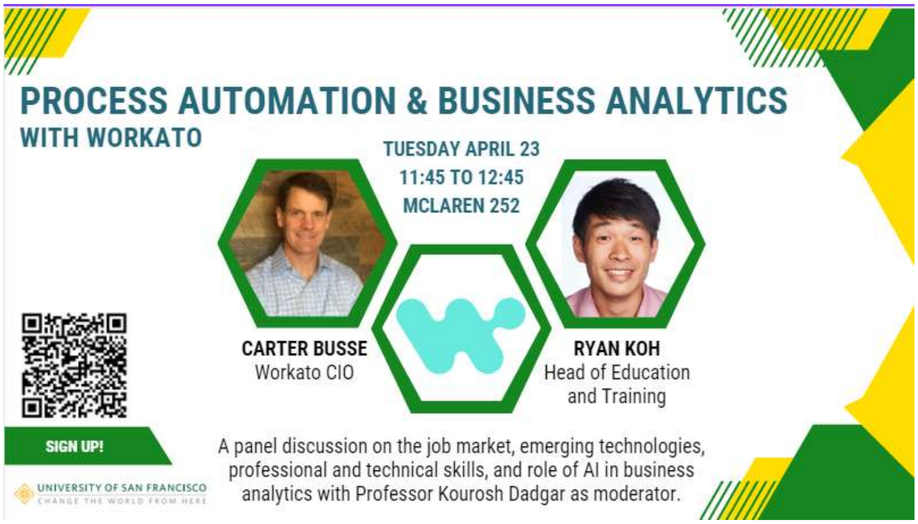
News



PROCESS AUTOMATION & BUSINESS ANALYTICS

WITH WORKATO

TUESDAY APRIL 23
11:45 TO 12:45
MCLAREN 252

CARTER BUSSE
Workato CIO

RYAN KOH
Head of Education
and Training

SIGN UP!

UNIVERSITY OF SAN FRANCISCO
CHANGE THE WORLD FROM HERE

A panel discussion on the job market, emerging technologies, professional and technical skills, and role of AI in business analytics with Professor Kourosh Dadgar as moderator.

Other topic: cheating. I will have lots of in-class work, and it must be turned in at the end of class.

Review

So far this semester…

- Java syntax: variables, variable types, classes, methods
- OOP: inheritance, overloaded methods, polymorphism, abstract methods/classes, interfaces
- Data structures: linked lists, trees, rings. Recursion
- Other topics: parts of a computer, Java math and logic, class String, references and objects, Exceptions

Labs: how to solve problems using computer programs, how to design algorithms

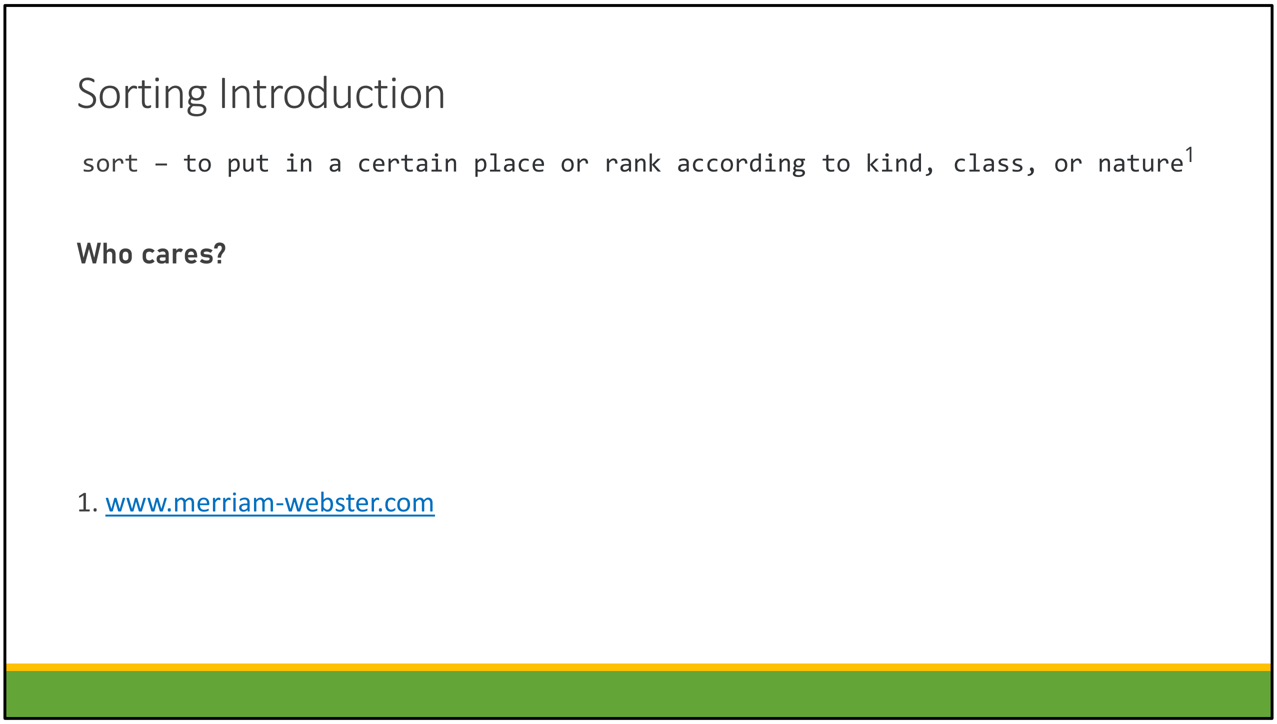
Today: analysis of algorithms

CS112 –
Java
Programming

Spring 2024

Sorting Algorithms

Good news no HW today on sorting—have Project02! But will be sort questions on final



