

CS 106B

Lecture 6: Sets and Maps

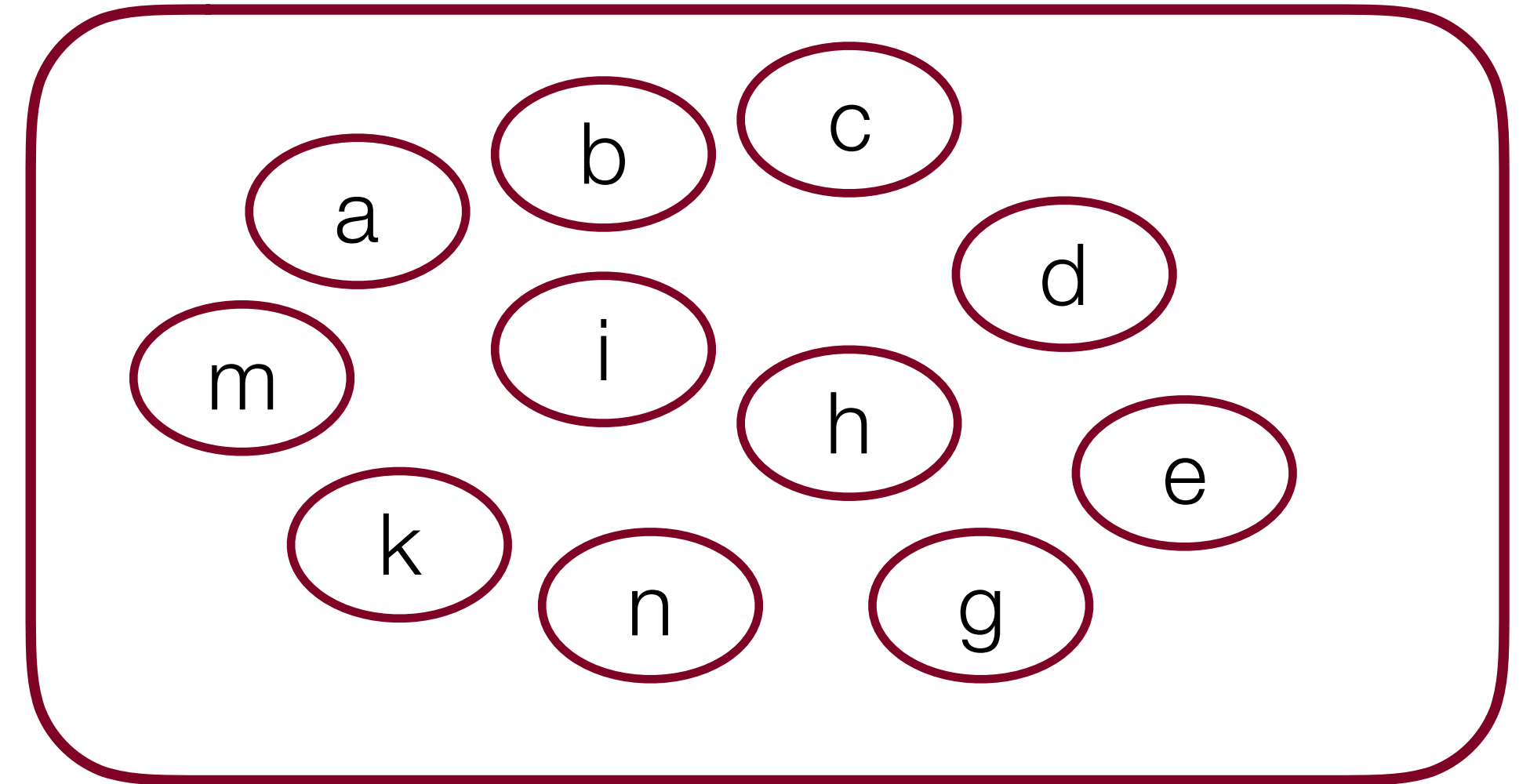
Wednesday, July 5, 2017

Programming Abstractions
Summer 2017
Stanford University
Computer Science Department

