# Lecture 1: Welcome!

CSE 373: Data Structures and Algorithms

## Agenda

- Introductions
- Syllabus
- Dust off data structure cob webs
- Meet the ADT
- What is “complexity”?

## Waitlist/ Overloads

- There are no overloads
- I have no control over these things :/
- Email cse373@cs.washington.edu for all registration questions
- Many students move around, likely a spot will open
- Keep coming to lecture!

## Hello!

***I am Kasey Champion***

Software Engineer @ Karat

High School Teacher @ Franklin High

champk@cs.washington.edu

Office in CSE 218

Office Hours: Wednesdays 9:30-11:30, Fridays 2:30-4:30

@techie4good

## Class Style

Kasey has to go to her "real job" after this
- The internets
- Your TAs
- Each other

Please come to lecture (yes, there will be panoptos)
- Warm Ups -> Extra Credit
- Collaboration
- Demos
- Ask questions! Point out mistakes!

Sections
- TAs = heroes
- Exam Practice problems
- Sections start this week

# Course Administration

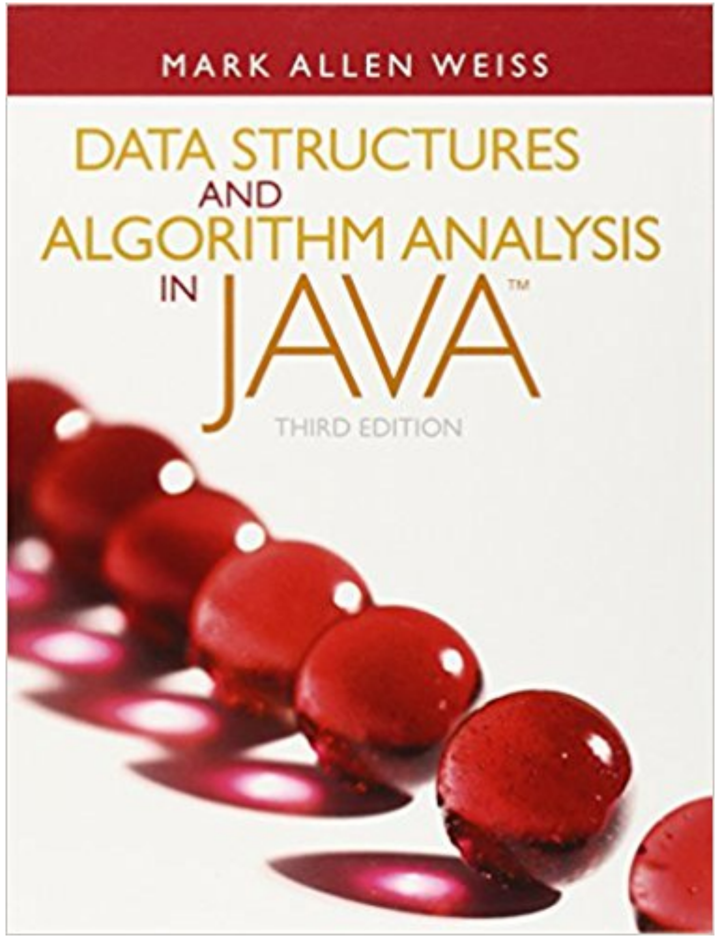
Course Page
- All course content/announcements posted here
- Pay attention for updates!

Canvas
- Grades will be posted here

Office Hours
- Will be posted on Course Page
- Will start next week

Google Discussion Board
- Great place to discuss questions with other students
- Will be monitored by course staff
- No posting of project code!