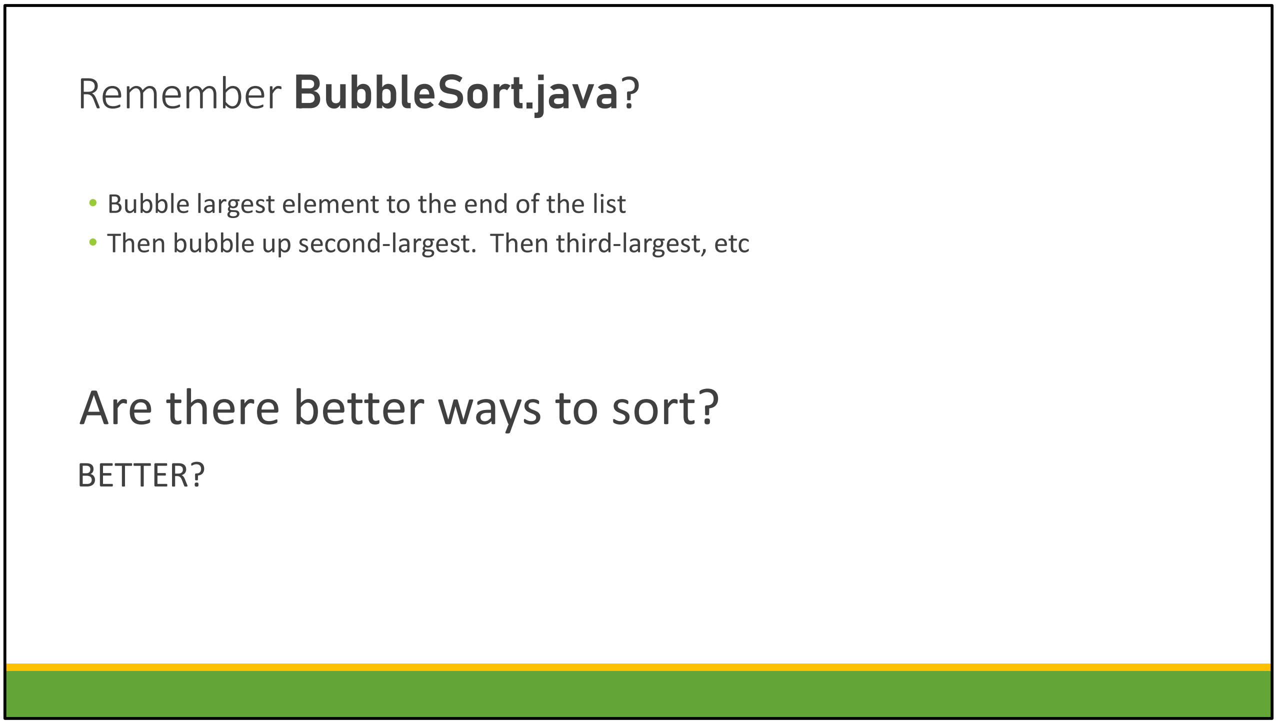
Sorting Introduction

`sort – to put in a certain place or rank according to kind, class, or nature`[1]

Who cares?

[1] www.merriam-webster.com

Pack boxes into container: “biggest rocks first”.
Pack compute jobs onto server farm.
Schedule data packets onto shared channel.
Search sorted list faster than unsorted with Binary Search…



Remember **BubbleSort.java**?

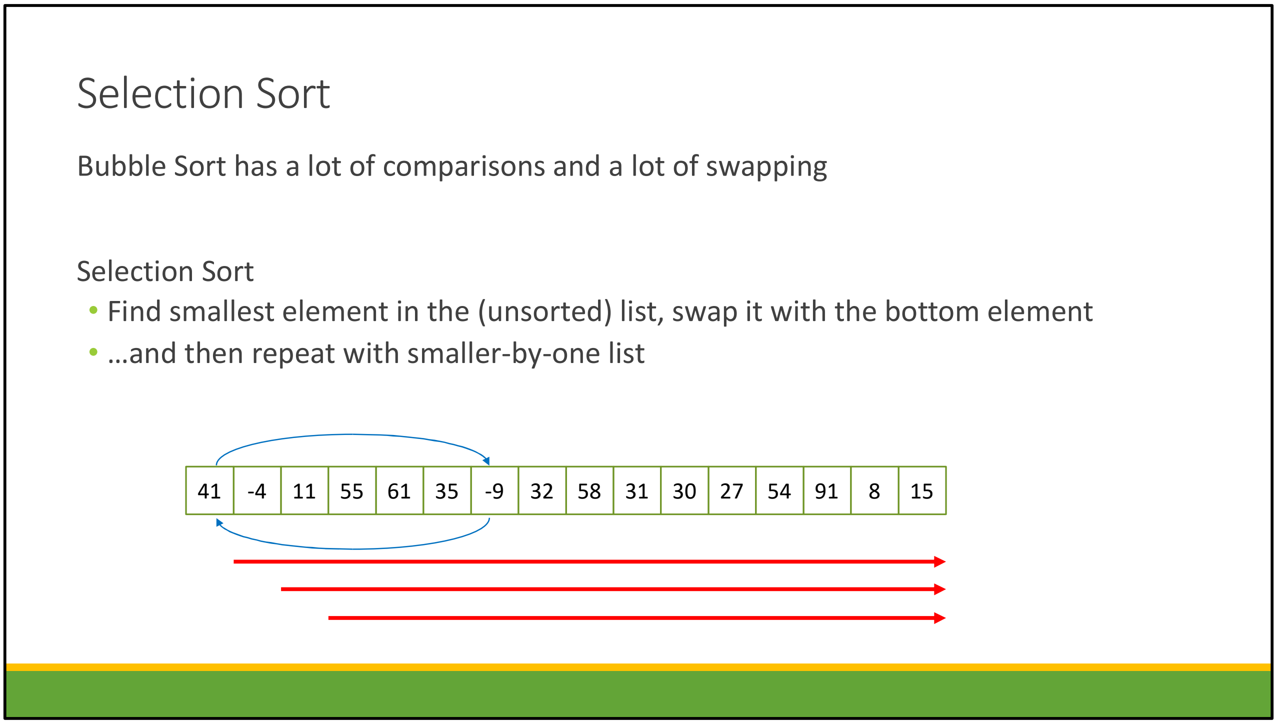
- Bubble largest element to the end of the list
- Then bubble up second-largest. Then third-largest, etc

Are there better ways to sort?

BETTER?

Write up in SCRATCH.java. Class type-along.

