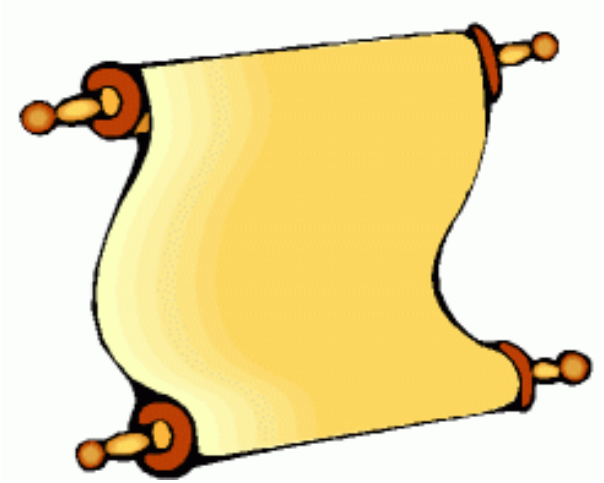
Data Structures and Algorithms

CS 110

Physical Data Structures



Which of these is the best?

Data Structures in a Computer

- We can program different ways of **organizing** data inside of the computer
- Each different way of organizing the data has various tradeoffs
  - What operations are supported? (e.g. add, delete, find, etc.)
  - How efficient are these operations?
  - How much overhead is involved in organizing the data?
- These issues are discussed at length in the Data Structures course

Data Structures in Processing

- Data structures can be implemented in Processing as classes
- What would the field of the class be in this case?
- What would the methods be?

Built-in Collection Classes

- ArrayList
  - A built-in object that stores and manages an *arbitrary* number of data items of any type (Objects).
  - Objects in an ArrayList are access by **index** [0..size-1]

- HashMap
  - A built-in object that stores and manages an *arbitrary* number of data items of any type (Objects).
  - Objects in a HashMap are access by a **key**, which can be another Object, frequently a String.

ArrayList

- Constructors

```
ArrayList<Object> lst1 = new ArrayList();
ArrayList<Object> lst2 = new ArrayList(initialSize);
```

- Fields
- Methods

```
size()                          // Returns the num of items held.
add(Object o)                   // Appends o to end.
add(int idx, Object o)          // Inserts o at pos idx.
remove(int idx)                 // Removes item at pos idx.
get(int idx)                    // Gets items at idx. No removal.
set(int idx, Object o)          // Replaces item at idx with o.
clear()                         // Removes all items.
isEmpty()                       // true if empty.
```

ArrayList Example – Box Dropper

```
// Box Dropper
ArrayList<Box> boxes = new ArrayList();
void setup() {
  size(500, 500);
}

void draw() {
  background(0);

  for (int i = boxes.size()-1; i>=0; i--) {
    boxes.get(i).update();
    boxes.get(i).draw();
    // Remove Box from ArrayList if below sketch
    if (boxes.get(i).y > height) {
      boxes.remove(i);
      println(boxes.size() + " boxes remaining");
    }
  }
}
```

```
void mousePressed() {
  Box b = new Box(mouseX, mouseY);
  boxes.add( b );
  println( boxes.size() + " boxes in ArrayList" );
}

class Box {
  float x, y, v;

  Box(float tx, float ty) {
    x = tx;  // x position
    y = ty;  // y position
    v = 0.0; // y velocity
  }

  void draw() {
    fill(200);
    rect(x, y, 20, 20);
  }

  void update() {
    y += v;             // Physics
    v += 0.02;
  }
}
```

Cooler Array List Example

The Basic Idea

- Start with a single tile that contains the entire image
- On each frame
  - Choose random tile to start falling
  - Choose random tile to split into two new tiles
- At a high-level, how would we use the methods of the ArrayList to implement these two steps?