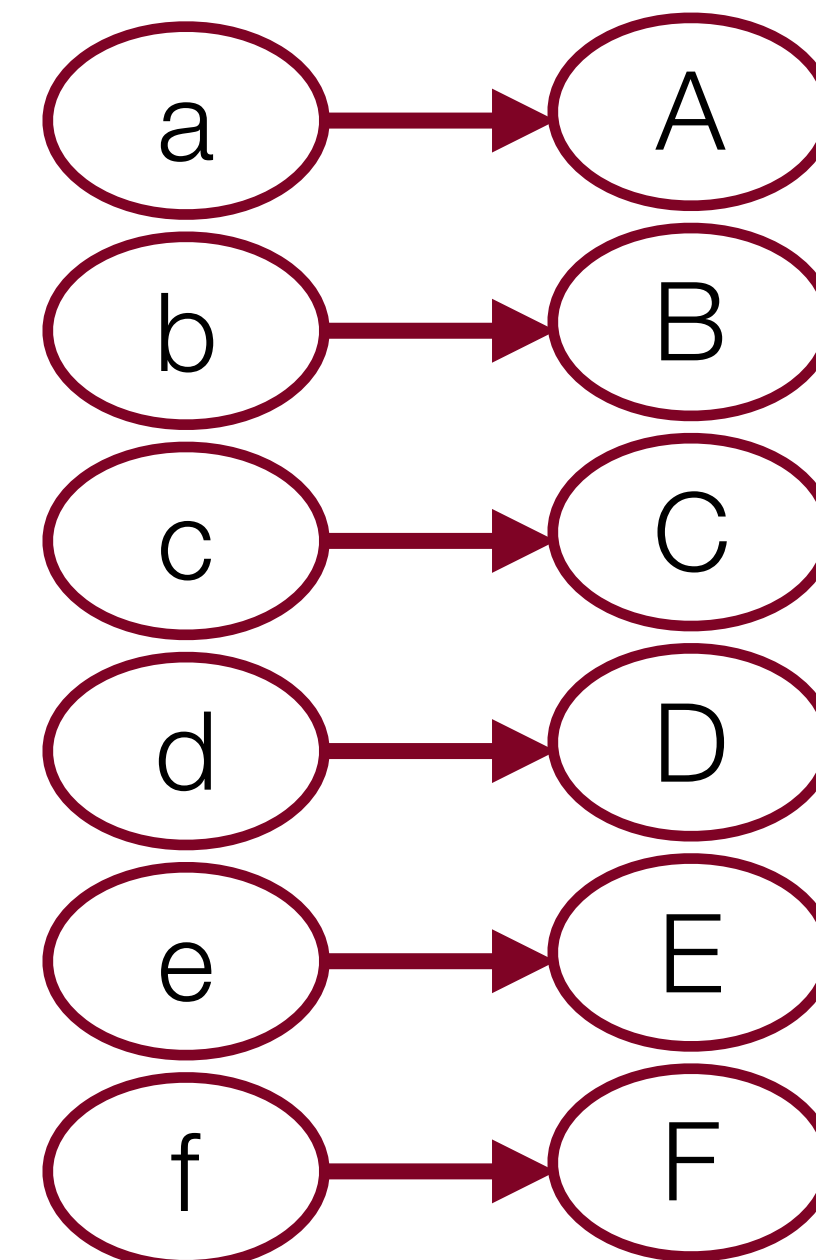
Lecturer: Chris Gregg

reading:
Programming Abstractions in C++, Chapter 5.4-5.6

Set:



Map:



Today's Topics

- Logistics:
 - Assignment 2: Serafini (ADTs) out today
- the "const" qualifier
- Postfix refresher
- Structs (details will come later!)
- Sets
- Maps



Assignment 2: ADTs

- Assignment two is on "Abstract Data Types"
- The assignment has **two separate programs**, which you will turn in all at once:
 - WordLadder: connect one word to another by changing one letter at a time.
 - Ngrams: randomly generate new text that sounds like it came from an input text.



Assignment 2A: Word Ladder

Welcome to CS 106B Word Ladder!

Give me two English words, and I will change the first into the second by changing one letter at a time.

Dictionary file name: **dictionary.txt**

Word 1 (or Enter to quit): **code**

Word 2 (or Enter to quit): **data**

A ladder from data back to code:

data date cate cade code

Word 1 (or Enter to quit):

Have a nice day.

Uses a "queue": more on this later today!

Need to find
neighbor words:

- aate, bate, cate, ..., zate ← all possible neighbors where only the 1st letter is changed
- date, dbte, dcte, ..., dzte ← all possible neighbors where only the 2nd letter is changed
- ...
- data, datb, datc, ..., datz ← all possible neighbors where only the 4th letter is changed



Assignment 2B: Ngrams

Welcome to CS 106X Random Writer ('N-Grams')!
This program generates random text based on a document.
Give me an input file and an 'N' value for groups of
words, and I will generate random text for you.

Input file name: **hamlet.txt**
Value of N: **3**

of random words to generate (0 to quit): **40**
... chapel. Ham. Do not believe his tenders, as you go to this fellow.
Whose grave's this, sirrah? Clown. Mine, sir. [Sings] O, a pit of clay
for to the King that's dead. Mar. Thou art a scholar; speak to it. ...

of random words to generate (0 to quit): **20**
... a foul disease, To keep itself from noyance; but much more handsome
than fine. One speech in't I chiefly lov'd. ...

of random words to generate (0 to quit): **0**
Exiting.

Uses a "map": more on this on Monday!



const

- When we pass variables by reference into a function, we do so for a couple of reasons:
 - We don't want to make copies of big objects
 - As it turns out, C++ has new functionality that allows us to return big objects in some cases without lots of copying (but the Stanford libraries don't have that functionality yet)

and / or

- We need to modify an object in place (we will do this a great deal with recursion)



const

- What if we want to pass a variable by reference, but we *know* we won't modify it?
- We could just have self-control and not modify it.
- Or, we could make the compiler keep us honest. To do this, we use the keyword **const**



const

- **const** allows a programmer to tell the compiler that the object passed cannot be changed in the function. E.g.,

```
void printLifeGrid(Grid<char> const &lifeGrid);
```

- There is no need for the `printLifeGrid()` function to change the `lifeGrid`, but we would rather pass the grid by reference to avoid big copies.



const



- We use `const` to tell the compiler to give us an error if we do try to modify a const-declared variable in a function.
- This *also* tells someone reading our code that we are guaranteeing that the object will be the same when the function ends as when it began.



Postfix (RPN) Refresher

What does the following postfix (RPN) computation equal?

