cup, cooked
109 cals 2.5 g pro

wild rice
1/2 cup, cooked
83 cals 3.5 g pro

1 baked potato
large (299 g)
278 cals 8 g pro

1 sweet potato
large (180 g)
162 cals 4 g pro

1 whole grain tortilla
sprouted, Ezekiel
80 cals 3 g pro

unrefined EVOO
1 teaspoon or 5 mL
40 cals 0 g pro

balsamic vinegar
1 tablespoon (15 mL)
20 cals 0.8 g pro

4 green olives
16 cals 0.15 g pro

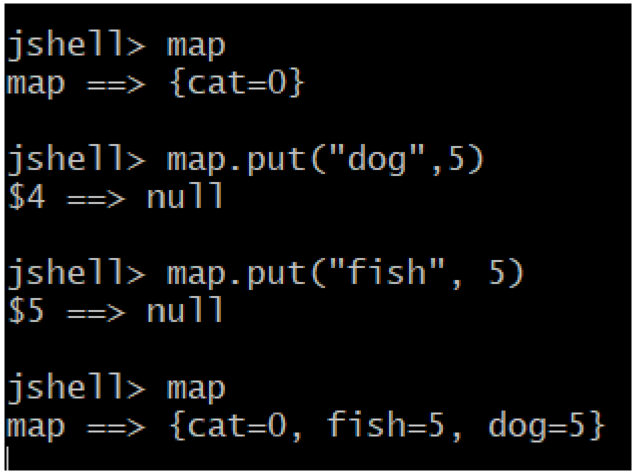
Earth Balance butter
1 teaspoon or 5 mL
27 cals 0 g pro

chart key: 1 tsp = 5 mL; 1 tbsp = 15 mL; 1 oz = 30 mL; 1 cup = 8 oz = 240 mL
grams (g); protein (PRO); calories (CALS); teaspoon (tsp); tablespoon (tbsp); ounce (oz); mililiters (mL)

Rebel Dietitian, Dana McDonald, RD, CNSC rebeldietitian.us

Map Code in Java

- jshell



```
jshell> map
map ==> {cat=0}

jshell> map.put("dog",5)
$4 ==> null

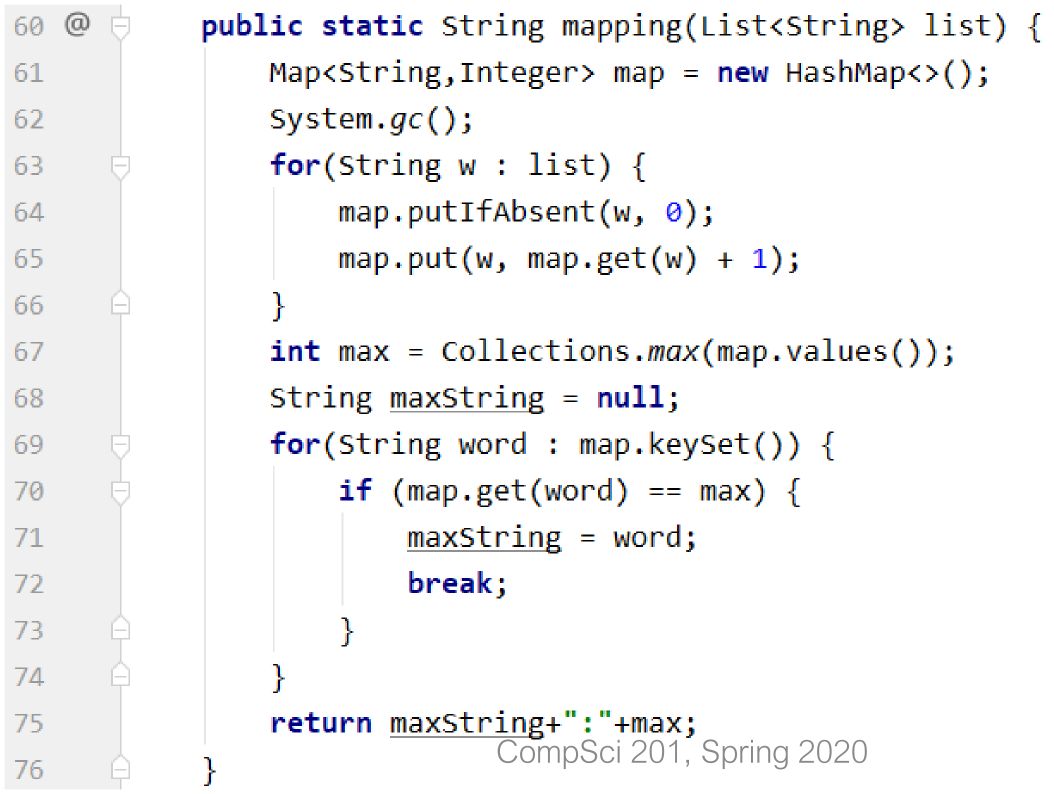
jshell> map.put("fish", 5)
$5 ==> null

jshell> map
map ==> {cat=0, fish=5, dog=5}
```