HashMap

- Constructors

```
HashMap<Object,Object> map1 = new HashMap();
HashMap<Object,Object> map2 = new HashMap(initialCapacity);
```

- Fields
- Methods

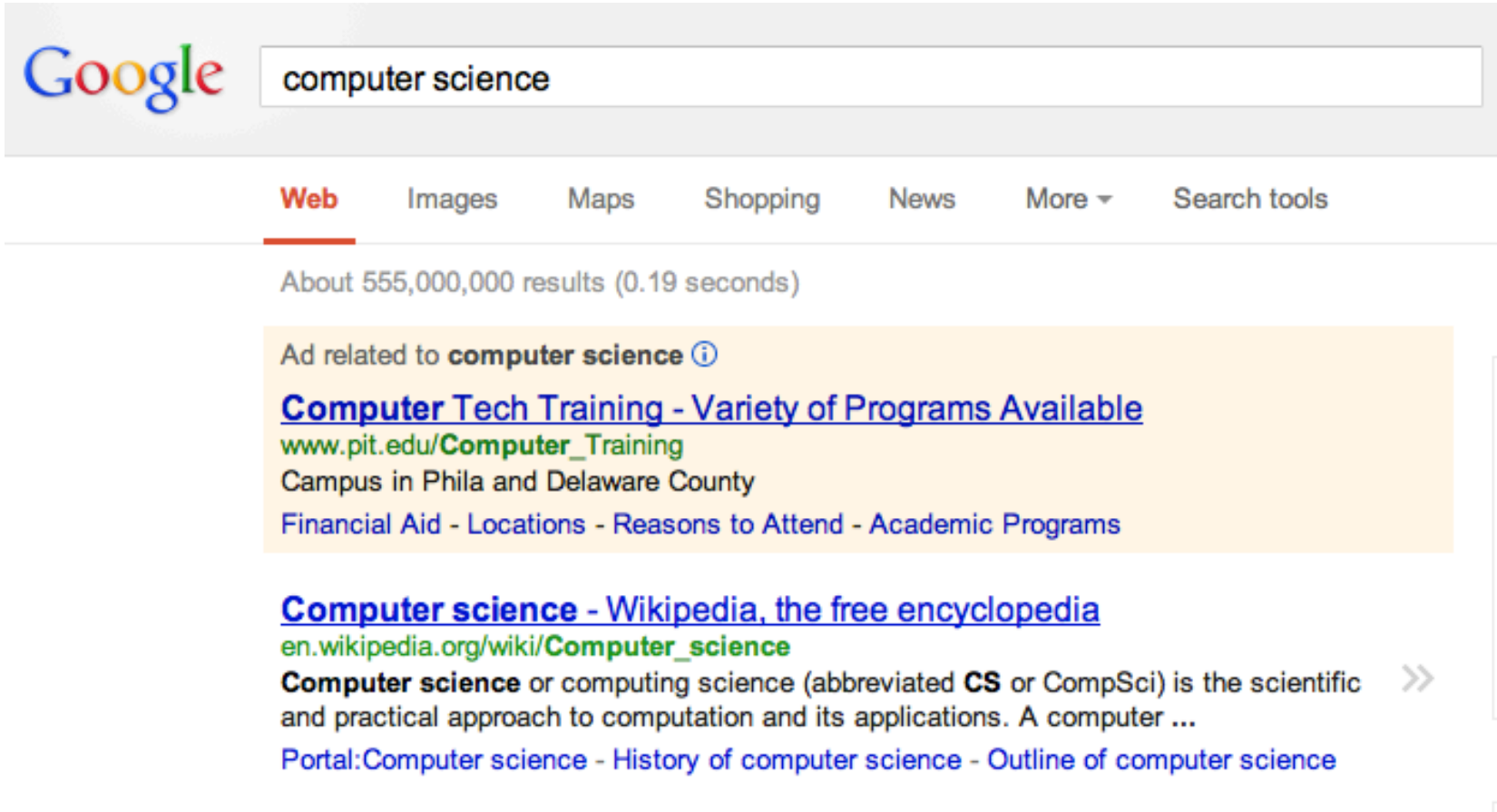
```
size()                          // Returns num of items held.
put(Object key, Object o)       // Puts o in map at key
remove(Object key)              // Remove Object at key
get(Object key)                 // Get Object at key
containsKey(Object key)         // True if map contains key
containsValue(Object val)       // True if map contains val
clear()                         // Removes all items.
isEmpty()                       // true if empty.
```

More Data Structures

Trees,
Heaps,
Graphs,
Linked Lists,
Queues,
Stacks,
etc.

http://en.wikipedia.org/wiki/List_of_data_structures

Imagine the Data Structures that Google Uses



Algorithm

- A well-defined set of instructions for solving a particular kind of problem.