Textbook
- Optional
- Data Structures and Algorithm Analysis in Java by Mark Allen Weiss



## Grade Break Down

Homework (55%)

- 4 Partner Projects (40%)
  - Partners encouraged
  - Graded automatically
- 3 Individual Assignments (15%)
  - Must be individual
  - Graded by TAs

Exams (35%)

- Midterm Exam – Friday February 15th in class (20%)
- Final Exam – Tuesday March 19th 8:30-10:30 here! (25%)

## Syllabus

### Homework Policies

- 3 late days
  - Both partners must use one
  - When you run out you will forfeit 20% each 24 hour period an assignment is late
  - No assignment will be accepted more than 2 days late

### Project Regrades

- Get back half your missed points for part 1 when you turn in part 2
- Email Kasey if you believe grades are incorrect

### Exams

- Allowed 8.5”x11” note page
- NO MAKE UPS!
  - Let Kasey know ASAP if you cannot attend an exam

### Academic Integrity

- No posting code on discussion board or ANYWHERE online
- We do run MOSS
- No directly sharing code with one another (except for partners)

### Extra Credit

- Available on some homework assignments
- Available for attending lecture
- Worth up to 0.05 GPA bump

## Questions?

Clarification on syllabus, General complaining/moaning

## What is this class about?

CSE 143 – OBJECT ORIENTED PROGRAMMING

- Classes and Interfaces
- Methods, variables and conditionals
- Loops and recursion
- Linked lists and binary trees
- Sorting and Searching
- O(n) analysis
- Generics

CSE 373 – DATA STRUCTURES AND ALGORITHMS

- Design decisions
- Design analysis
- Implementations of data structures
- Debugging and testing
- Abstract Data Types
- Code Modeling
- Complexity Analysis
- Software Engineering Practices

## Data Structures and Algorithms

What are they anyway?

## Basic Definitions

### Data Structure

- A way of organizing and storing related data points
- Examples from CSE 14X: arrays, linked lists, stacks, queues, trees

### Algorithm

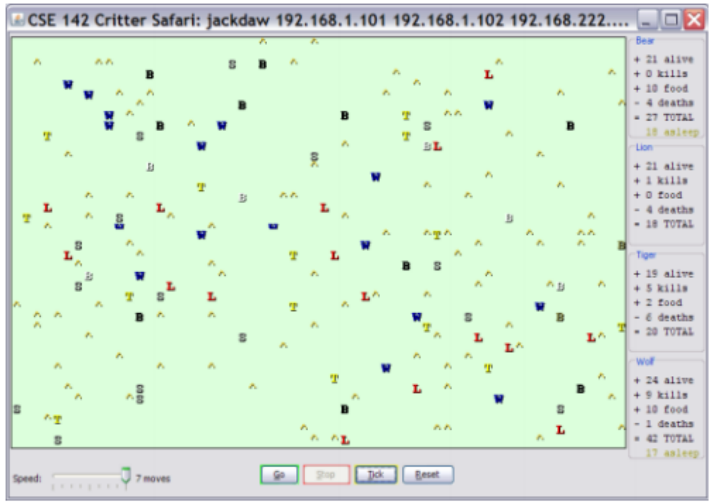
- A series of precise instructions used to perform a task
- Examples from CSE 14X: binary search, merge sort, recursive backtracking