10 3 5 * 9 4 - / +

Feel free to use our stack algorithm:

**Read the input and push numbers onto a stack until you reach an operator.
When you see an operator, apply the operator to the two numbers that are popped from the stack.
Push the resulting value back onto the stack.
When the input is complete, the value left on the stack is the result.**

Answer: **13**

How would our stack-based RPN know that we had made an error, e.g.,

10 3 5 * - + 9 4 -

Answer: the stack is empty when we try to pop two operands



Brief Introduction to Structs

Recall that in C++, we can only return one value from a function. We have overcome this in the past by using references:

```
/*  
 * Solves a quadratic equation  $ax^2 + bx + c = 0$ ,  
 * storing the results in output parameters root1 and root2.  
 * Assumes that the given equation has two real roots.  
 */  
void quadratic(double a, double b, double c,  
               double& root1, double& root2) {  
    double d = sqrt(b * b - 4 * a * c);  
    root1 = (-b + d) / (2 * a);  
    root2 = (-b - d) / (2 * a);  
}
```

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



Brief Introduction to Structs

- There is another way we can return variables by packaging them up in a type called a "struct"
- Structs are a way to *define a new type* for us to use.
- Once we define a struct, we can use that type anywhere we would normally use another type (e.g., an `int`, `double`, `string`, etc.)

```
struct Roots {  
    double root1;  
    double root2;  
};
```

new type name

struct variables,
referred to with dot
notation

don't forget the semicolon



Brief Introduction to Structs

- Let's re-write our quadratic equation solver to use the Roots struct.



Brief Introduction to Structs

- Let's re-write our quadratic equation solver to use the Roots struct.

```
struct Roots {
    double root1;
    double root2;
};

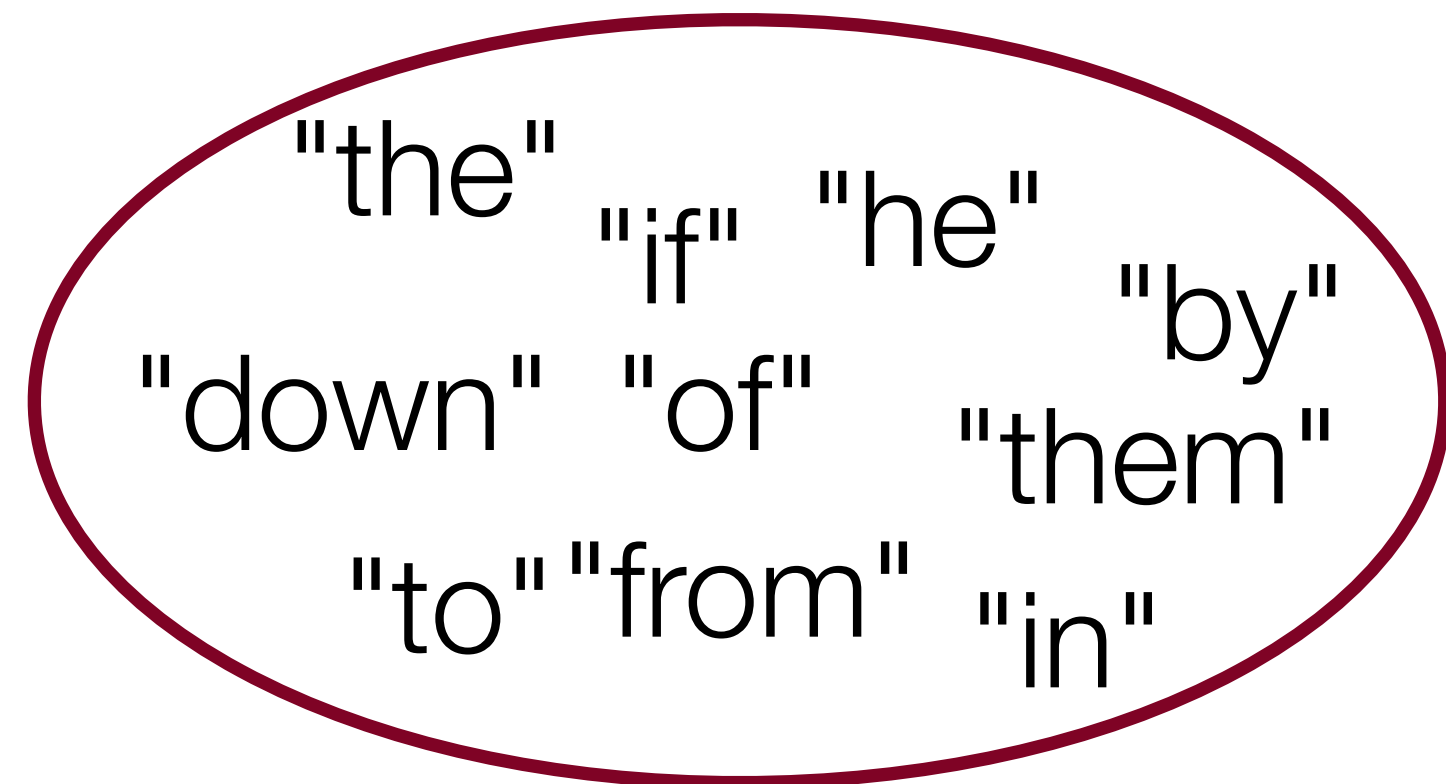
/*
 * Solves a quadratic equation  $ax^2 + bx + c = 0$ ,
 * storing the results in output parameters root1 and root2.
 * Assumes that the given equation has two real roots.
 */
Roots quadratic(double a, double b, double c) {
    Roots roots;
    double d = sqrt(b * b - 4 * a * c);
    roots.root1 = (-b + d) / (2 * a);
    roots.root2 = (-b - d) / (2 * a);
    return roots;
}
```