- Algorithms exist for systematically solving many types of problems
  - Sorting
  - Searching
  - …

Searching

This is a fundamentally important problem for a myriad of applications (from finding webpages to searching for fragments of DNA)

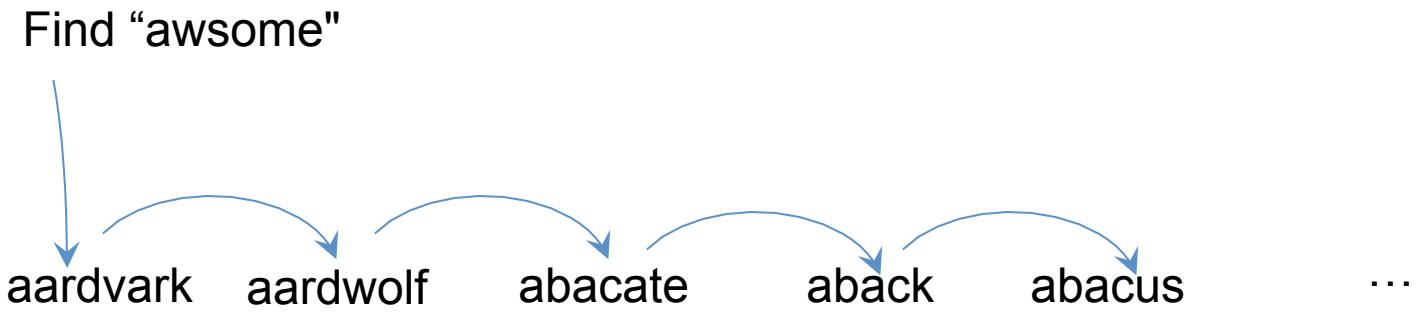
The problem:

Given a collection of data, determine if a query is contained in that collection.

Motivating Example: Spellchecker!

Exhaustive (Linear) Search

- Systematically enumerate all possible values and compare to value being sought
- For an array, iterate from the beginning to the end, and test each item in the array