LIVE CODING

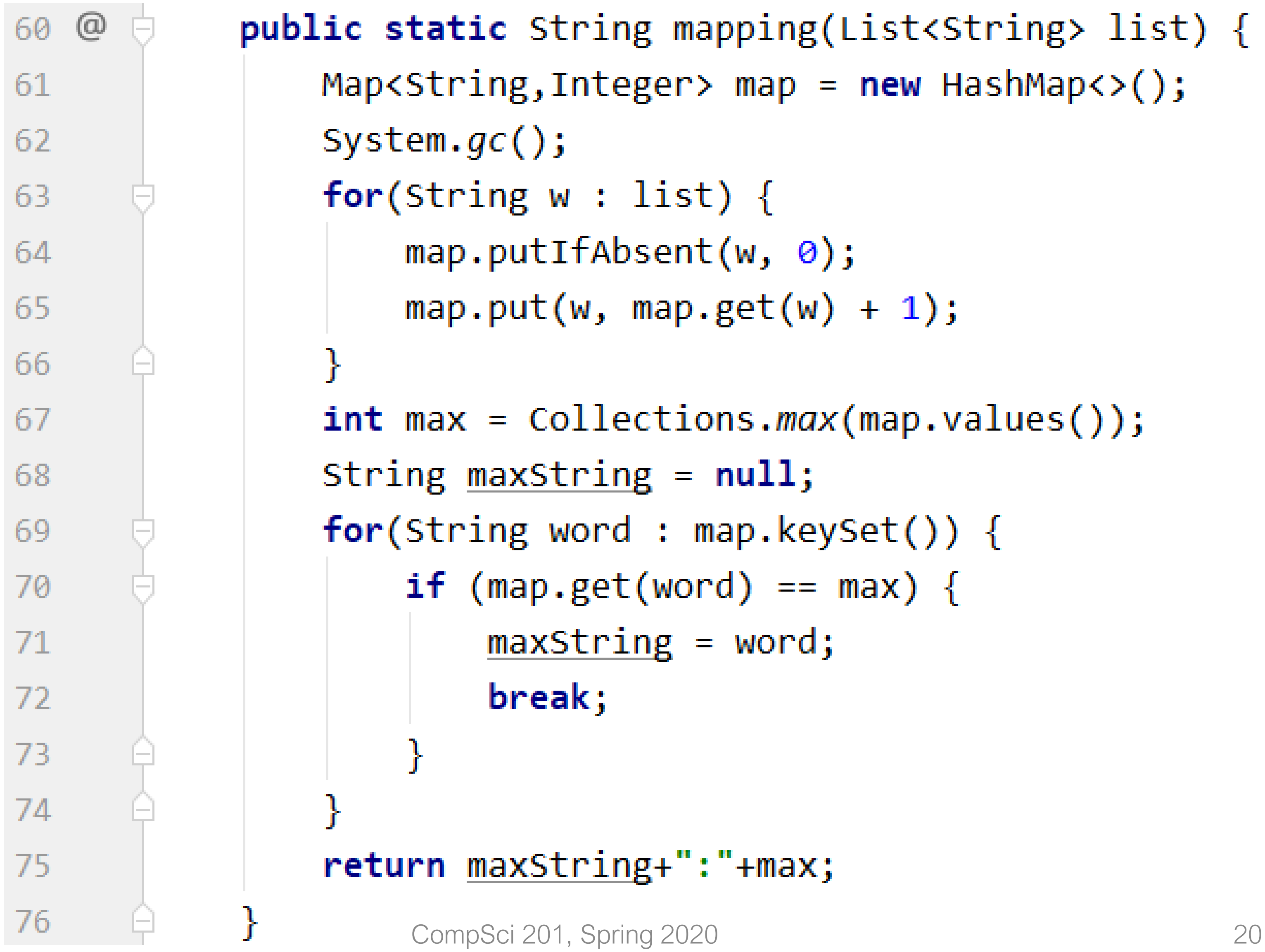
Examining Map Code
in CountingStringsBenchmark.java

- First time key is seen, set value to zero. Why?
  - **`map.get(key)`** return?
  - **`map.put(key,value)`** does?
  - **`map.putIfAbsent(key,value)`** does?



```java
public static String mapping(List<String> list) {
    Map<String,Integer> map = new HashMap<>();
    System.gc();
    for(String w : list) {
        map.putIfAbsent(w, 0);
        map.put(w, map.get(w) + 1);
    }
    int max = Collections.max(map.values());
    String maxString = null;
    for(String word : map.keySet()) {
        if (map.get(word) == max) {
            maxString = word;
            break;
        }
    }
    return maxString+":"+max;
}
```

Same code (just larger)



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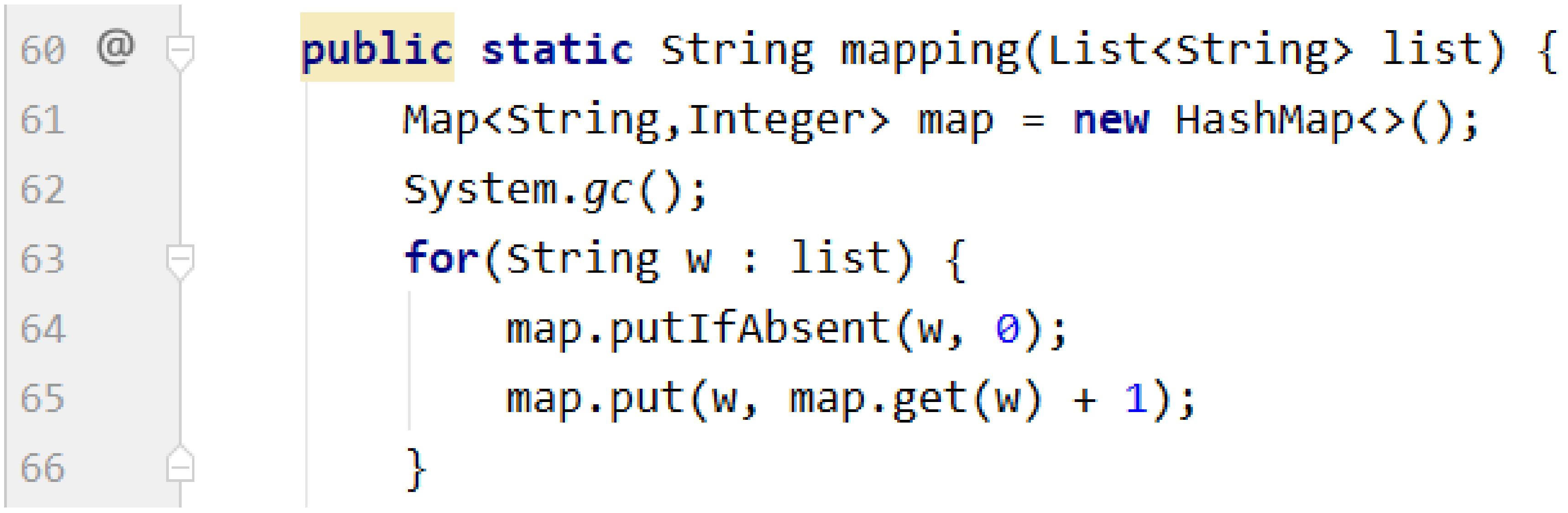
        Map<String,Integer> map = new HashMap<>();
        System.gc();
        for(String w : list) {
            map.putIfAbsent(w, 0);
            map.put(w, map.get(w) + 1);
        }
        int max = Collections.max(map.values());
        String maxString = null;
        for(String word : map.keySet()) {
            if (map.get(word) == max) {
                maxString = word;
                break;
            }
        }
        return maxString+":"+max;
    }
```

Building Map <String,Integer> as <Key,Value>

- **For each string s, create <S,0> initially**
  - We are going to increment the value, start at 0
  - Notice line 65: analogous to **`map[w] += 1`**
    - That syntax doesn't work in Java