Better? FASTER, small memory use, simple SW to write & debug



Selection Sort

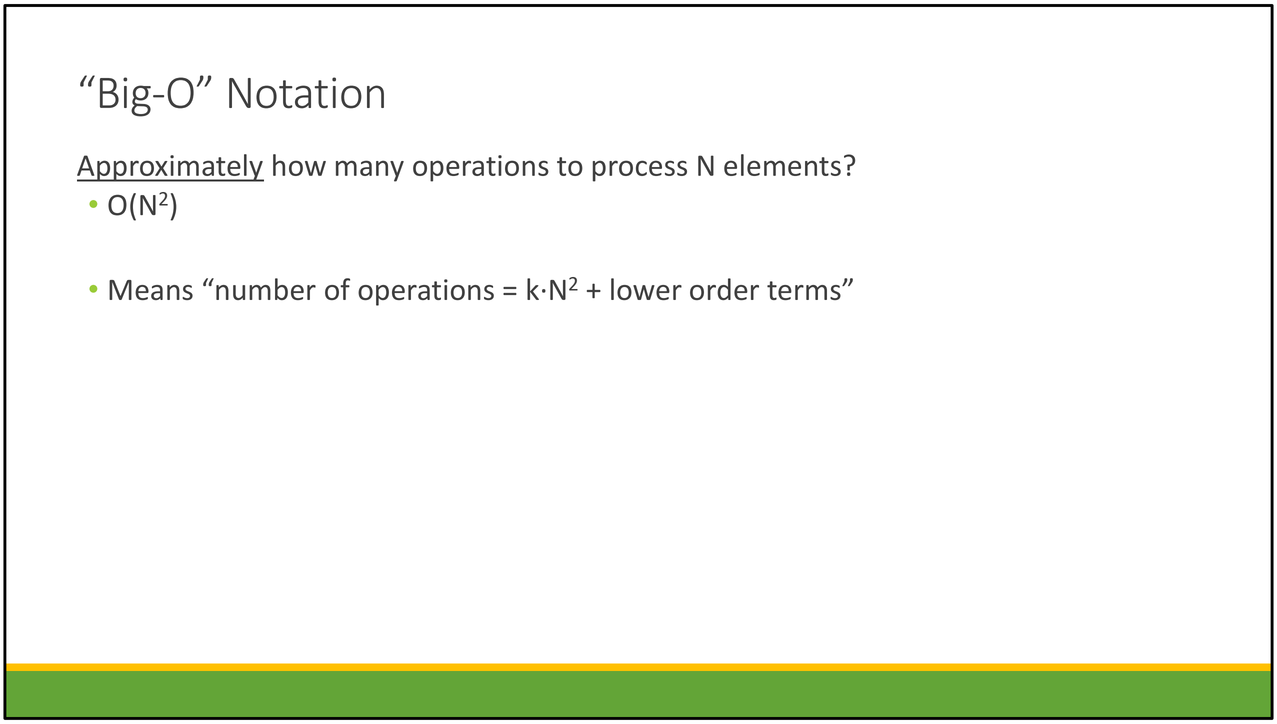
Bubble Sort has a lot of comparisons and a lot of swapping

Selection Sort

- Find smallest element in the (unsorted) list, swap it with the bottom element
- …and then repeat with smaller-by-one list

41	-4	11	55	61	35	-9	32	58	31	30	27	54	91	8	15

Write code. Then review code w COUNTED # OF COMPARES & ASSIGNS. Measure time!

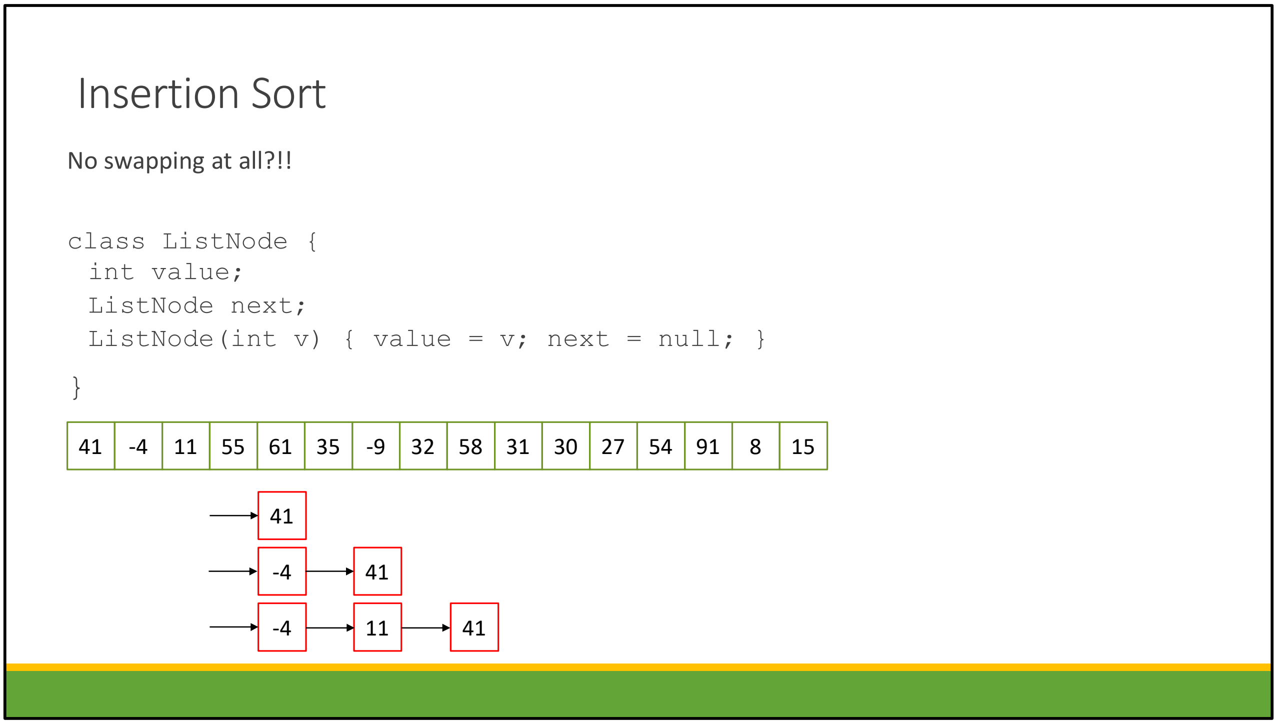


“Big-O” Notation

Approximately how many operations to process N elements?

