WEEK FOURTEEN

Acknowledgements: Slides created based off material provided by Dr. Michael Raymer and Dr. Travis Doom

ALGORITHMS

- Approach to solving a computational problem
- Algorithms must be:
  - Finite: must terminate eventually
  - Correct: must solve the problem every time
  - Deterministic: made of concrete, computer-executable steps, and produce the same output every time
- Good algorithms are:
  - Bug-free
  - Secure
  - Fast
  - Don’t hog memory

SEARCH ALGORITHMS

- Linear search
  - Step through items one-by-one until the desired item is located
- Binary search
  - Requires a sorted list
  - Split the list in half, check if the value is greater than or less than the central pivot
    - If greater, move to the right side of the list and repeat
    - If less than, move to the left side of the list and repeat

SORTING ALGORITHMS

- Selection sort
  - Remove the min/max item from an unsorted list and add (swap) it to the beginning/end of a new sorted list
- Insertion sort
  - Take each element, in position order, and move it into the appropriate sorted location in a ‘new’ sorted list
- Bubble sort
  - Sort in multiple passes
  - In each pass, successively swap neighboring elements if they are in the wrong natural order
  - Continue passes until all elements are fully ordered

Selection

7 3 2 6 9 5 2

2 3 2 6 9 5 7

2 2 3 6 9 5 7

2 2 3 6 9 5 7

2 2 3 5 9 6 7

2 2 3 5 6 9 7

2 2 3 5 6 7 9

7 3 2 6 9 5 2

7 3 2 6 2 5 9

5 3 2 6 2 7 9

5 3 2 2 6 7 9

2 3 2 5 6 7 9

2 2 3 5 6 7 9