Sets and Maps

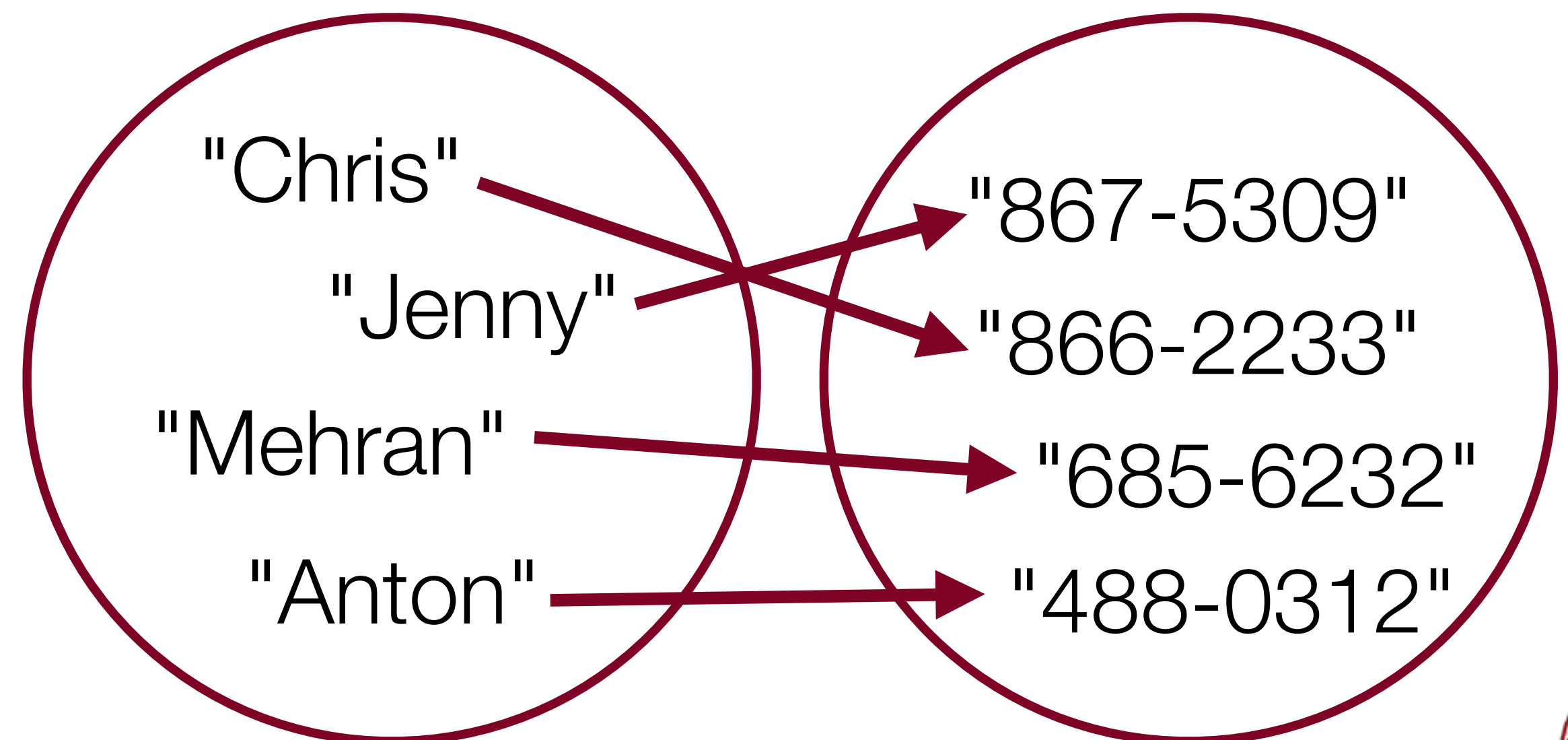
Sets

- Collection of elements with *no duplicates*.



Maps

- Collection of key/value pairs
- The key is used to find its associated value.

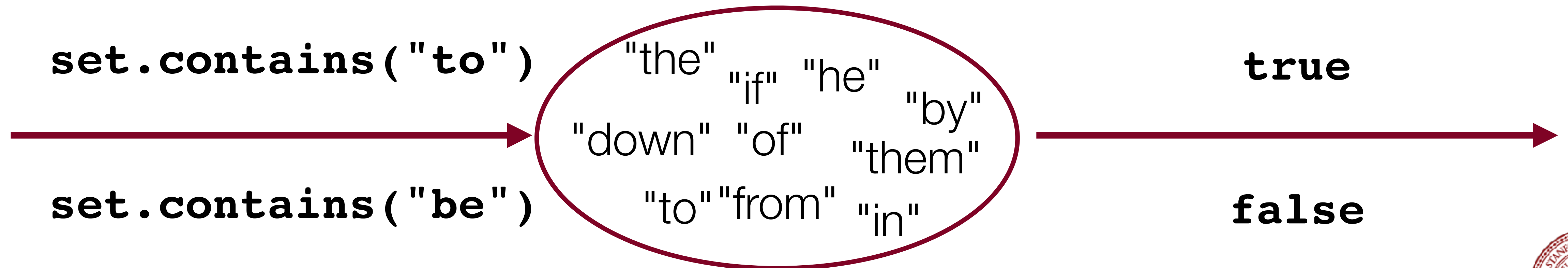


Sets

🔑 • **set**: a collection of elements with no duplicates.