- $O(N^2)$
- Means “number of operations = $k \cdot N^2$ + lower order terms”

Analyze for Bubble Sort, Selection Sort
Gives order of magnitude



Insertion Sort

No swapping at all?!!

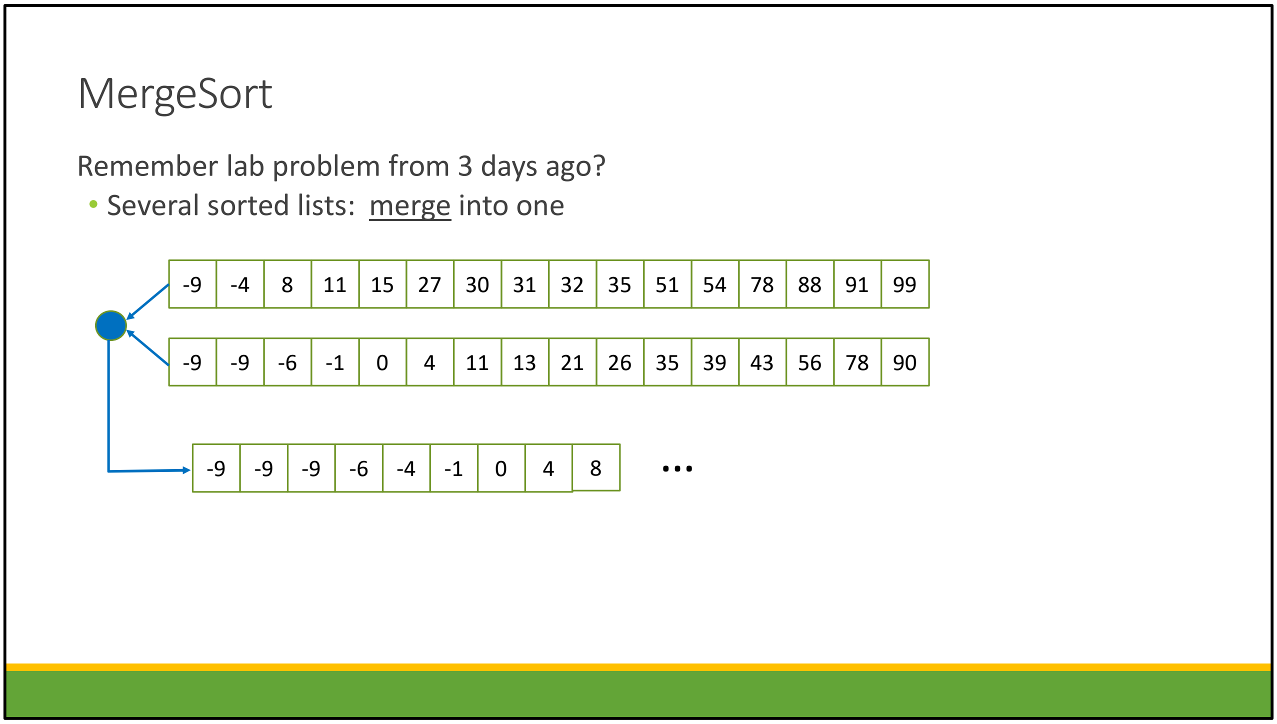
```
class ListNode {
 int value;
 ListNode next;
 ListNode(int v) { value = v; next = null; }
}
```

41	-4	11	55	61	35	-9	32	58	31	30	27	54	91	8	15

→ 41
→ -4 → 41
→ -4 → 11 → 41

Look @ & run SW: no swaps: why so slow? Expensive operations.
EVER USE Insertion Sort? If data "almost" sorted, use doubly linked list, insert at end, sort in O(N)!

High Performance Sorting Algorithms



MergeSort

Remember lab problem from 3 days ago?