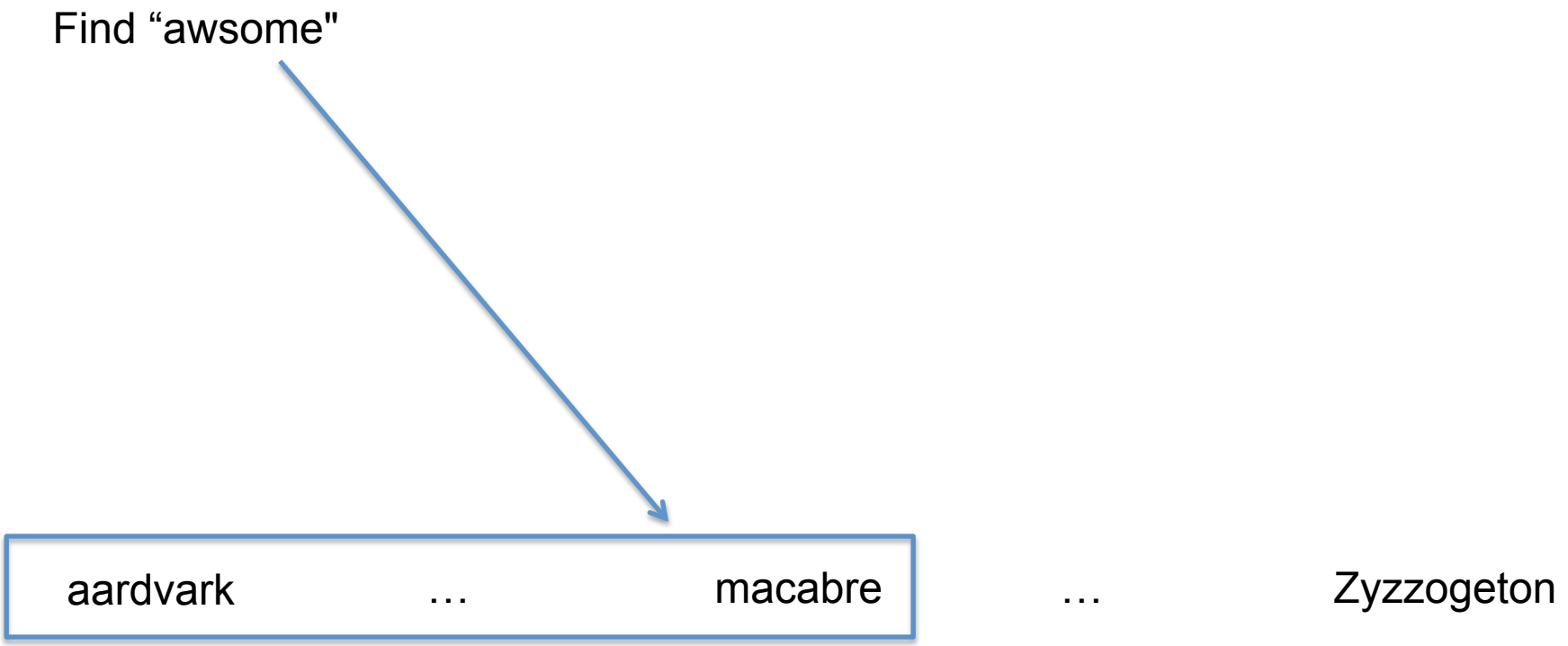
Binary Search

- Quickly find an item (val) in a sorted list.
- Recursive Procedure:

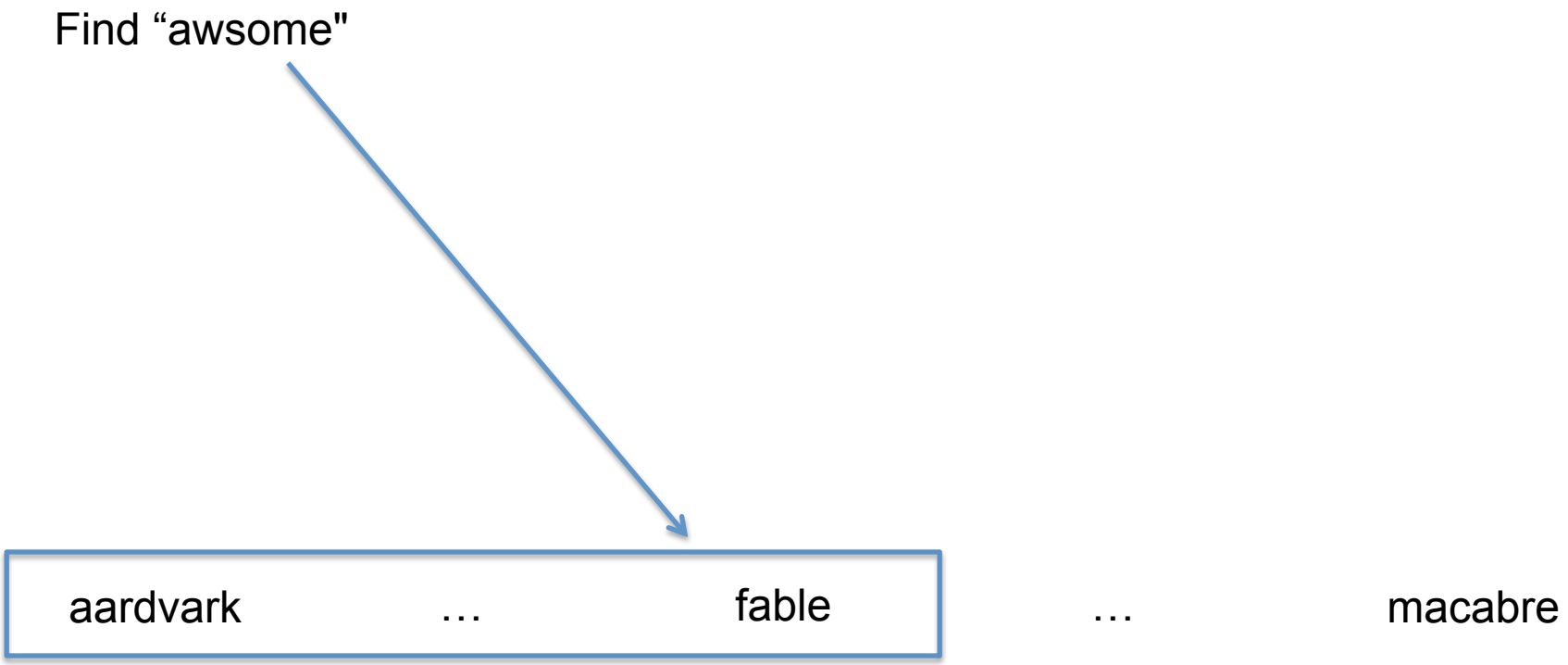
```
binarySearch(startIdx, stopIdx, data, query)
        if startIdx == stopIdx
                return data[startIdx] == query
        midPoint = (startIdx+stopIdx)/2
        if words[midPoint] >= query
                return binarySearch(startIdx, midPoint, data, query)
        else
                return binarySearch(midPoint+1, stopIdx, data,query)
```