Operations include **add**, **contains**, and **remove**, and they are all fast

Sets *do not* have indexes



Sets: Simple Example

```
Set<string> friends;  
friends.add("chris");  
friends.add("anton");  
cout << friends.contains("voldemort") << endl;  
for(string person : friends) {  
    cout << person << endl;  
}
```



Set Essentials

int set.size()

Returns the number of elements in the set.

void set.add(value)

Adds the new value to the set (ignores it if the value is already in the set)

bool set.contains(value)

Returns `true` if the value is in the set, `false` otherwise.

void set.remove(value)

Removes the value if present in the set. Does not return the value.

bool set.isEmpty()

Returns `true` if the set is empty, `false` otherwise.

Sets also have other helpful methods. See the online docs for more.



Looping Over a Set

```
for(type currElem : set) {  
    // process elements one at a time  
}
```

can't use a normal `for` loop and get each element `[i]`

```
for(int i=0; i < set.size(); i++) {  
    // does not work, no index!  
    cout << set[i];  
}
```



Types of Sets

Set

Iterate over elements in
sorted order

REALLY FAST!

$O(\log n)$ per
retrieval

Implemented using a
"binary search tree"

HashSet

Iterate over elements in
unsorted (jumbled) order

**REALLY,
RIDICULOUSLY FAST!**

$O(1)$ per retrieval

Implemented using a
"hash table"



Set Operands

Sets can be compared, combined, etc.

s1 == s2

true if the sets contain exactly the same elements

s1 != s2

true if the sets don't contain the same elements

s1 + s2

returns the union of s1 and s2 (all elements in both)

s1 * s2

returns intersection of s1 and s2 (elements must be in both)

s1 - s2

returns difference of s1, s2 (elements in s1 but not s2)



Count Unique Words



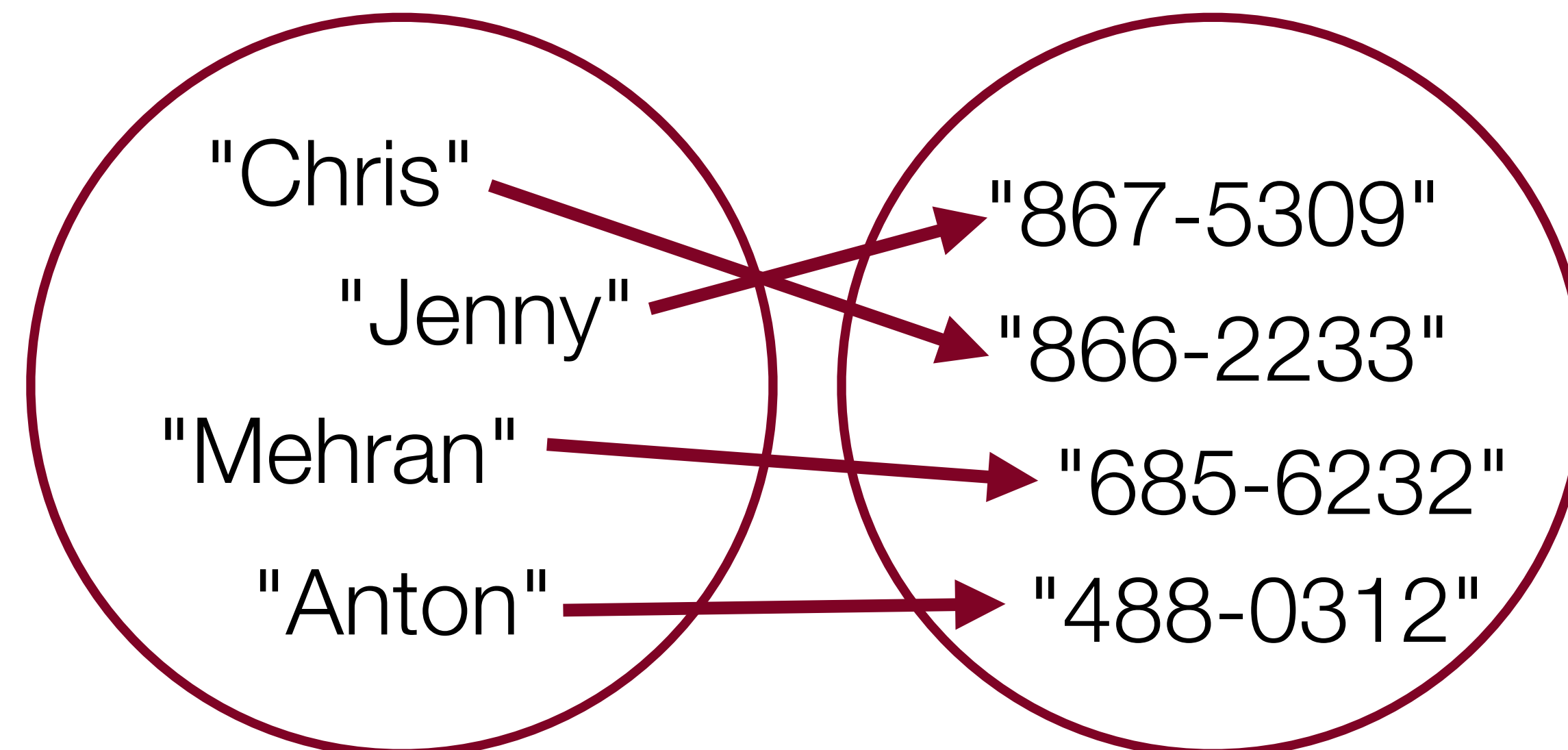
Maps



map: A collection of pairs (k, v) , sometimes called **key/value** pairs, where v can be found quickly if you know k .

a.k.a. dictionary, associative array, hash

a generalization of an array, where the "indexes" need not be ints.