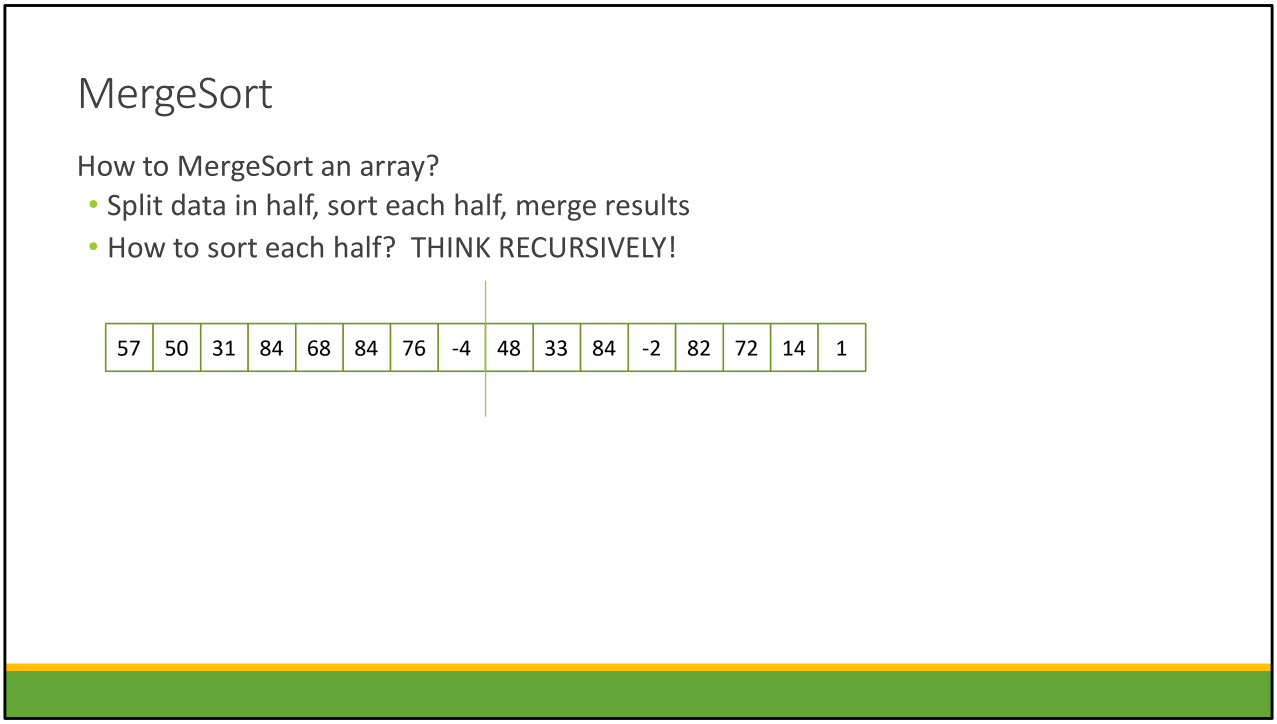
- Several sorted lists: merge into one

-9	-4	8	11	15	27	30	31	32	35	51	54	78	88	91	99

-9	-9	-6	-1	0	4	11	13	21	26	35	39	43	56	78	90

-9	-9	-9	-6	-4	-1	0	4	8	…

ONLY PULL FROM FRONT OF LISTS. O(N), very cheap



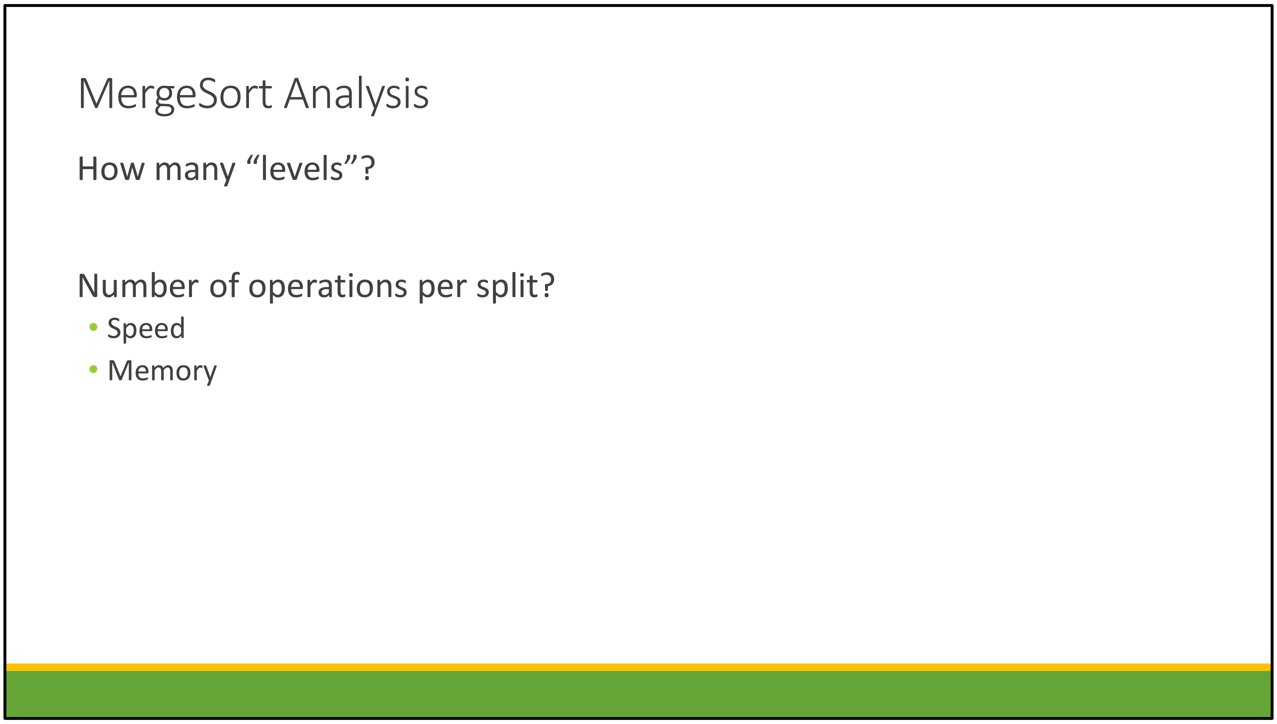
MergeSort

How to MergeSort an array?

- Split data in half, sort each half, merge results
- How to sort each half? THINK RECURSIVELY!

57	50	31	84	68	84	76	-4	48	33	84	-2	82	72	14	1

Need extra memory to store merged results
Look at code, in detail. RUN!