The most efficient way to play "guess the number" …

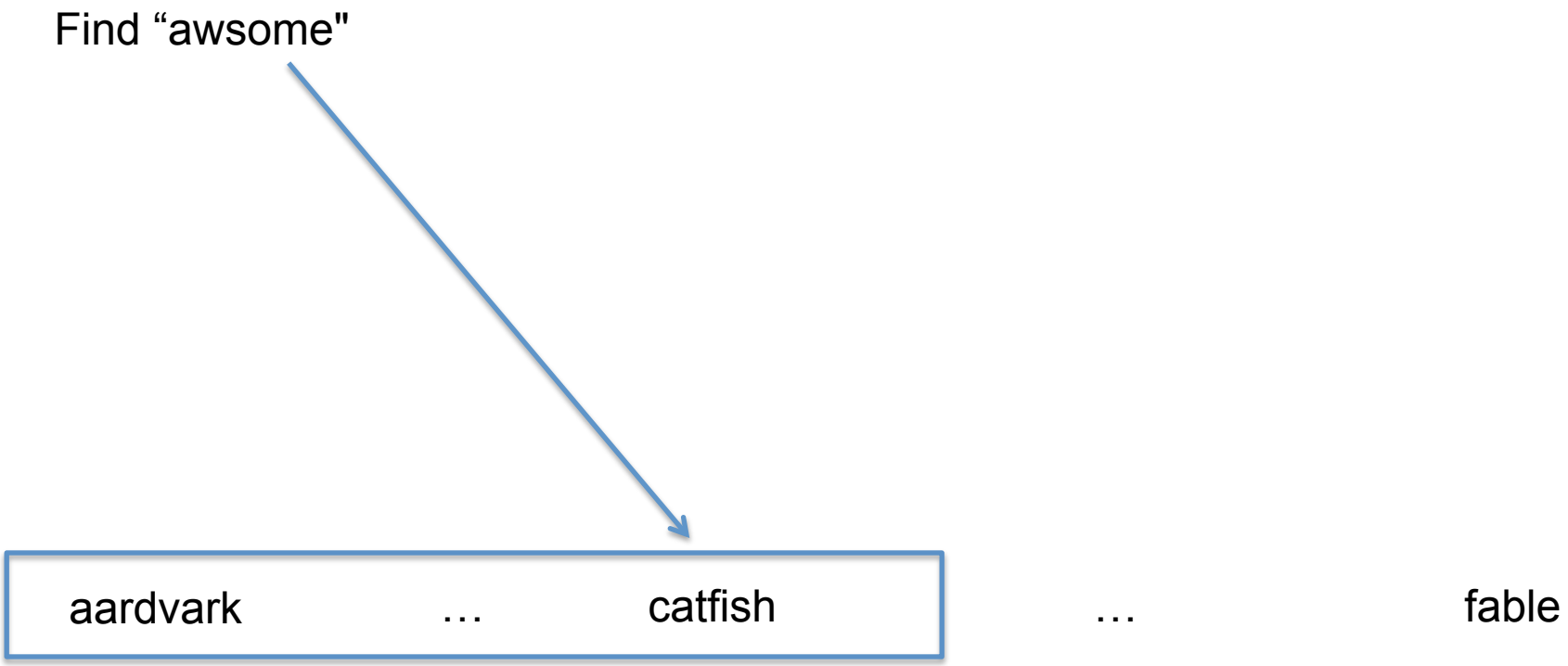
Binary Search Example



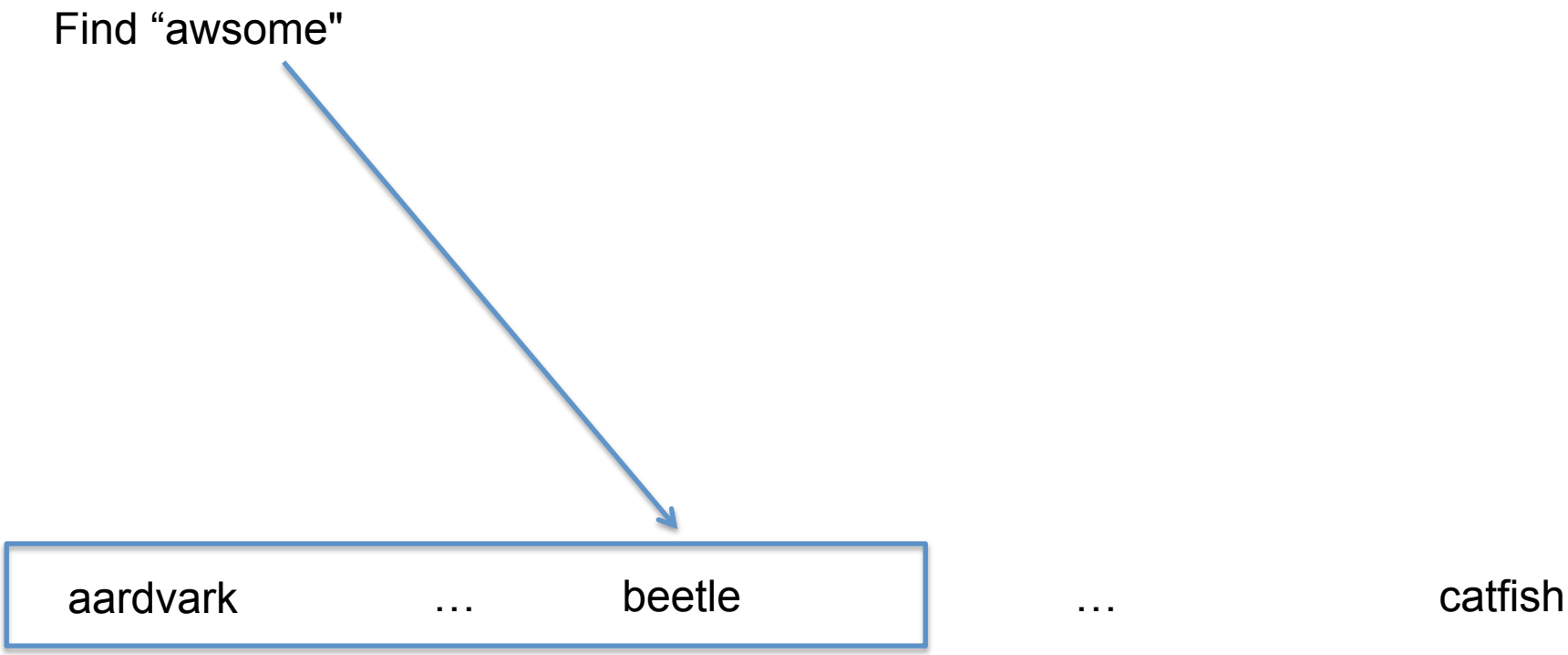
Binary Search Example



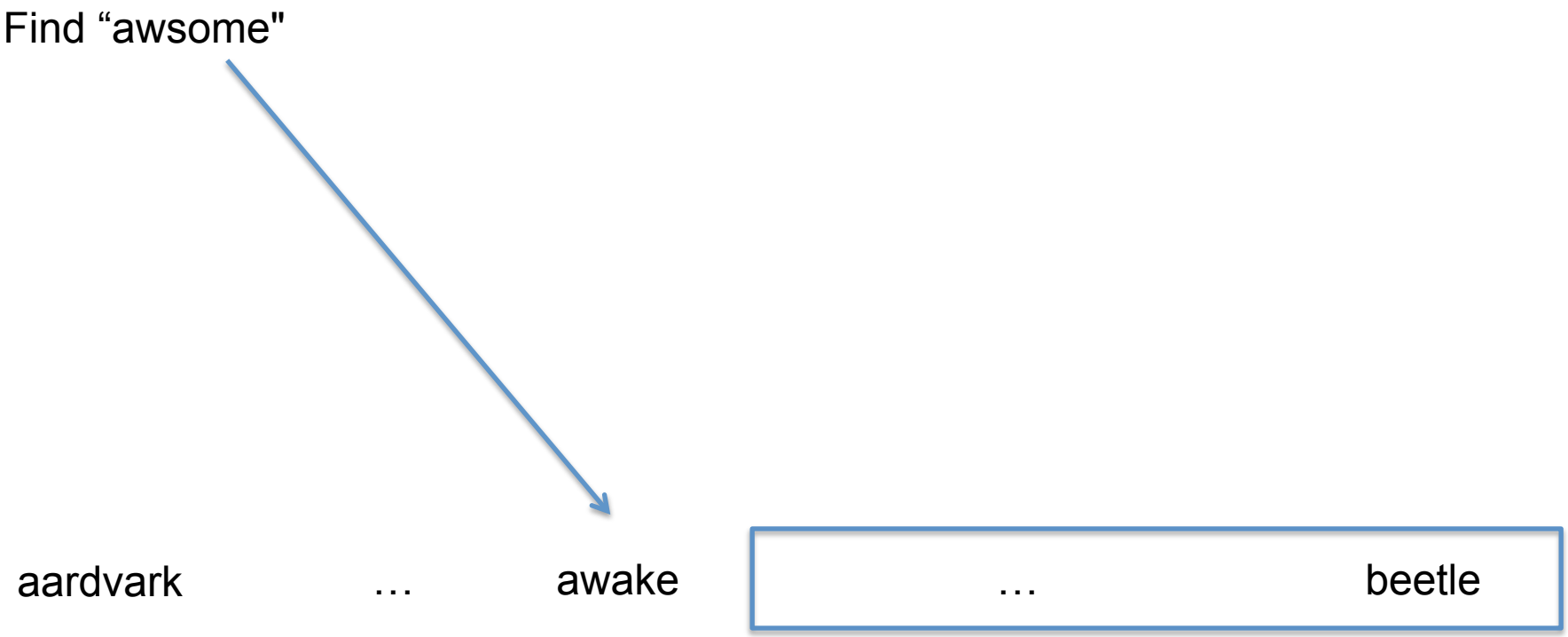
Binary Search Example



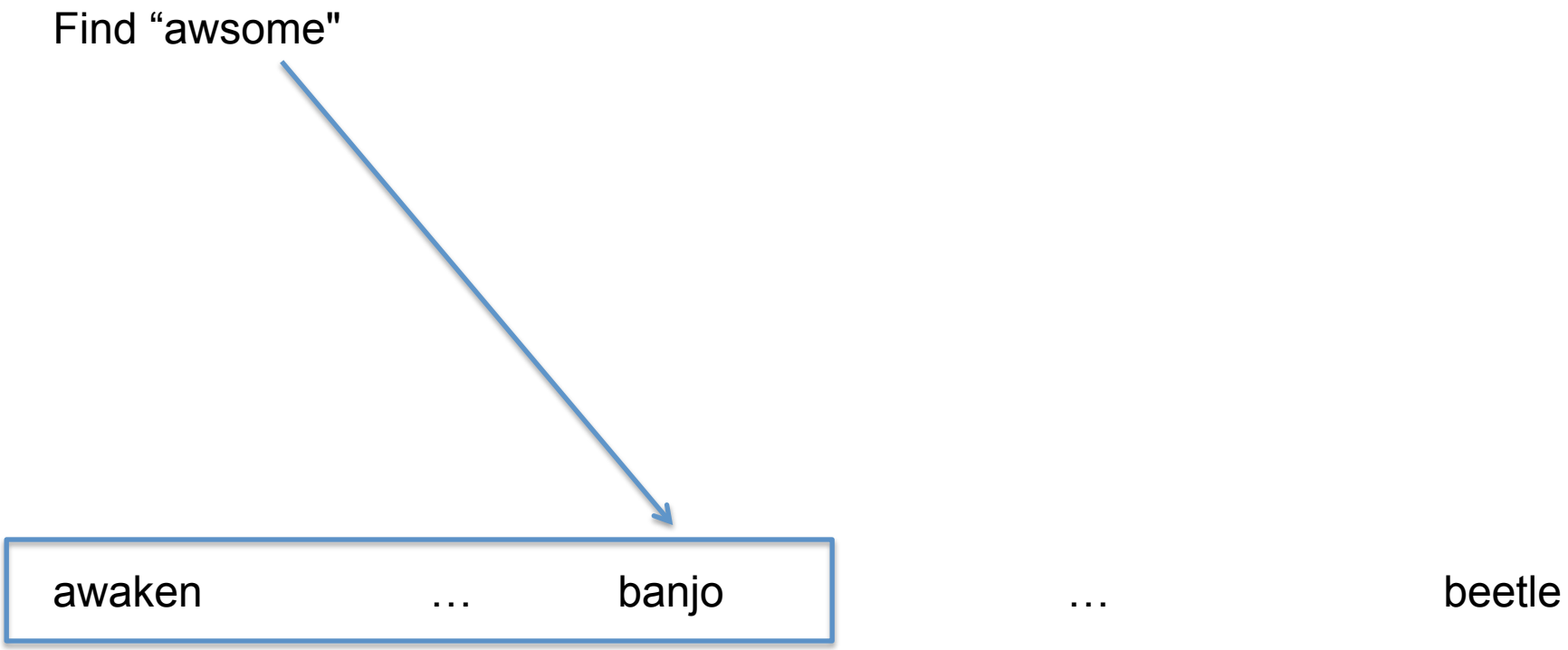
Binary Search Example



Binary Search Example