Using Maps

A map allows you to get from one half of a pair to the other.

store an association from "Jenny" to "867-5309"

```
//      key      value  
// m["Jenny"] = "867-5309"; or  
m.put("Jenny", "867-5309");
```



Map

What is Jenny's number?

```
// string ph = m["Jenny"] or  
string ph = m.get("Jenny")  
"206-685-2181"
```



Map



Maps are Everywhere

key = title, value = article

key:
"Yosemite National Park"

value:

Yosemite National Park

From Wikipedia, the free encyclopedia

Coordinates: 37°51′N 119°33′W﻿ / ﻿37.85°N 119.55°W﻿ / 37.85; -119.55^[1]

"Yosemite" redirects here. For other uses, see Yosemite (disambiguation).

Yosemite National Park (/ˈjoʊˈseɪmitij/ *yoh-SEM-it-ee^[4]*) is a *national park* spanning portions of Tuolumne, Mariposa and Madera counties in Northern California.^{[5][6]} The park, which is managed by the **National Park Service**, covers an area of 747,956 acres (1,168.681 sq mi; 302,687 ha; 3,026.87 km²)^[2] and reaches across the western slopes of the **Sierra Nevada** mountain range.^[7] About 4 million people visit Yosemite each year.^[3] most spend the majority of their time in the seven square miles (18 km²) of **Yosemite Valley**.^[8] Designated a **World Heritage Site** in 1984, Yosemite is internationally recognized for its **granite**



key:
"Mariana Trench"

value:

Mariana Trench

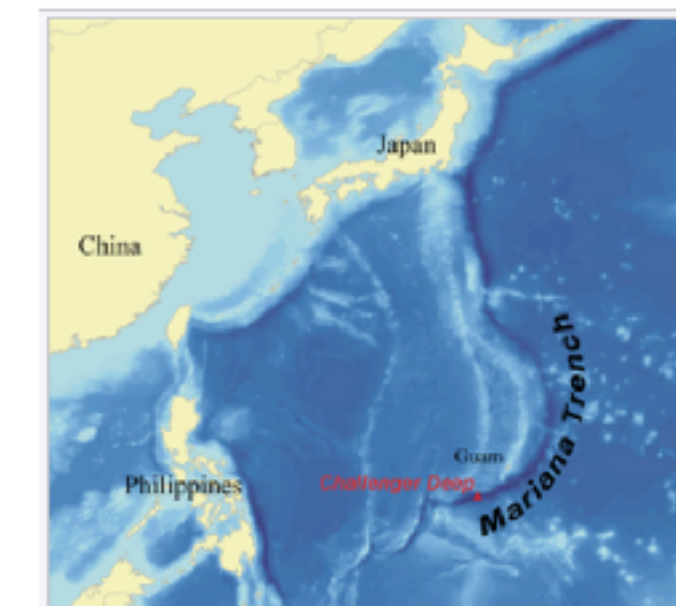
From Wikipedia, the free encyclopedia

Coordinates: 11°21′N 142°12′E﻿ / ﻿11.35°N 142.2°E﻿ / 11.35; 142.2

*This article is about the deep sea trench. For the Canadian band named after the geological formation, see **Marianas Trench (band)**.*

The **Mariana Trench** or **Marianas Trench**^[1] is the **deepest** known part of the world's oceans. It is located in the western **Pacific Ocean**, to the east of the **Mariana Islands**. The trench is about 2,550 kilometres (1,580 mi) long with an average width of 69 kilometres (43 mi). It reaches a maximum-known depth of 10,994 metres (36,070 ft) (\pm 40 metres [130 ft]) at a small slot-shaped valley in its floor known as the **Challenger Deep**, at its southern end,^[2] although some unrepeated measurements place the deepest portion at 11,034 metres (36,201 ft).^[3]

At the bottom of the trench the **water column** above



Creating Maps

Requires 2 type parameters: one for keys, one for values.

```
// maps from string keys to integer values
```

```
Map<string, int> votes;
```

```
// maps from double keys to Vector<int> values
```

```
Map<string, Vector<string>> friendMap;
```



Map Methods

<code>m.clear();</code>	removes all key/value pairs from the map
<code>m.containsKey(<i>key</i>)</code>	returns true if the map contains a mapping for the given key
<code>m[<i>key</i>]</code> or <code>m.get(<i>key</i>)</code>	returns the value mapped to the given key; if key not found, adds it with a default value (e.g. 0, "")
<code>m.isEmpty()</code>	returns true if the map contains no k/v pairs (size 0)
<code>m.keys()</code>	returns a Vector copy of all keys in the map
<code>m[<i>key</i>] = <i>value</i>;</code> or <code>m.put(<i>key</i>, <i>value</i>);</code>	adds a mapping from the given key to the given value; if the key already exists, replaces its value with the given one
<code>m.remove(<i>key</i>);</code>	removes any existing mapping for the given key
<code>m.size()</code>	returns the number of key/value pairs in the map
<code>m.toString()</code>	returns a string such as "{a:90, d:60, c:70}"
<code>m.values()</code>	returns a Vector copy of all values in the map