```
60 @    public static String mapping(List<String> list) {
61          Map<String,Integer> map = new HashMap<>();
62          System.gc();
63          for(String w : list) {
64              map.putIfAbsent(w, 0);
65              map.put(w, map.get(w) + 1);
66          }
```

Map concepts, HashMap concepts

- Keys should be immutable, cannot change
  - If you change a key, you change it's hashCode, so where does it go? What Bucket?
  - Keys unique, there's a KeySet!

- HashMap: *key* uses .hashCode(), *value* anything
  - How big is the set of lockers? Can it change?
  - Big enough, but can grow if needed

The java.util.Map interface, concepts

- HashMap <Key,Value> or <K,V

Method	return	purpose
`map.size()`	int	# keys
`map.get(K)`	V	get value
`map.keySet()`	Set<K>	Set of keys
`map.values()`	Collection<V>	All values
`map.containsKey(K)`	boolean	Is key in Map?
`map.put(K,V)`	V (ignored)	Insert (K,V)
`map.entrySet()`	Set<Map.Entry>	Get (K,V) pairs
`map.clear()`	void	Remove all keys
`map.putIfAbsent(K,V)`	V (ignored)	Insert if not there

HashMap Internals

- What does map.get(key) actually do?
  - Find h = key.hashCode()
  - Find the hth bucket/locker/location of map/table
    - Actually use **`Math.abs(h) % (# buckets)`**

- Look at all the values in that bucket/locker
  - Could be ArrayList or LinkedList or …
  - Traverse searching for .equals(key)

- What is best case? Average case? Worst Case

Toward Diyad for HashMap

- We saw synthetic workload in previous program
    - Reading words from file, similar program
    - https://coursework.cs.duke.edu/201spring20/classcode/blob/master/src/CountingStringsFile.java

- How does HashMap work?
    - Compare parallel arrays, HashMap as before
    - Add method to illustrate how HashMap works

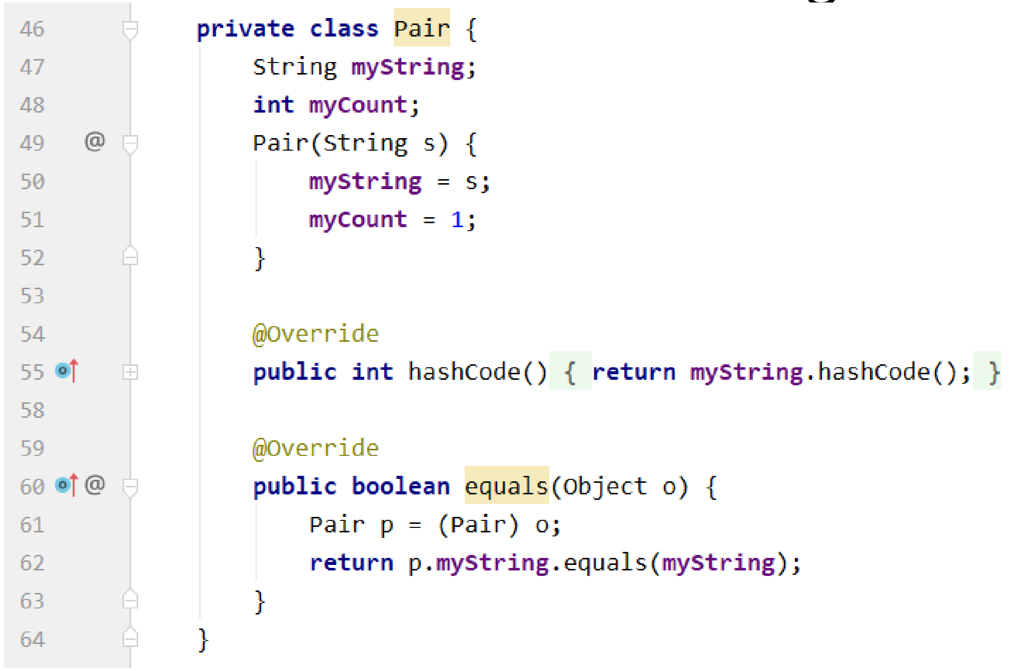
CountingStringsFile.java

- Method parallelArraysMax(list) – previously saw
- Method hashMapMax(list) – same map code
- Method hashMax(list) – version how hashmap works

LIVE CODING

Not Ideal Design: Pair as pojo

- **Private: *plain old java object*, only used here**
  - Only uses one field for .equals and .hashCode
  - Code ensures no two Pairs have same string
- **Class is private**
  - Restricted use
  - No getter/setter
    - Access myCount

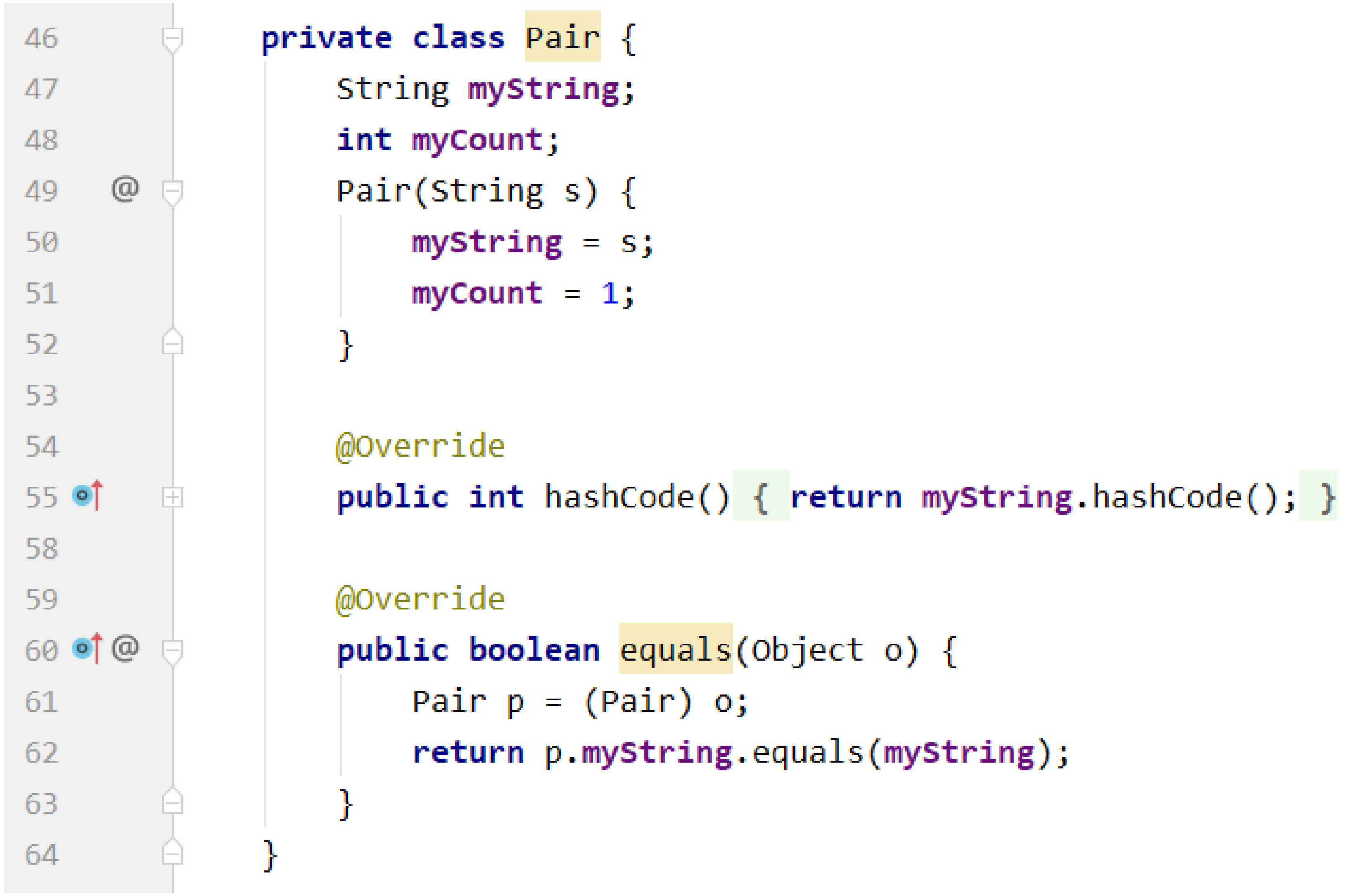