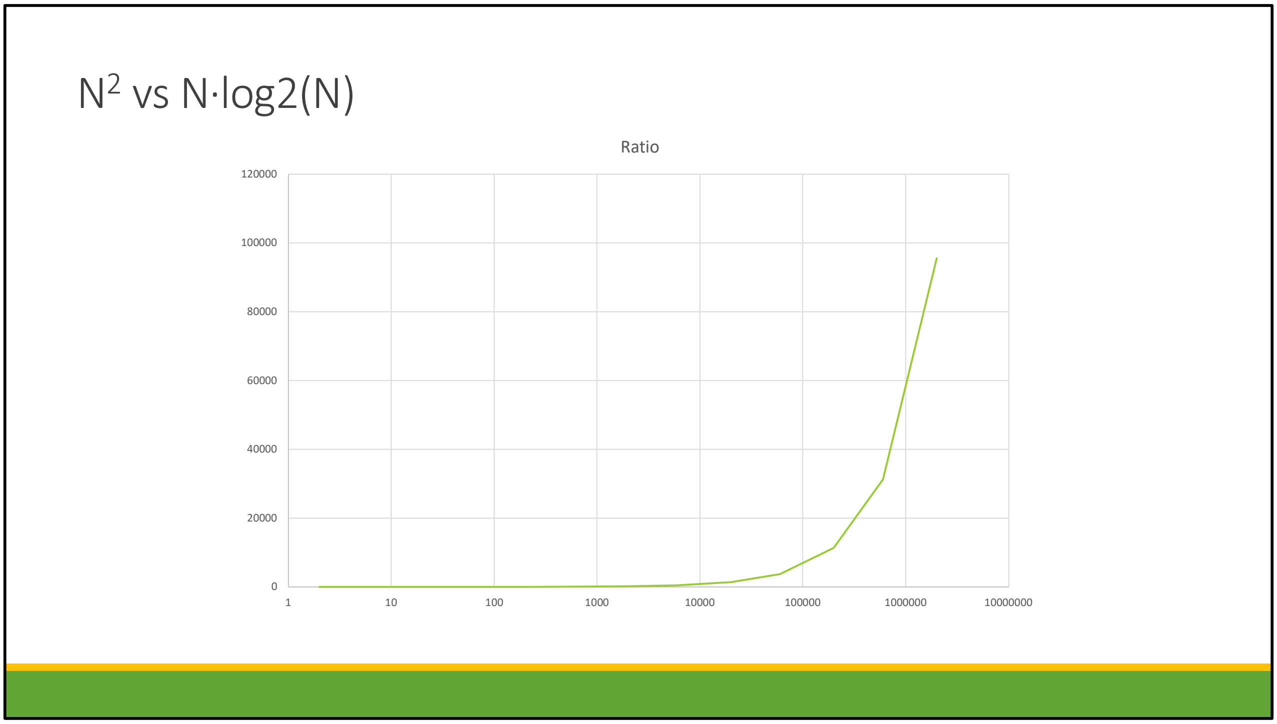
MergeSort Analysis

How many “levels”?

Number of operations per split?

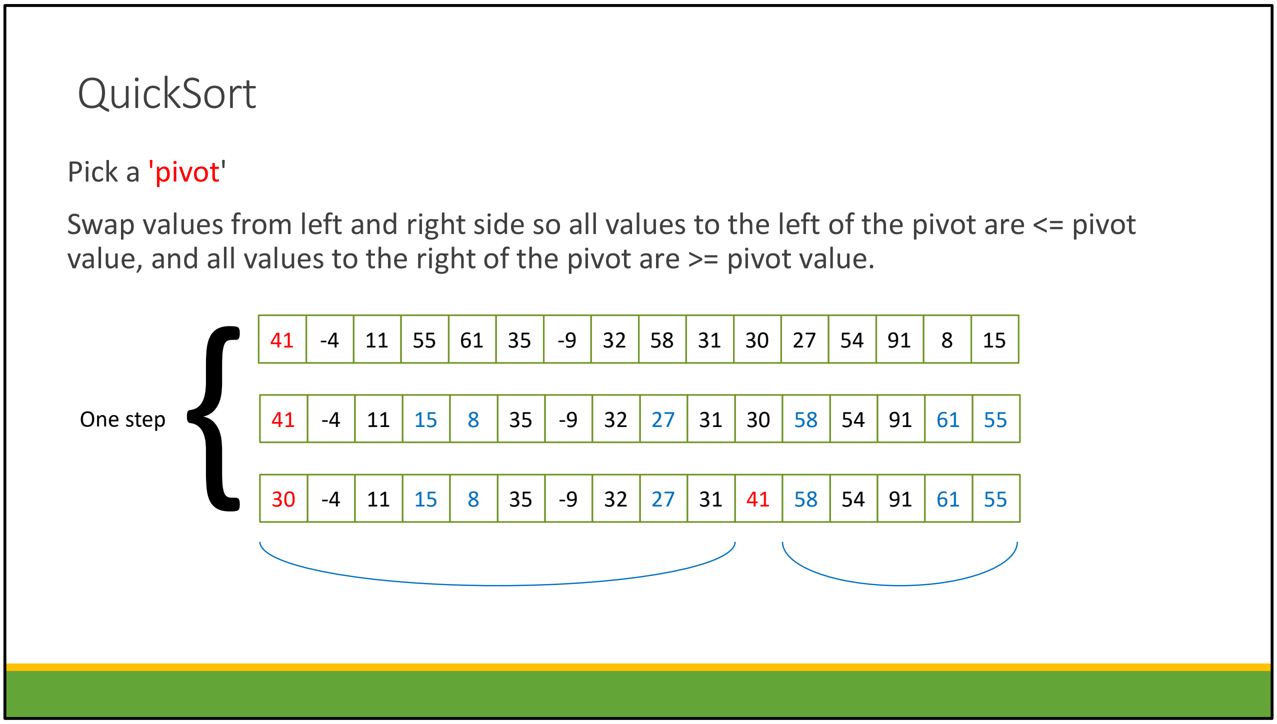
- Speed
- Memory

Assume N = 2^k. Layers are N, N/2, N/4, … 0. log2(N) layers.
3N comparisons per layer, 2N data copies. Total cost = O(N log2(N))
Uses N+N/2+N/4+N/8+… = 2N extra memory



N^2 vs N·log2(N)

For 1M elements, BubbleSort takes 60k x longer than MergeSort
- 10 seconds for Merge sort? 1 week for Bubble sort



QuickSort

Pick a 'pivot'

Swap values from left and right side so all values to the left of the pivot are <= pivot value, and all values to the right of the pivot are >= pivot value.