2 2 3 5 6 7 9

Insertion

7 3 2 6 9 5 2

7 | 3 2 6 9 5 2

7 | 3 2 6 9 5 2

3 7 | 2 6 9 5 2

2 3 7 | 6 9 5 2

2 3 6 7 | 9 5 2

2 3 6 7 9 | 5 2

2 3 5 6 7 9 | 2

2 2 3 5 6 7 9

7 3 2 6 9 5 2

7 3 2 6 9 5 | 2

7 3 2 6 9 | 2 5

7 3 2 6 | 2 5 9

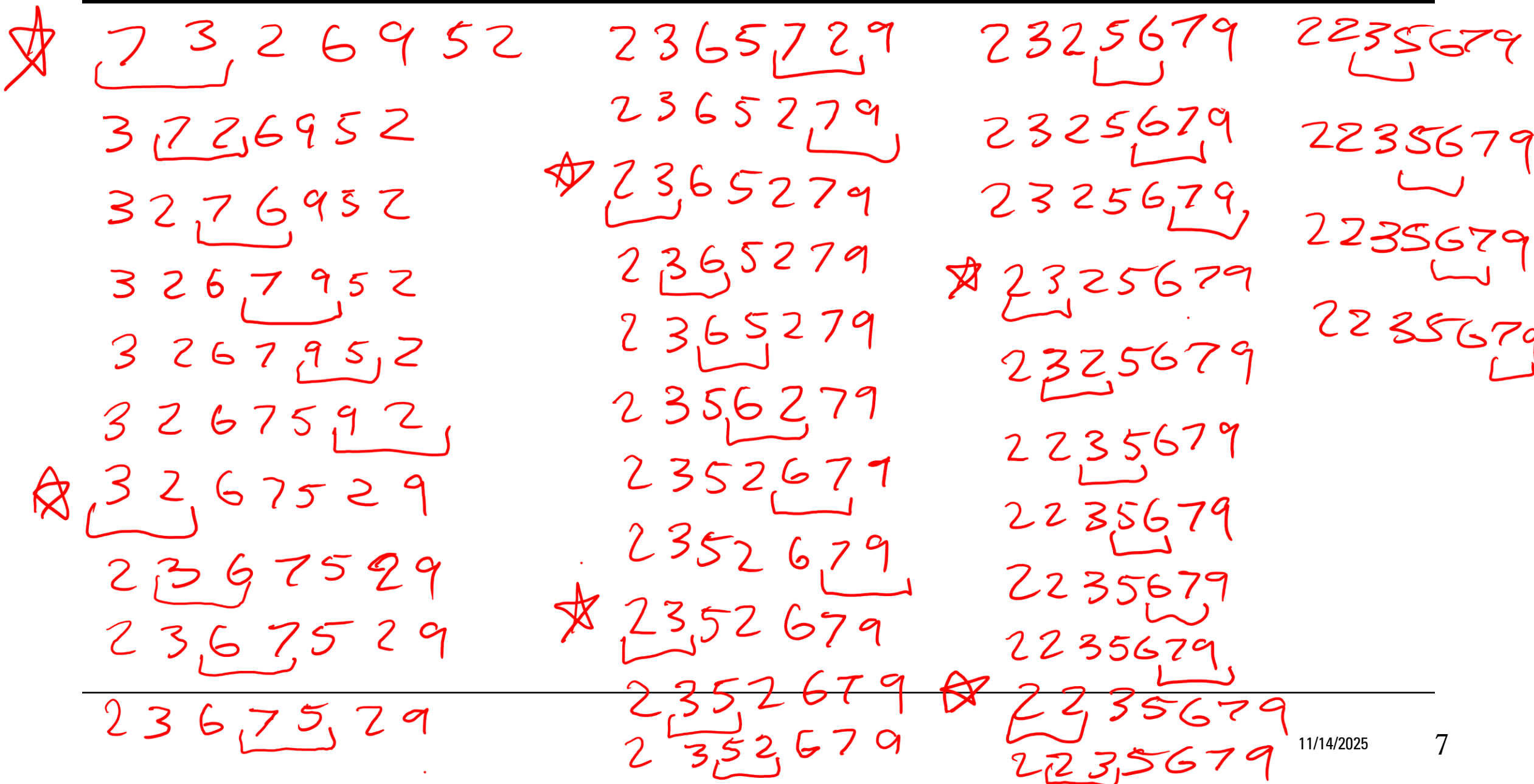
7 3 2 | 2 5 6 9

7 3 | 2 2 5 6 9

7 | 2 2 3 5 6 9

2 2 3 5 6 7 9

Bubble Sort


7 3 2 6 9 5 2
3 7 2 6 9 5 2
3 2 7 6 9 5 2
3 2 6 7 9 5 2
3 2 6 7 5 9 2
3 2 6 7 5 2 9
2 3 6 7 5 2 9
2 3 6 7 5 2 9
2 3 6 7 5 2 9
2 3 6 5 7 2 9
2 3 6 5 2 7 9
2 3 6 5 2 7 9
2 3 6 5 2 7 9
2 3 6 5 2 7 9
2 3 5 6 2 7 9
2 3 5 2 6 7 9
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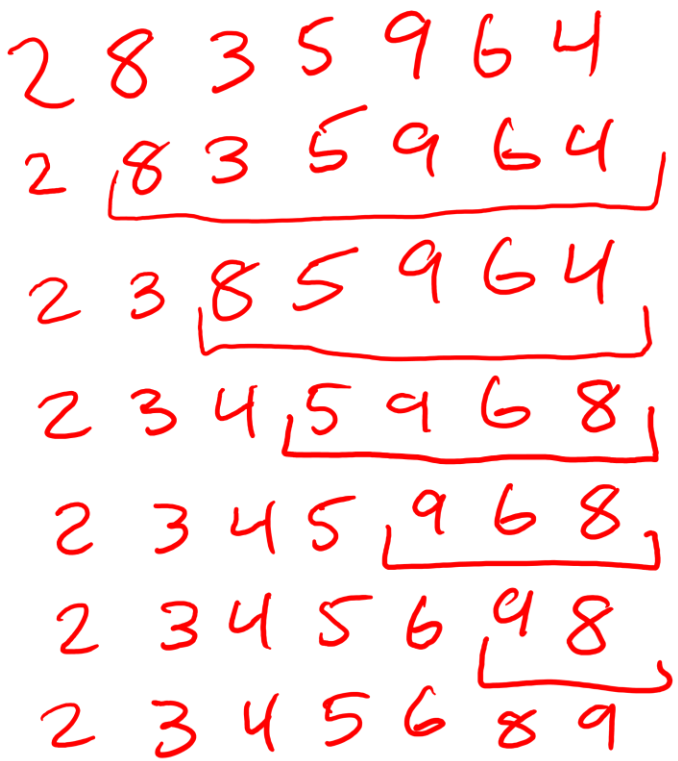
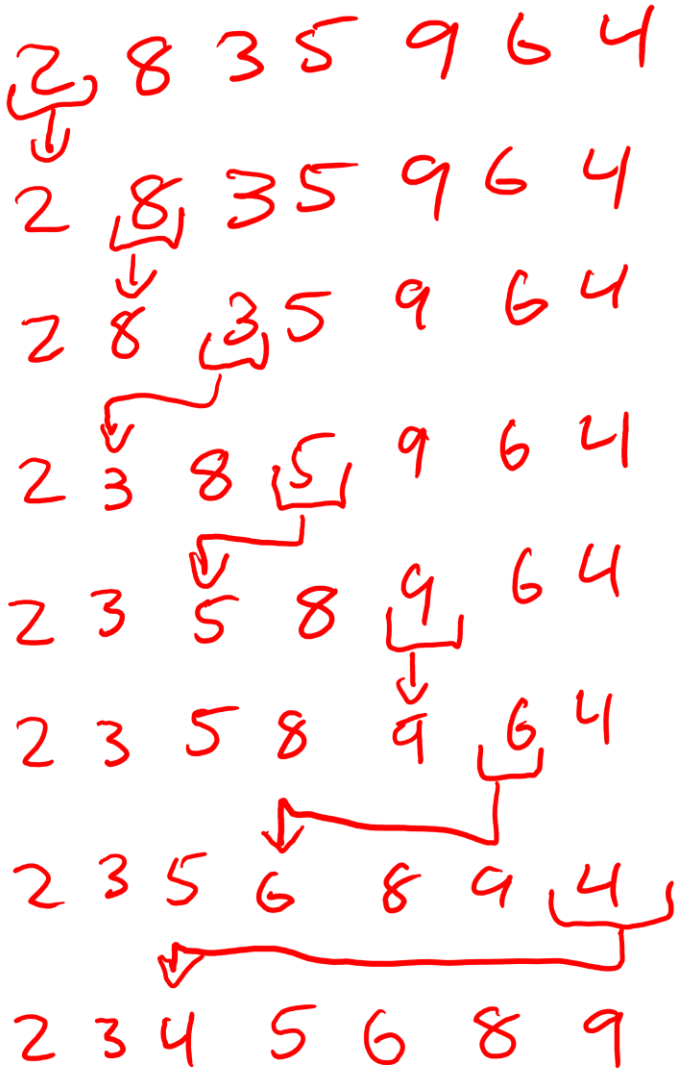
2 2 3 5 6 7 9
2 2 3 5 6 7 9