```java
private class Pair {
    String myString;
    int myCount;
    Pair(String s) {
        myString = s;
        myCount = 1;
    }

    @Override
    public int hashCode() { return myString.hashCode(); }

    @Override
    public boolean equals(Object o) {
        Pair p = (Pair) o;
        return p.myString.equals(myString);
    }
}
```

Pair class



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    }

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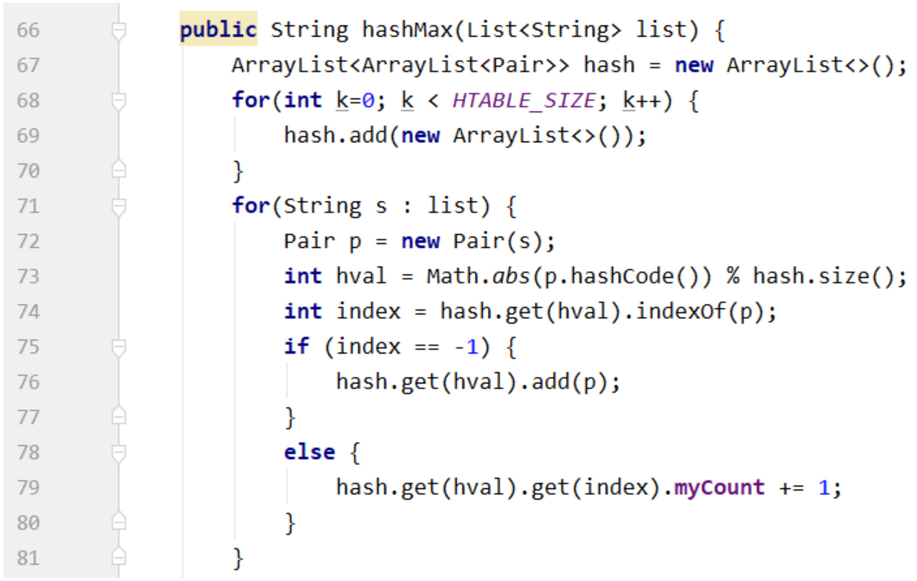
    public int hashCode() { return myString.hashCode(); }

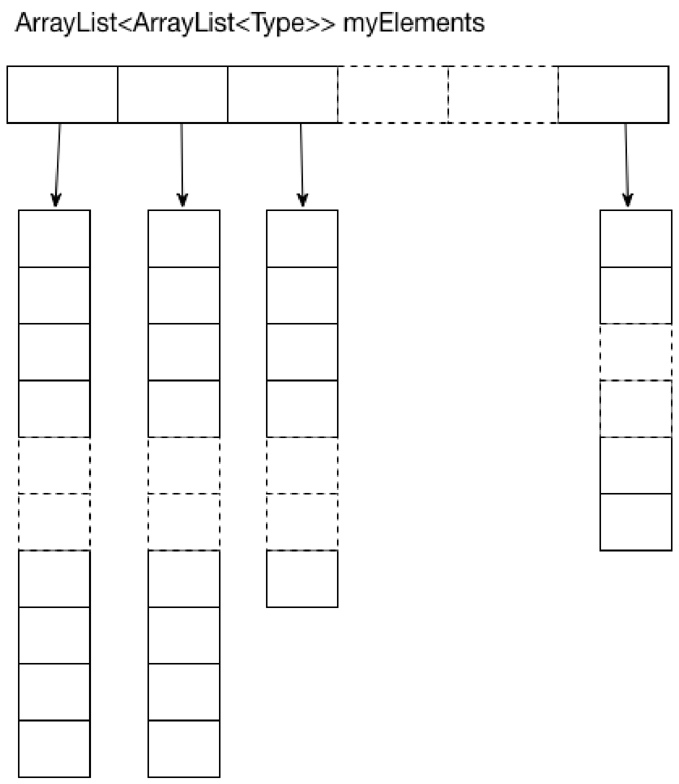
    @Override
    public boolean equals(Object o) {
        Pair p = (Pair) o;
        return p.myString.equals(myString);
    }
}
```

How to use Pair?