# *Review:* Clients vs Objects

## CLIENT CLASSES

A class that is executable, in Java this means it contains a Main method

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

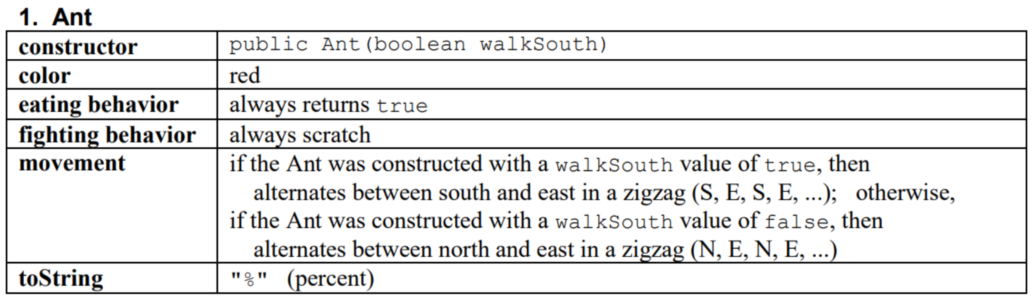

CSE 142 Critter Safari: jackdaw 192.168.1.101 192.168.1.102 192.168.222....
Speed:
7 moves
Go
Stop
Tick
Reset

```
Bear
+ 21 alive
+ 0 kills
+ 10 food
- 4 deaths
= 27 TOTAL
  10 asleep

Lion
+ 21 alive
+ 1 kills
+ 0 food
- 4 deaths
= 18 TOTAL

Tiger
+ 19 alive
+ 5 kills
+ 2 food
- 6 deaths
= 20 TOTAL

Wolf
+ 24 alive
+ 9 kills
+ 10 food
- 1 deaths
= 42 TOTAL
  17 asleep
```

## OBJECT CLASSES

A coded structure that contains data and behavior

Start with the data you want to hold, organize the things you want to enable users to do with that data



**1. Ant**

| | |
|---|---|
| **constructor** | `public Ant(boolean walkSouth)` |
| **color** | red |
| **eating behavior** | always returns `true` |
| **fighting behavior** | always scratch |
| **movement** | if the Ant was constructed with a `walkSouth` value of `true`, then alternates between south and east in a zigzag (S, E, S, E, ...); otherwise, if the Ant was constructed with a `walkSouth` value of `false`, then alternates between north and east in a zigzag (N, E, N, E, ...) |
| **toString** | `"%"` (percent) |

# Abstract Data Types (ADT)

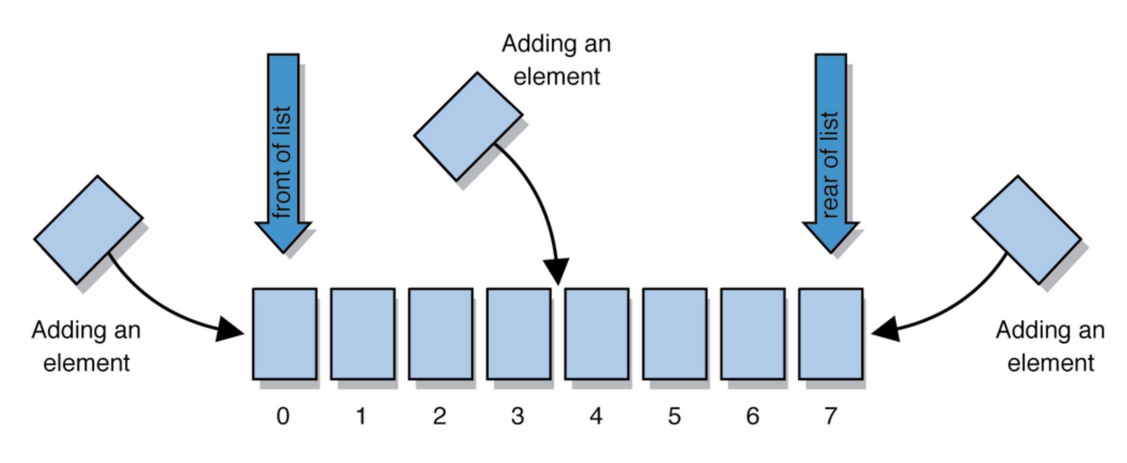
## Abstract Data types

- A definition for expected operations and behavior

Start with the operations you want to do then define how those operations will play out on whatever data is being stored

*Review:* List - a collection storing an ordered sequence of elements

- each element is accessible by a 0-based index
- a list has a size (number of elements that have been added)
- elements can be added to the front, back, or elsewhere
- in Java, a list can be represented as an ArrayList object