Map Example

```
Map<string, string> wiki;
```

```
// adds name / text pair to dataset
```

```
wiki.put("Neopalpa donaldtrumpi", articleHTML);
```


SCIENCE JAN 17 2017, 9:43 PM ET

Tiny Moth Named for President-Elect Donald Trump

by MINDY WEISBERGER, LIVE SCIENCE

SHARE   



Moth species *Neopalpa donaldtrumpi*.  Vazrick Nazari



Map Example

```
Map<string, string> wiki;  
  
// adds name / text pair to dataset  
wiki.put("Neopalpa donaldtrumpi", articleHTML);  
  
// returns corresponding articleHTML  
cout << wiki.get("Yosemite National Park");
```

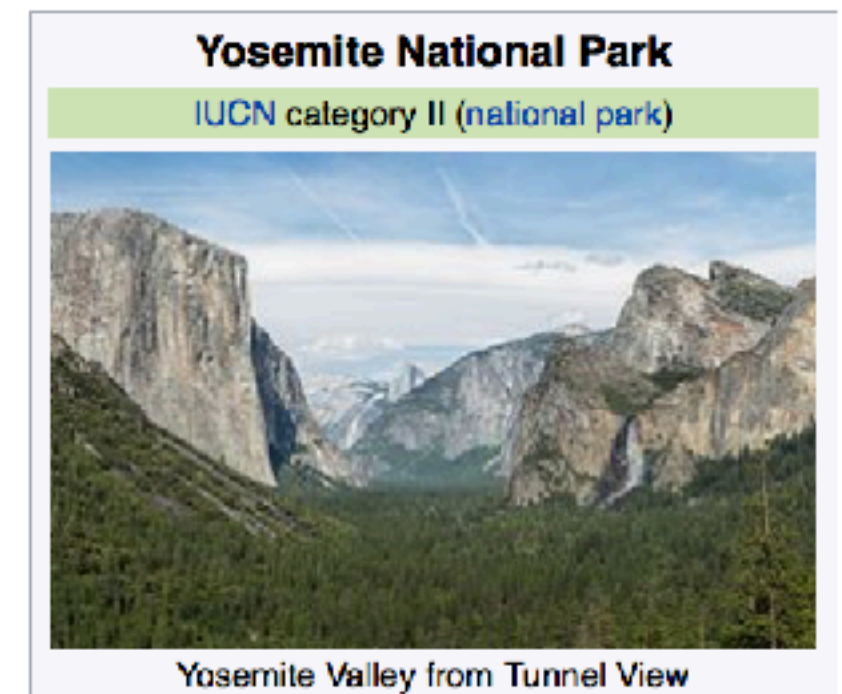
Yosemite National Park

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Map Example

```
Map<string, string> wiki;  
  
// adds name / text pair to dataset  
wiki.put("Neopaipa donaldtrumpi", articleHTML);  
  
// returns corresponding articleHTML  
cout << wiki.get("Yosemite National Park");  
  
// removes the article  
wiki.remove("Britain in the E.U.");
```

Brexit

From Wikipedia, the free encyclopedia

*For the 2016 Brexit referendum, see [United Kingdom European Union membership referendum, 2016](#).
For other uses, see [Brexit \(disambiguation\)](#).*

The [United Kingdom's withdrawal from the European Union](#) is widely known as **Brexit**, a portmanteau of "British" and "exit".^[1] Following a referendum held on 23 June 2016, in which 52% of votes cast were in favour of leaving the EU, the UK government intends to invoke [Article 50 of the Treaty of European Union](#) (the formal procedure for withdrawing) by the end of March 2017. This, within the treaty terms, would put the UK on a course to leave the EU by March 2019. Prime Minister [Theresa May](#), elected by the ruling [Conservative Party](#) in the wake of the referendum, has promised a bill to repeal the [European Communities Act 1972](#) and to incorporate existing [EU laws](#) into UK domestic law.^[2] In January 2017, May announced a 12-point plan of negotiating objectives and confirmed that the UK government would not seek continued membership of the [single market](#).^[3] The terms of withdrawal have not yet been negotiated and in the meantime, the UK remains a full member of the [European Union](#).

The UK joined the [European Economic Community](#) (EEC), a predecessor of the EU, in 1973, and confirmed its membership in a [1975 referendum](#) by 67% of the votes. Historical opinion polls 1973–2015 tended to reveal majorities in favour of remaining in the EEC, EC or EU. In the 1970s and 1980s, withdrawal from the EEC was advocated mainly by some [Labour Party](#) and [trade union](#) figures. From the 1990s, withdrawal from the EU was advocated mainly by some [Conservatives](#) and by the newly founded [UK Independence Party](#) (UKIP).