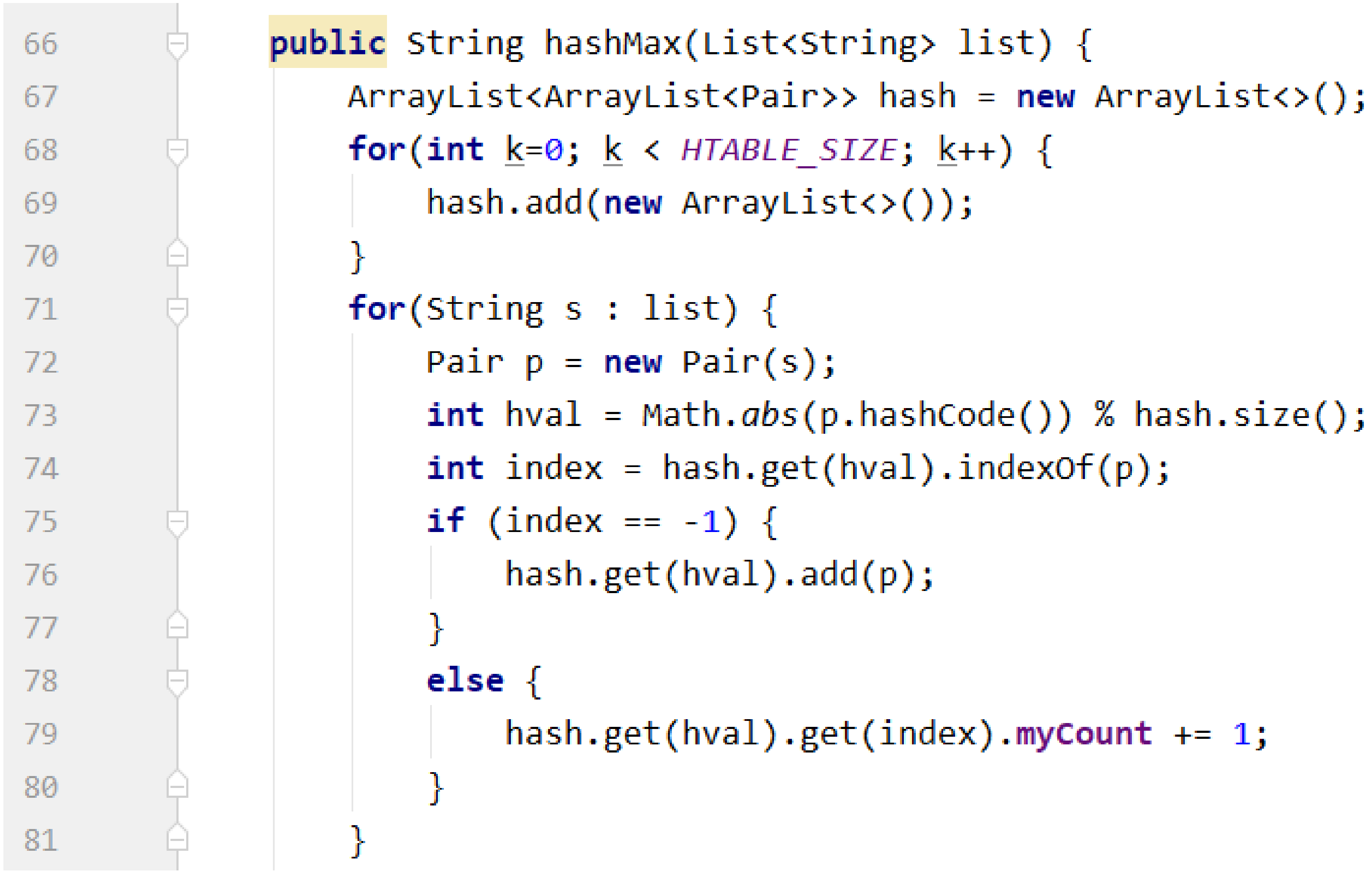
- 5,000 lockers. Each locker contains an ArrayList
  - Create Pair
  - Find locker
  - Look in list



```java
public String hashMax(List<String> list) {
    ArrayList<ArrayList<Pair>> hash = new ArrayList<>();
    for(int k=0; k < HTABLE_SIZE; k++) {
        hash.add(new ArrayList<>());
    }
    for(String s : list) {
        Pair p = new Pair(s);
        int hval = Math.abs(p.hashCode()) % hash.size();
        int index = hash.get(hval).indexOf(p);
        if (index == -1) {
            hash.get(hval).add(p);
        }
        else {
            hash.get(hval).get(index).myCount += 1;
        }
    }
```



hashMax – Build table part



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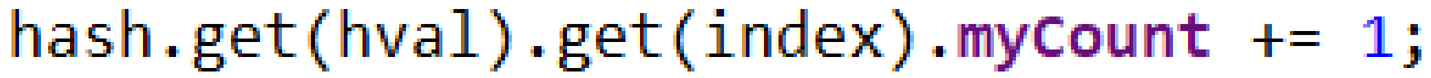
    ArrayList<ArrayList<Pair>> hash = new ArrayList<>();
    for(int k=0; k < HTABLE_SIZE; k++) {
        hash.add(new ArrayList<>());
    }
    for(String s : list) {
        Pair p = new Pair(s);
        int hval = Math.abs(p.hashCode()) % hash.size();
        int index = hash.get(hval).indexOf(p);
        if (index == -1) {
            hash.get(hval).add(p);
        }
        else {
            hash.get(hval).get(index).myCount += 1;
        }
    }
```

How do you read this line?