## *Review:* Interfaces

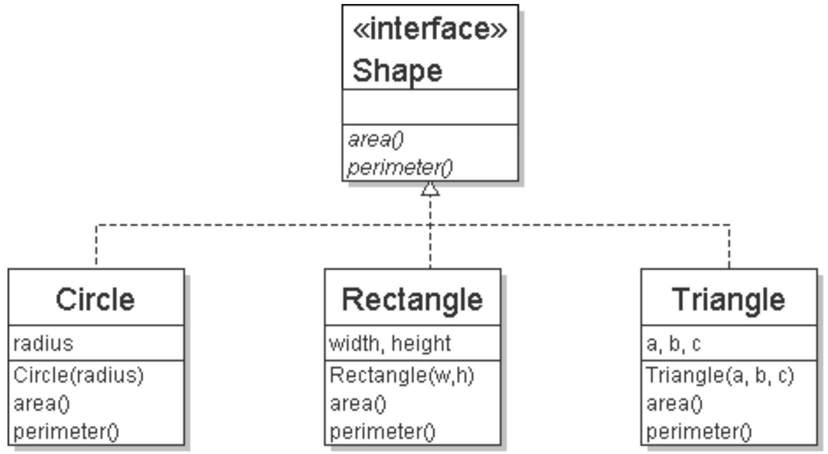
**interface**: A list of methods that a class promises to implement.

- Interfaces give you an is-a relationship *without* code sharing.
  - A `Rectangle` object can be treated as a `Shape` but inherits no code.
- Analogous to non-programming idea of roles or certifications:
  - "I'm certified as a CPA accountant.
    This assures you I know how to do taxes, audits, and consulting."
  - "I'm 'certified' as a Shape, because I implement the Shape interface.
    This assures you I know how to compute my area and perimeter."

```
public interface name {
    public type name(type name, ..., type name);
    public type name(type name, ..., type name);
    ...
    public type name(type name, ..., type name);
}
```

Example

```
// Describes features common to all
// shapes.
public interface Shape {
        public double area();
        public double perimeter();
}
```



# *Review:* Java Collections

Java provides some implementations of ADTs for you!

You used:

Lists `List<Integer> a = new ArrayList<Integer>();`

Stacks `Stack<Character> c = new Stack<Character>();`

Queues `Queue<String> b = new LinkedList<String>();`

Maps `Map<String, String> d = new TreeMap<String, String>();`

But some data structures you made from scratch… why?

Linked Lists - LinkedIntList was a collection of ListNode

Binary Search Trees – SearchTree was a collection of SearchTreeNodes

# Full Definitions

## Abstract Data Type (ADT)

- *A definition for expected operations and behavior*
- A mathematical description of a collection with a set of supported operations and how they should behave when called upon
- Describes what a collection does, not how it does it
- Can be expressed as an interface
- Examples: List, Map, Set

## Data Structure

- *A way of organizing and storing related data points*
- An object that implements the functionality of a specified ADT
- Describes exactly how the collection will perform the required operations
- Examples: LinkedIntList, ArrayIntList

# ADTs we'll discuss this qarter

- List
- Set
- Map
- Stack
- Queue
- Priority Queue
- Graph

# Case Study: The List ADT

**list:** stores an ordered sequence of information.

- Each item is accessible by an index.
- Lists have a variable size as items can be added and remove

**List ADT**

**state**

Set of ordered items
Count of items

**behavior**

get(index) return item at index
set(item, index) replace item at index
append(item) add item to end of list
insert(item, index) add item at index
delete(index) delete item at index
size() count of items

supported operations:

- **get(index):** returns the item at the given index
- **set(value, index):** sets the item at the given index to the given value
- **append(value):** adds the given item to the end of the list
- **insert(value, index):** insert the given item at the given index maintaining order
- **delete(index):** removes the item at the given index maintaining order
- **size():** returns the number of elements in the list

# Case Study: List Implementations

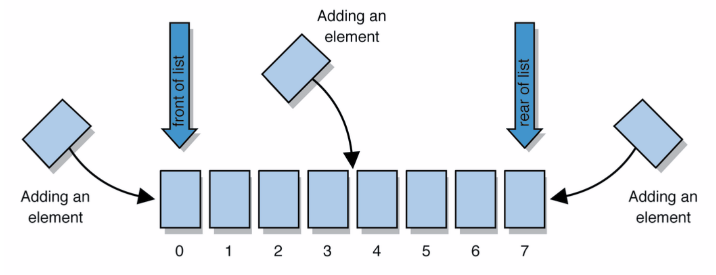
## List ADT

**state**

Set of ordered items
Count of items

**behavior**

get(index) return item at index
set(item, index) replace item at index
append(item) add item to end of list
insert(item, index) add item at index
delete(index) delete item at index
size() count of items