One step

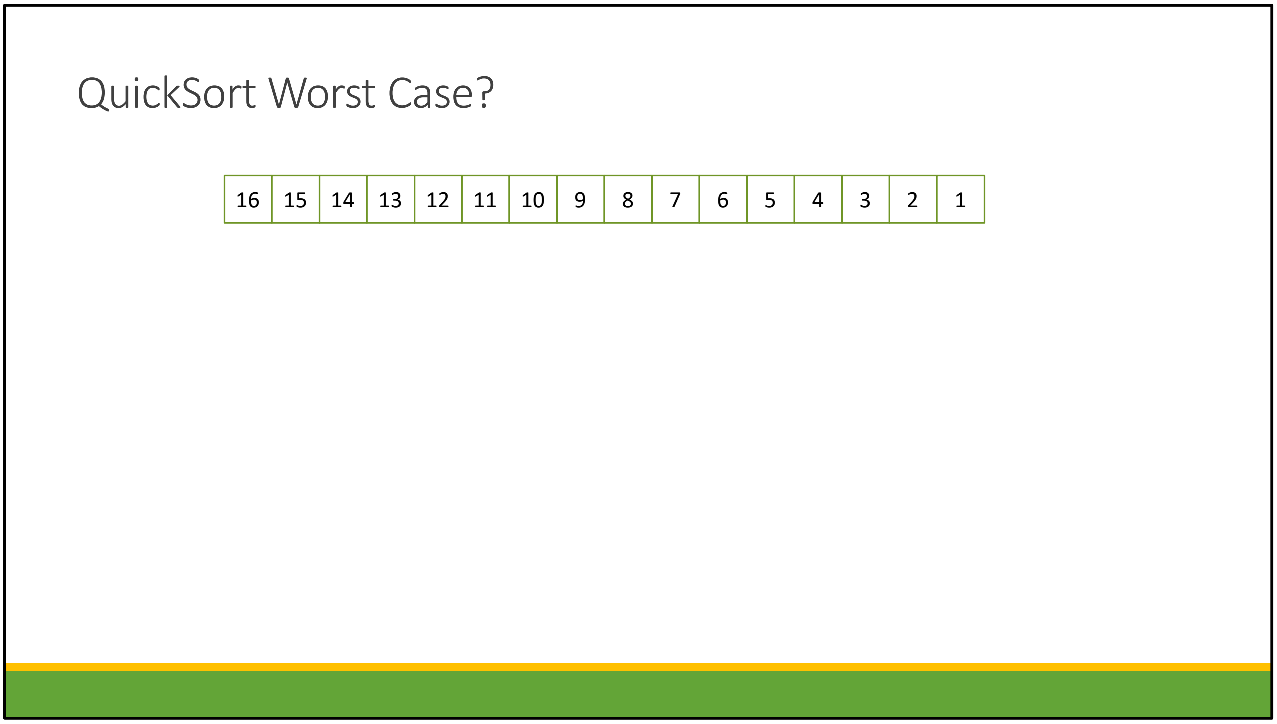
41	-4	11	55	61	35	-9	32	58	31	30	27	54	91	8	15
41	-4	11	15	8	35	-9	32	27	31	30	58	54	91	61	55
30	-4	11	15	8	35	-9	32	27	31	41	58	54	91	61	55

After swapping, PIVOT ELEMENT IN PROPER PLACE!

HOW MANY OPS?

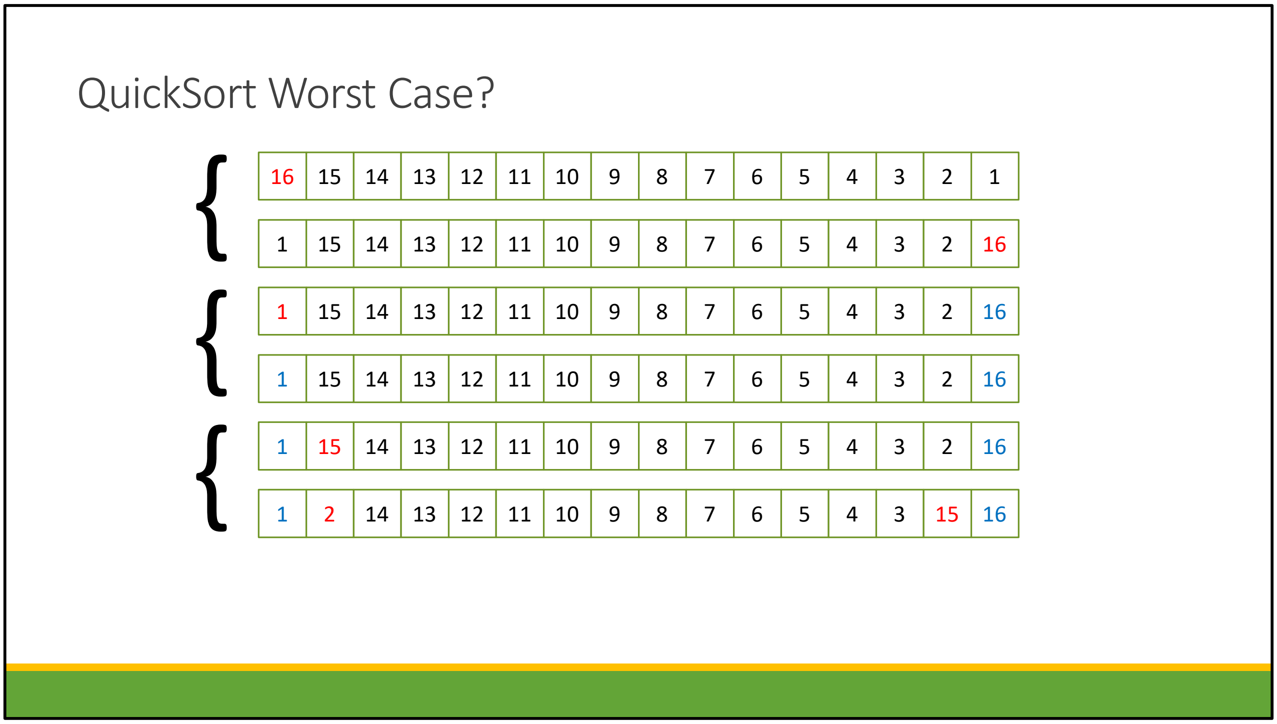
- At each step, N compars & swaps
- LOG2(N) steps like MergeSort. So O(N log2(N))

WALK THRU SW & RUN



QuickSort Worst Case?