```
hash.get(hval).get(index).myCount += 1;
```

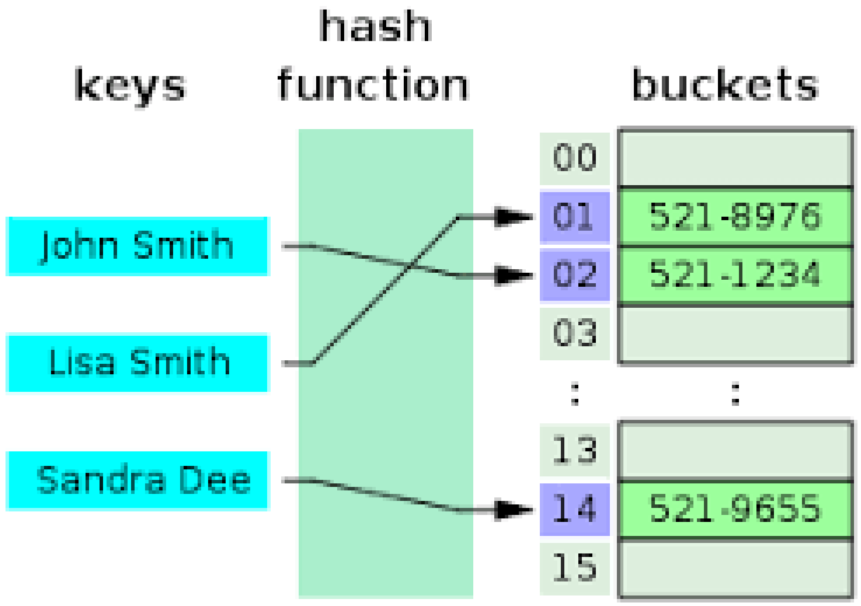
Analysis and Experiments

- Does code depend on # lockers/size of table?
  - Change **`HTABLE_SIZE`** and see

- Can different Pair objects be in same locker?
  - Yes, two different strings can have same **`hashCode()`**
  - **`p.equals(q)`** is false
    - but **`p.hashCode() == q.hashCode()`**

WOTO

http://bit.ly/201spring20-0212-1



Barbara Liskov

- Turing Award Winner in 2008 for contributions to practical and theoretical foundations of programming language and system design, especially related to data abstraction, fault tolerance, and distributed computing.
- Developed CLU programming language

The advice I give people in general is that you should figure out what you like to do, and what you can do well—and the two are not all that dissimilar, because you don’t typically like doing something if you don’t do it well. … So you should instead watch—be aware of what you’re doing, and what the opportunities are, and step into what seems right, and see where it takes you.

Exam 1

- Review syllabus for policies
  - Missing Exam 1 – Fill out form on webpage
  - Bring 1 page of notes, front and back, 8.5x11 inches, name and netid on it, MUST TURN IN

- Exam covers all topics through today
  - Arrays, ArrayLists, HashSets, HashMaps, Classes, etc
  - Mix of read code, short answer, write code
  - Problems have recommended Time to take

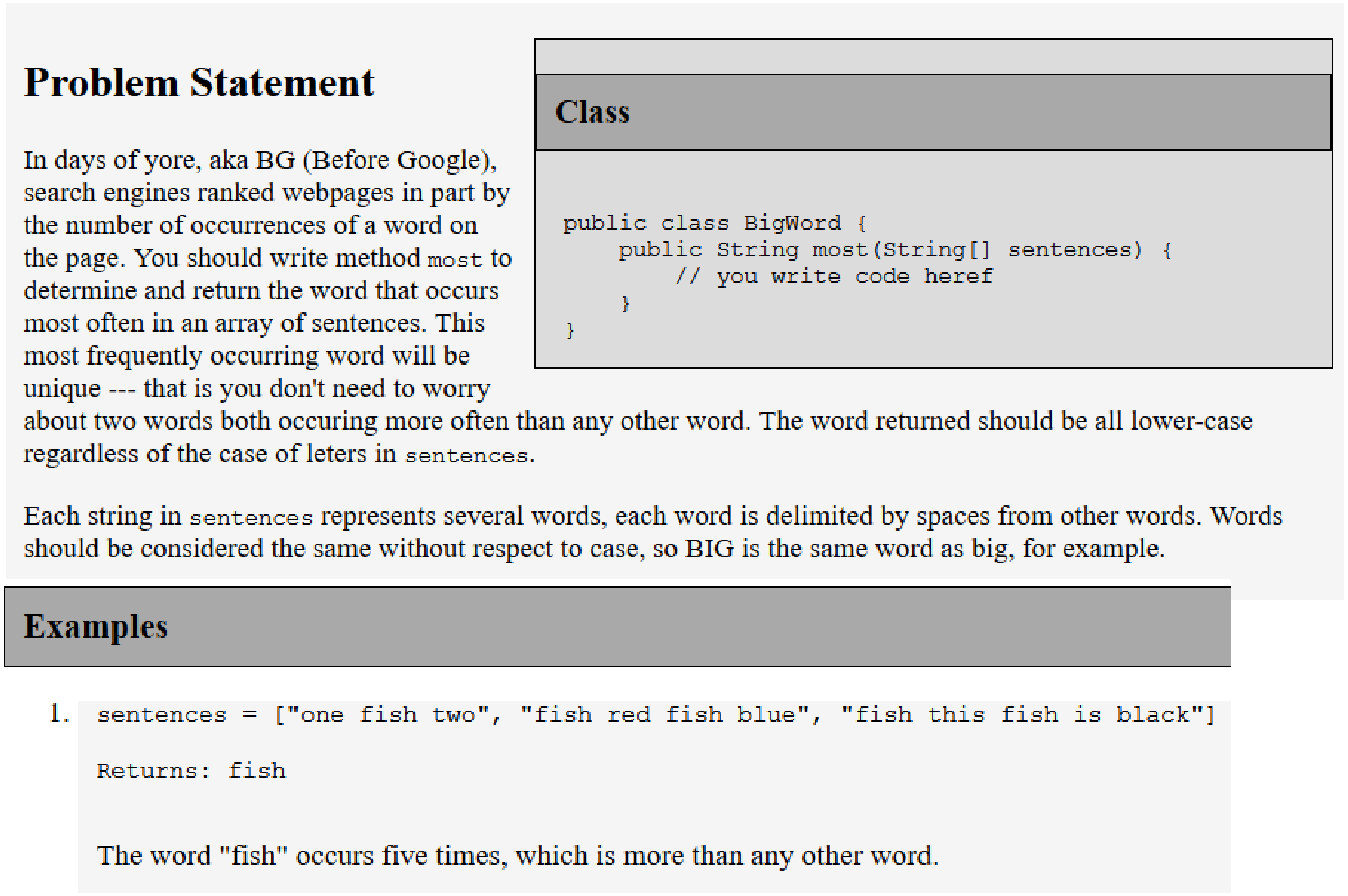
- Map questions will be primarily reading
  - You should be able to update a map and basic map methods

LIVE CODE

Maps on APTs

- https://www2.cs.duke.edu/csed/newapt/bigword.html
- Before you knew about maps …
  - Count each word, maximal value? Done
  - How do we get each word in each string?
    - Call `s.split(" ")`
  - How do we find out how many occurrences?
    - Helper method or `Collections.frequency(…)`
- All words, one word; one loop, two loops

BigWord APT



Problem Statement

In days of yore, aka BG (Before Google), search engines ranked webpages in part by the number of occurrences of a word on the page. You should write method `most` to determine and return the word that occurs most often in an array of sentences. This most frequently occurring word will be unique --- that is you don't need to worry about two words both occuring more often than any other word. The word returned should be all lower-case regardless of the case of leters in `sentences`.

Each string in `sentences` represents several words, each word is delimited by spaces from other words. Words should be considered the same without respect to case, so BIG is the same word as big, for example.

Class