## ArrayList

uses an Array as underlying storage

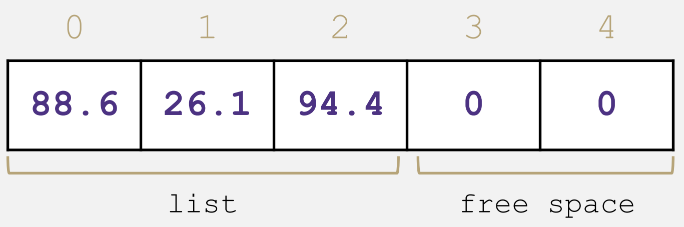
### ArrayList<E>

**state**

data[]
size

**behavior**

get return data[index]
set data[index] = value
append data[size] = value, if out of space grow data
insert shift values to make hole at index, data[index] = value, if out of space grow data
delete shift following values forward
size return size



## LinkedList

uses nodes as underlying storage

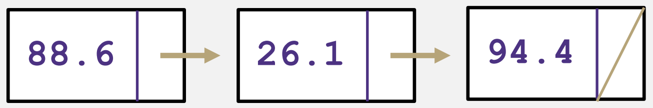
### LinkedList<E>

**state**

Node front
size

**behavior**

get loop until index, return node’s value
set loop until index, update node’s value
append create new node, update next of last node
insert create new node, loop until index, update next fields
delete loop until index, skip node
size return size