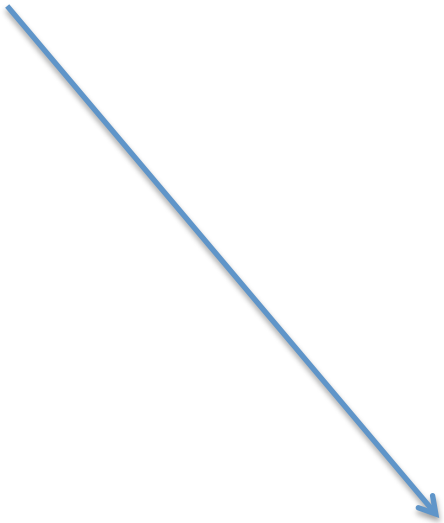
Binary Search Example



Repeat a few more times…

Binary Search Example

Find “awsome"



awry

Return false

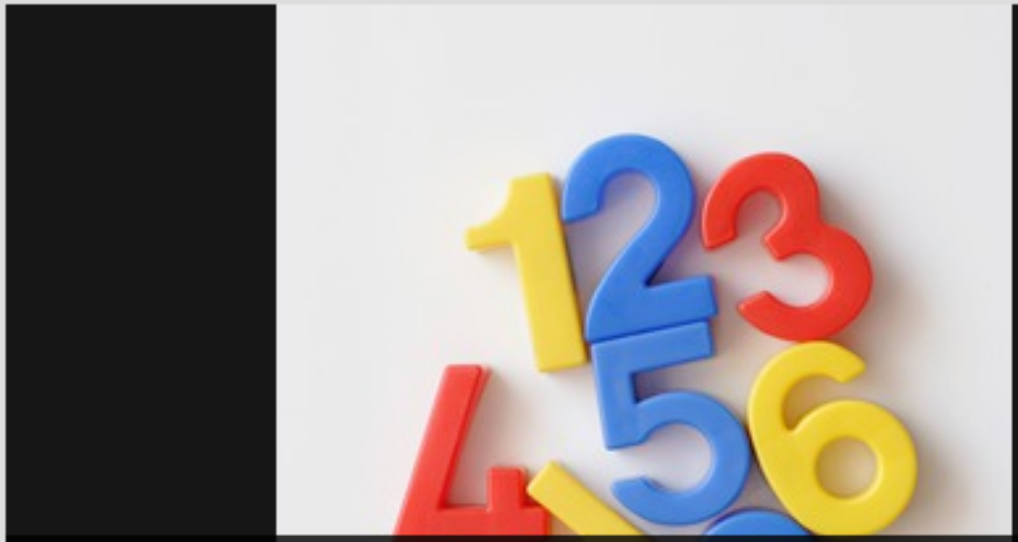
Spell-Checking Midsummer Night's Dream

- Exhaustive Search: **385,554 milliseconds** to check the entire text
- Binary Search: **104 milliseconds** to check the entire text
- Speedup: **3,707 times**!!!

www.forbes.com/2011/06/16/weird-interview-questions_slide_11.html

Forbes.com

In Pictures: Weird Job Interview Questions



"Can I Guess?"

CLOSE

Given the numbers 1 to 1,000, what is the minimum number of guesses needed to find a specific number if you are given the hint "higher" or "lower" for each guess you make?

Asked at Facebook

Sitcom/Dictator Game

http://www.smalltime.com/Dictator

Transitioning to Java in 1 Slide

Processing:

```
void setup() {
        println(“Hello World!”);
}
```

Java:

```
class test {
    public static void main(String[] args) {
        System.out.println("Hello World!");
    }
}
```