```
public class BigWord {
    public String most(String[] sentences) {
        // you write code heref
    }
}
```

Examples

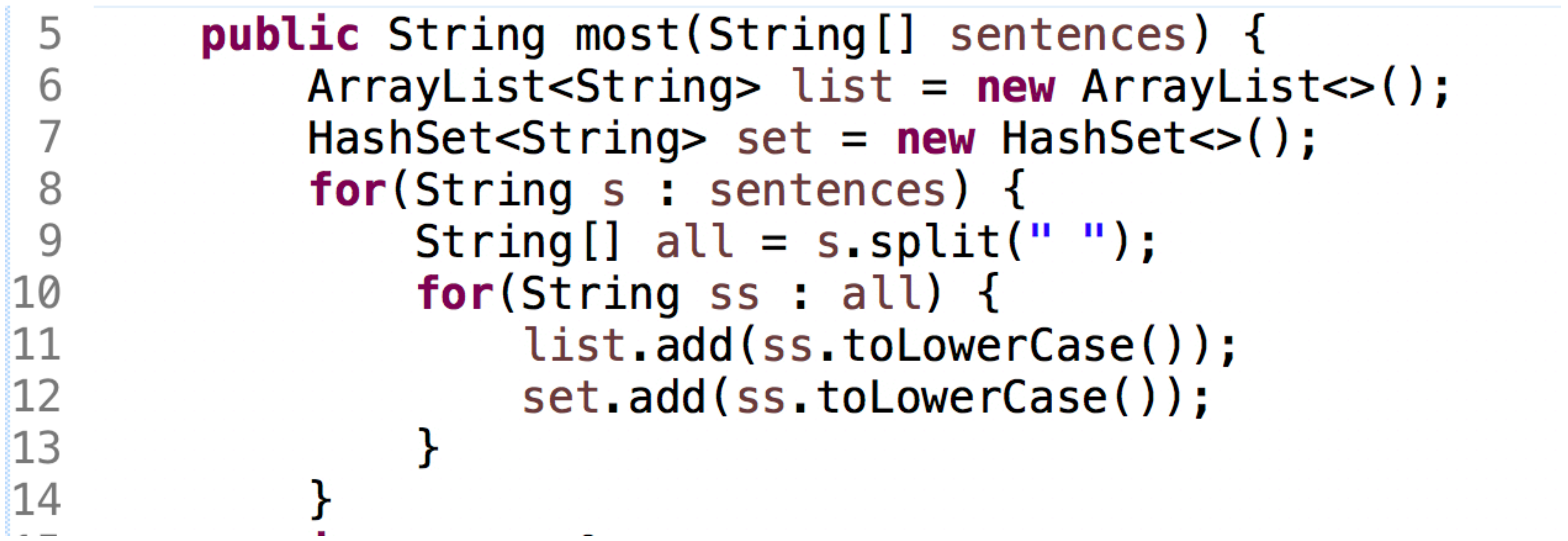
1. `sentences = ["one fish two", "fish red fish blue", "fish this fish is black"]`

   `Returns: fish`

   The word "fish" occurs five times, which is more than any other word.

Lists, and Sets, and … Oh My!

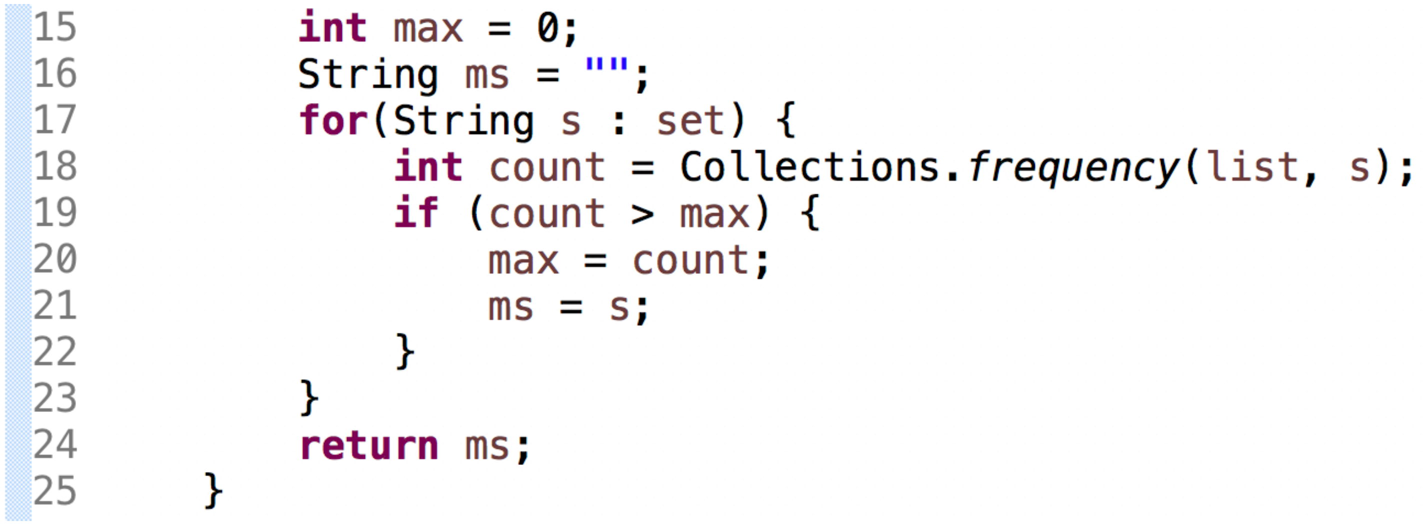
- **First step: get all words, store in a list and a set**
  - Don't need both, nod to efficiency
  - For each loop? Easier if index not needed