# Implementing ArrayList

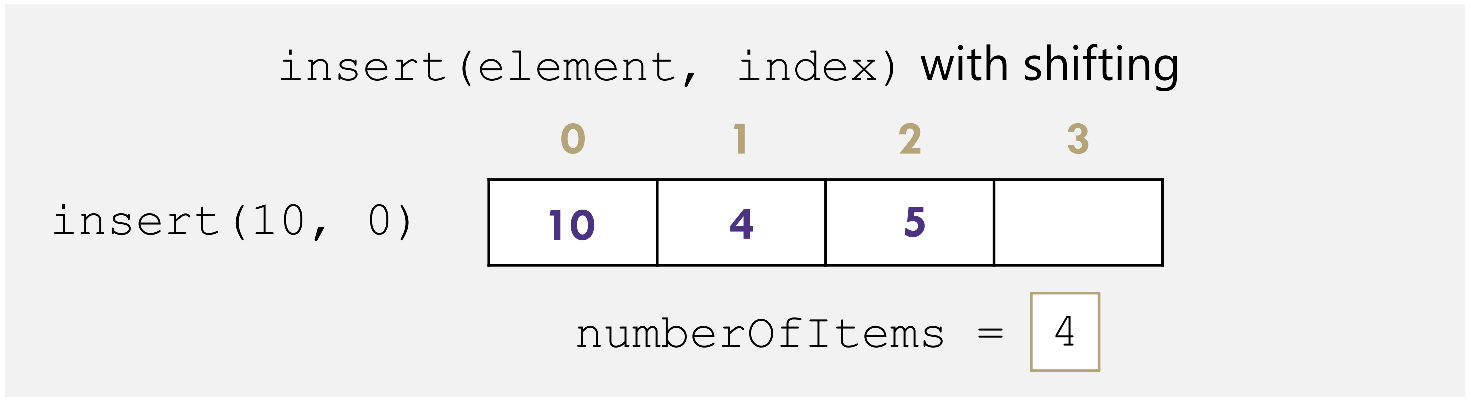
**ArrayList<E>**

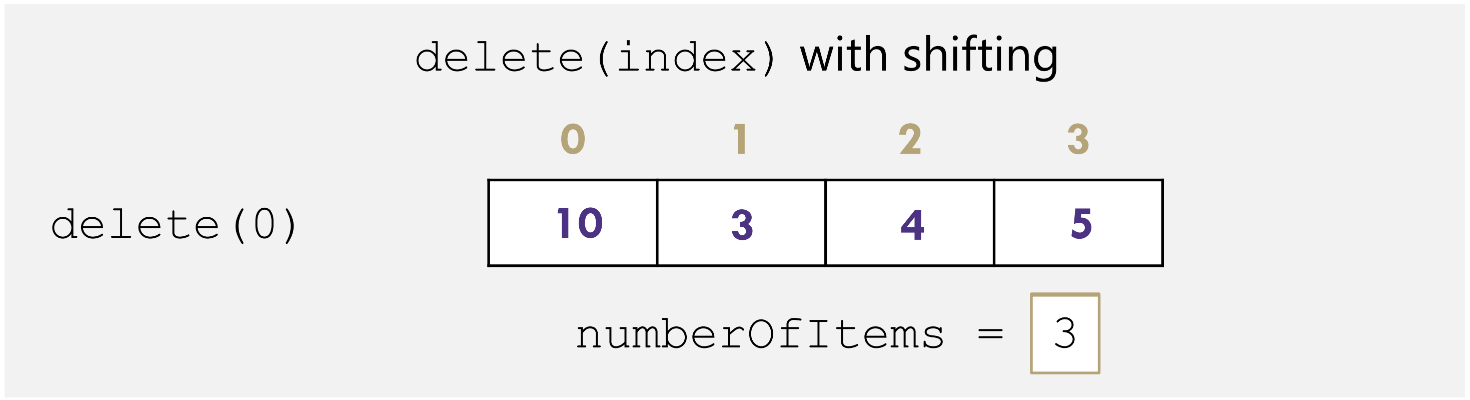
**state**

data[]
size

**behavior**

get return data[index]
set data[index] = value
append data[size] = value, if out of space grow data
insert shift values to make hole at index, data[index] = value, if out of space grow data
delete shift following values forward
size return size