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

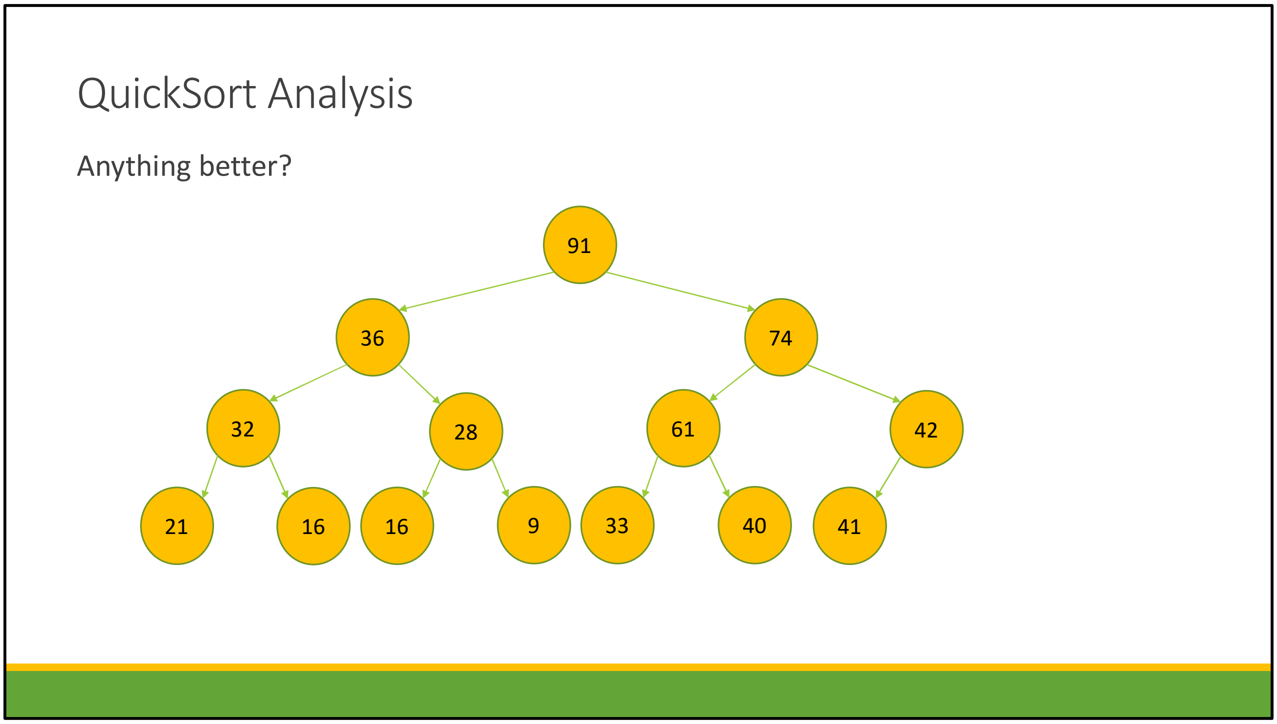


QuickSort Worst Case?

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	16
1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	16
1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	16
1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	16
1	2	14	13	12	11	10	9	8	7	6	5	4	3	15	16

What are pivots? How many steps? QuickSort is O(N log2(N)) on average. Is O(N*N) in worst case, like SelectionSort.

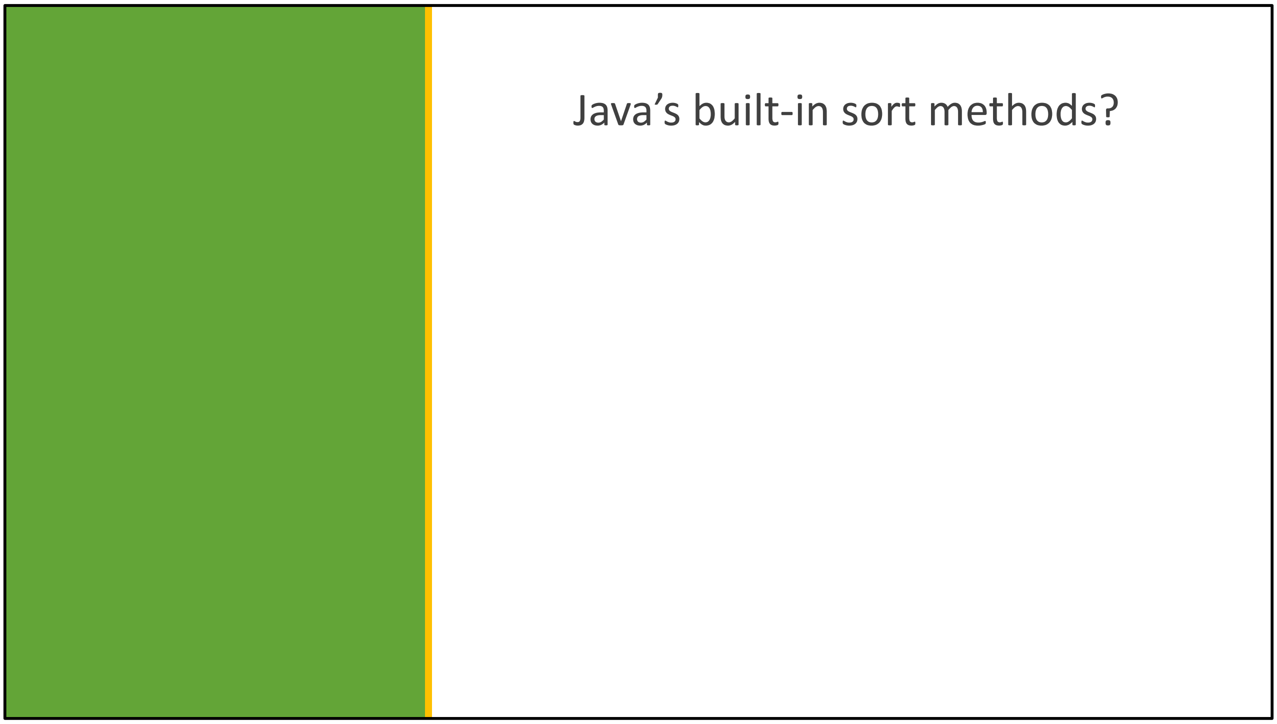
RUN PROG WITH ORDERED INPUT! CRASHES!



QuickSort Analysis

Anything better?

HEAPSORT
Worst case O(Nlog(N))
No memory needed
But average time > QuickSort & MergeSort. Worst case very good though.



Java’s built-in sort methods?

Arrays.sort(). Collections.sort().

Java’s sort? Timsort: a blend of mergesort and insertionsort