```java
    public String most(String[] sentences) {
        ArrayList<String> list = new ArrayList<>();
        HashSet<String> set = new HashSet<>();
        for(String s : sentences) {
            String[] all = s.split(" ");
            for(String ss : all) {
                list.add(ss.toLowerCase());
                set.add(ss.toLowerCase());
            }
        }
```

Finding maximal # occurrences

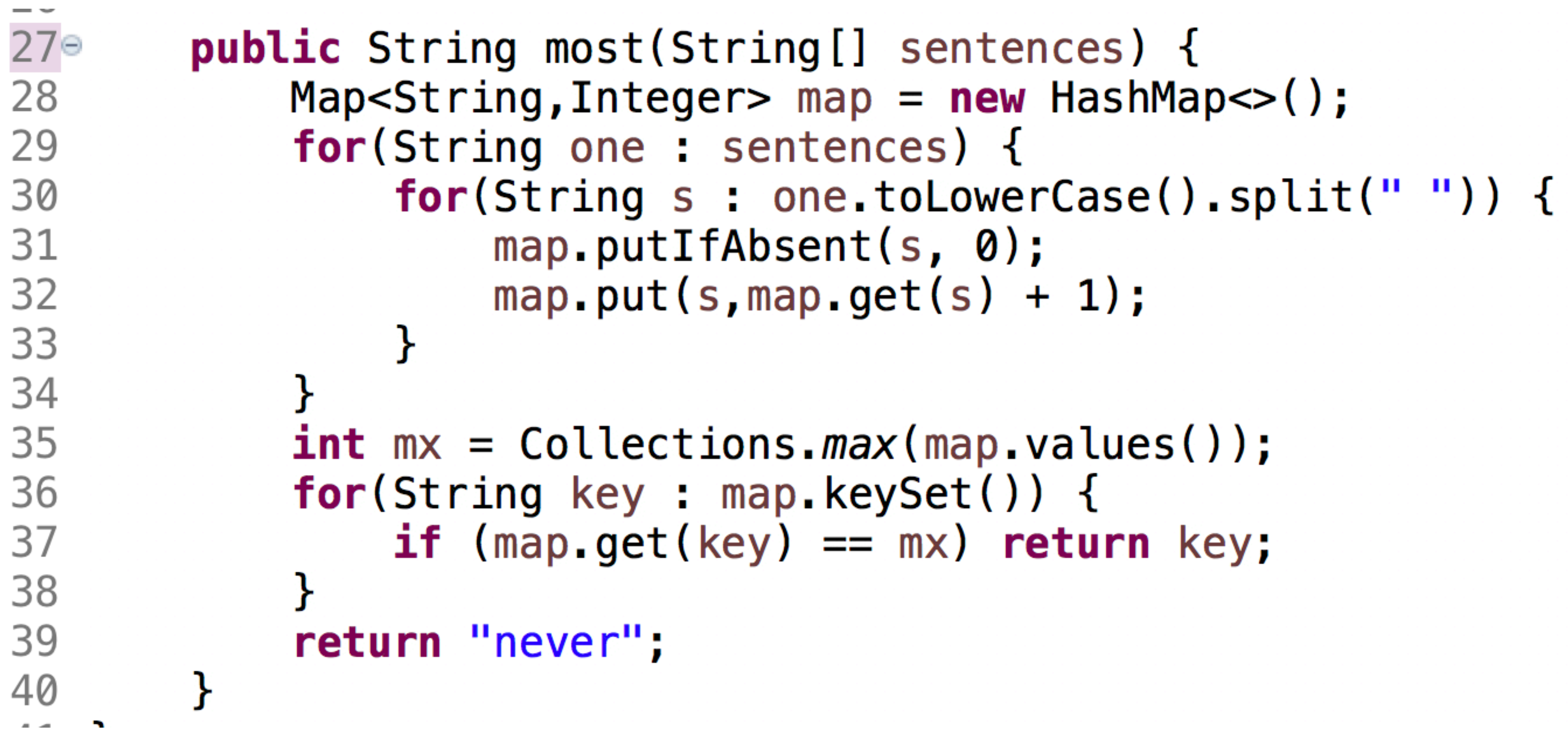
- **Can we substitute list for set in code below?**
  - N words in list, M words in set
  - Code below is O(MN), if list used? O(N^2)



```java
        int max = 0;
        String ms = "";
        for(String s : set) {
            int count = Collections.frequency(list, s);
            if (count > max) {
                max = count;
                ms = s;
            }
        }
        return ms;
    }
```

Investigate Map Solution

- One pass over the data instead of many passes
  - .Understand all map methods
  - Why is line 39 never executed? Still needed?



```
27     public String most(String[] sentences) {
28         Map<String,Integer> map = new HashMap<>();
29         for(String one : sentences) {
30             for(String s : one.toLowerCase().split(" ")) {
31                 map.putIfAbsent(s, 0);
32                 map.put(s,map.get(s) + 1);
33             }
34         }
35         int mx = Collections.max(map.values());
36         for(String key : map.keySet()) {
37             if (map.get(key) == mx) return key;
38         }
39         return "never";
40     }
```

APT Quiz next week

- You’ve practiced programming on APTs and assignments. Typically you don’t write the code with paper/pencil
  - Limitations of exams: not easy to “write” code
- We use APT quizzes to verify: can you solve a problem by programming
  - Have you understood and mastered the Java concepts we’ve studied

APT Quiz Details

- **You’ll get a “practice” quiz as a prelude to and as part of discussion section**
  - You should work to do these on your own before discussion
  - You should get answers to questions in discussion

- **You CANNOT, CANNOT, CANNOT collaborate on the quiz. We run reasonably sophisticated similarity detection software**

Quiz Logistics

- You can start the quiz anytime between Thursday and Monday (Feb. 20-24)
  - Do not start until you have two consecutive hours to complete the quiz

- You must track time yourself. As soon as you access the quiz, your time starts
  - We will only count code you submit before time is up, even though you can keep submitting. You should not keep submitting

APT Quiz

- **We expect that everyone will get the first problem**
  - Sometimes we are wrong. But it's designed to be straightforward. If you've done the APTs? You'll succeed

- **We expect everyone will know how to solve the other problems, but sometimes coding and debugging is not easy**
  - There is a time limit, if stuck? Try next problem