# Implementing ArrayList

**ArrayList<E>**

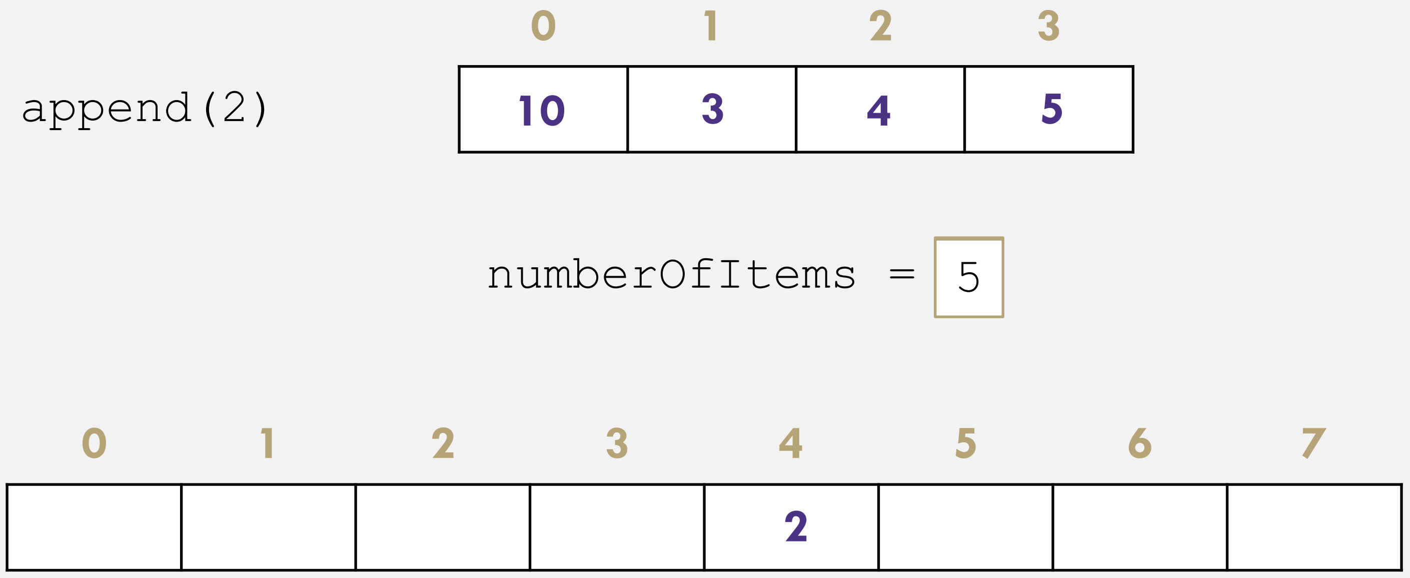
**state**

```
data[]
size
```

**behavior**

```
get return data[index]
set data[index] = value
append data[size] =
value, if out of space
grow data
insert shift values to
make hole at index,
data[index] = value, if
out of space grow data
delete shift following
values forward
size return size
```

`append(element)` with growth



# Design Decisions

For every ADT there are lots of different ways to implement them

Based on your situation you should consider:

- Memory vs Speed
- Generic/Reusability vs Specific/Specialized
- One Function vs Another
- Robustness vs Performance

This class is all about implementing ADTs based on making the right design tradeoffs!

> A common topic in interview questions

## *Review:* “Big Oh”

**efficiency**: measure of computing resources used by code.
- can be relative to speed (time), memory (space), etc.
- most commonly refers to run time

Assume the following:
- Any single Java statement takes same amount of time to run.
- A method call's runtime is measured by the total of the statements inside the method's body.
- A loop's runtime, if the loop repeats N times, is N times the runtime of the statements in its body.

We measure runtime in proportion to the input data size, N.
- **growth rate**: Change in runtime as N gets bigger. How does this algorithm perform with larger and larger sets of data?

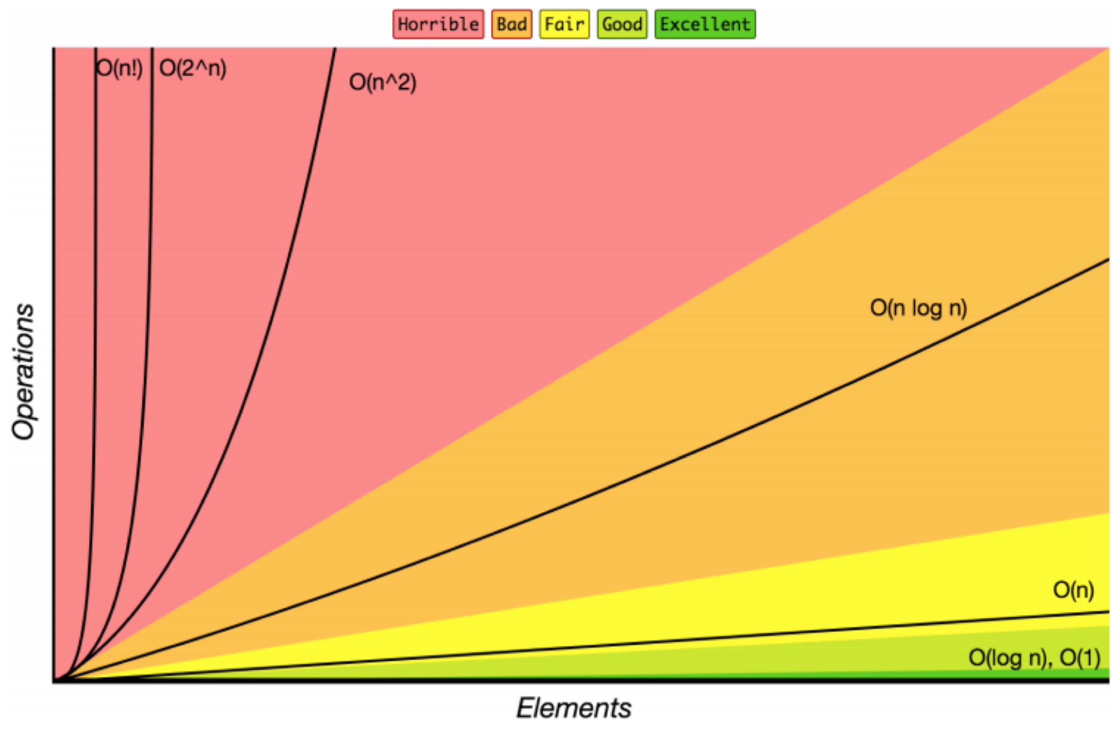
```
b = c + 10;

for (int i = 0; i < N; i++) {
    for (int j = 0; j < N; j++) {
        dataTwo[j][i] = dataOne[i][j];
        dataOne[i][j] = 0;
    }
}
for (int i = 0; i < N; i++) {
    dataThree[i] = b;
}
```