Contents [hide]

- [The term "Brexit"](#)
- [Historical background](#)



Types of Maps

Map

Iterate over elements in
sorted order

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$O(\log n)$ per
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Implemented using a
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HashMap

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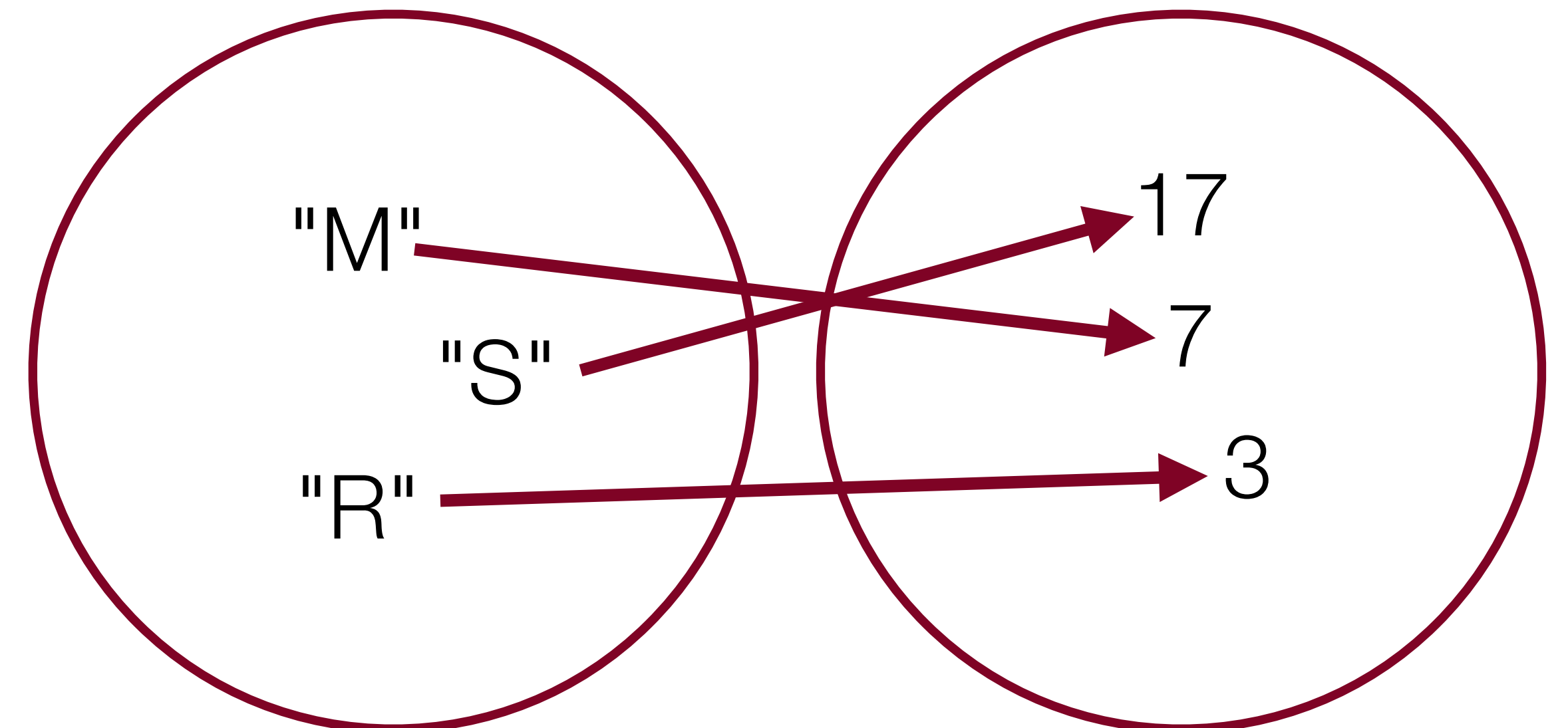


Map Example: Tallying Votes

count votes:

// (M)ilk, (S)tokes, (R)ogers
"MMRMSSSMSSMMMMRRMMMMRRRMMM"

key:	"M"	"S"	"R"
value:	17	7	3



*In 1976 Harvey Milk became the first openly gay elected official in the US



Tallying Words



Looping Over a Map

```
Map<string, double> gpa = load();  
for (string name : gpa) {  
    cout << name << "'s GPA is ";  
    cout << gpa[name] << endl;  
}
```

*The order is unpredictable in a HashMap



Recap

•Structs

- Used to define a type that holds multiple other types.
- Useful for returning more than one value, or keeping things together (e.g., a coordinate could be an x,y and it is nice to keep them together:

```
struct coordinate {  
    double x,y;  
}
```

- Uses dot notation to access elements.

•Sets:

- Container that holds non-duplicate elements
- $O(\log n)$ behavior per element access (**HashSet**: $O(1)$, but unordered)

•Map:

- Container that relates keys to values.
- Needs two types when defining: `Map<keyType, valueType>`
- $O(\log n)$ behavior per element access (**HashMap**: $O(1)$, but unordered)



References and Advanced Reading

- **References:**

- Stanford Set reference: <http://stanford.edu/~stepp/cppdoc/Set-class.html>
- Stanford Map reference: stanford.edu/~stepp/cppdoc/Map-class.html
- const: http://www.cprogramming.com/tutorial/const_correctness.html

- **Advanced Reading:**

- Hashing: https://en.wikipedia.org/wiki/Hash_table
- Relational Databases: https://en.wikipedia.org/wiki/Relational_database (especially idencies)
- const: <http://duramecho.com/ComputerInformation/WhyHowCppConst.html>



Extra Slides