This algorithm runs **$2N^2 + N + 1$** statements.
- We ignore constants like 2 because they are tiny next to N.
- The highest-order term ($N^2$) “dominates” the overall runtime.
- We say that this algorithm runs "on the order of" $N^2$.
- or **O($N^2$)** for short ("**Big-Oh** of N squared")

## *Review:* Complexity Class

**complexity class:** A category of algorithm efficiency based on the algorithm's relationship to the input size N.

| Complexity Class | Big-O | Runtime if you double N | Example Algorithm |
|---|---|---|---|
| constant | O(1) | unchanged | Accessing an index of an array |
| logarithmic | $O(\log_2 N)$ | increases slightly | Binary search |
| linear | O(N) | doubles | Looping over an array |
| log-linear | $O(N \log_2 N)$ | slightly more than doubles | Merge sort algorithm |
| quadratic | $O(N^2)$ | quadruples | Nested loops! |
| … | … | … | … |
| exponential | $O(2^N)$ | multiplies drastically | Fibonacci with recursion |



## List ADT tradeoffs

Time needed to access i-th element:

- Array: O(1) constant time
- LinkedList: O(n) linear time

Time needed to insert at i-th element

- Array: O(n) linear time
- LinkedList: O(n) linear time

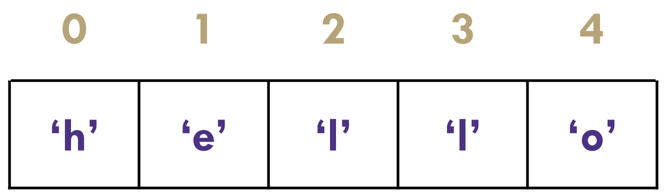
Amount of space used overall

- Array: sometimes wasted space
- LinkedList: compact

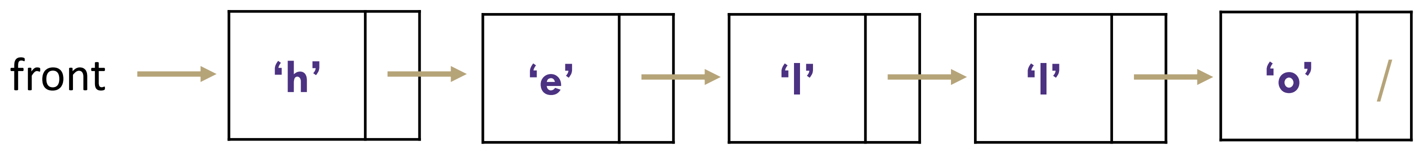
Amount of space used per element

- Array: minimal
- LinkedList: tiny extra

```
char[] myArr = new char[5]
```



```
LinkedList<Character> myLl = new LinkedList<Character>();
```



## TODO list

Skim through full Syllabus on class web page

Sign up for Google Discussion

Review 142/143 materials. Materials provided on class webpage.

Sign Up for Practice-It http://practiceit.cs.washington.edu