Selection



Insection



Bubble

Pass #1

2 8 3 5 9 6 4

2 8 3 5 9 6 4

2 3 8 5 9 6 4

2 3 5 8 9 6 4

2 3 5 8 9 6 4

2 3 5 8 6 9 4

2 3 5 8 6 4 9

2 3 5 8 6 4 9

2 3 5 8 6 4 9

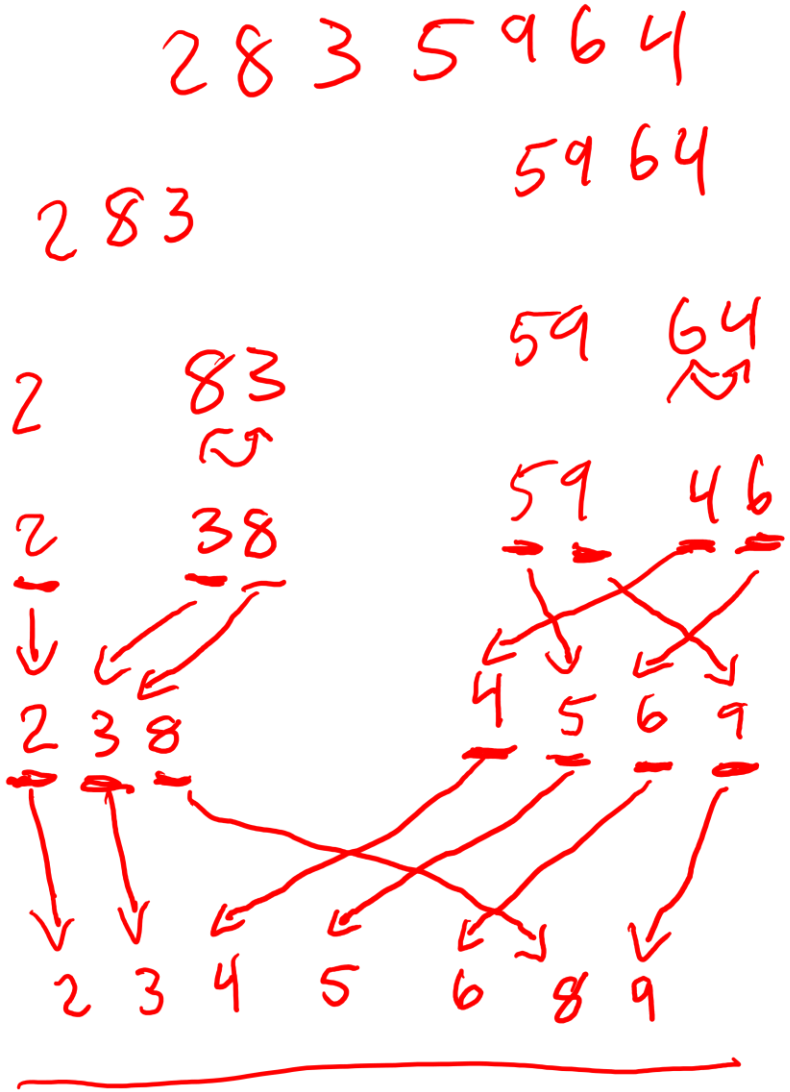
2 3 5 6 8 4 9

2 3 5 6 4 8 9

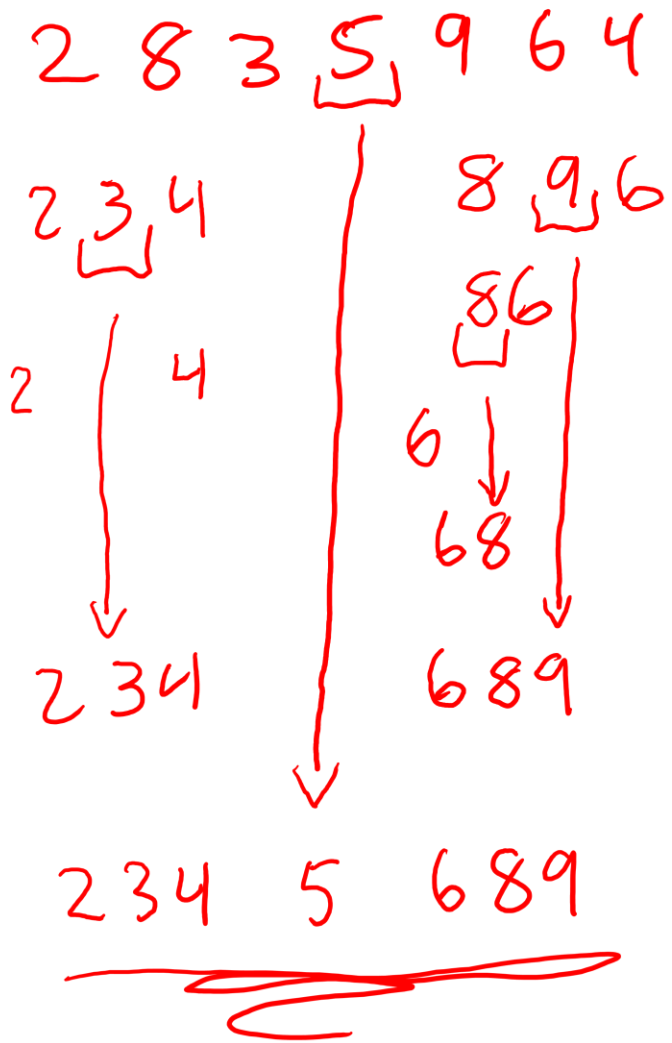
2 3 5 4 6 8 9

2 3 4 5 6 8 9

Merge


2 8 3 5 9 6 4
2 8 3
5 9 6 4
2
8 3
5 9
6 4
2
3 8
5 9
4 6
2 3 8
4 5 6 9
2 3 4 5 6 8 9

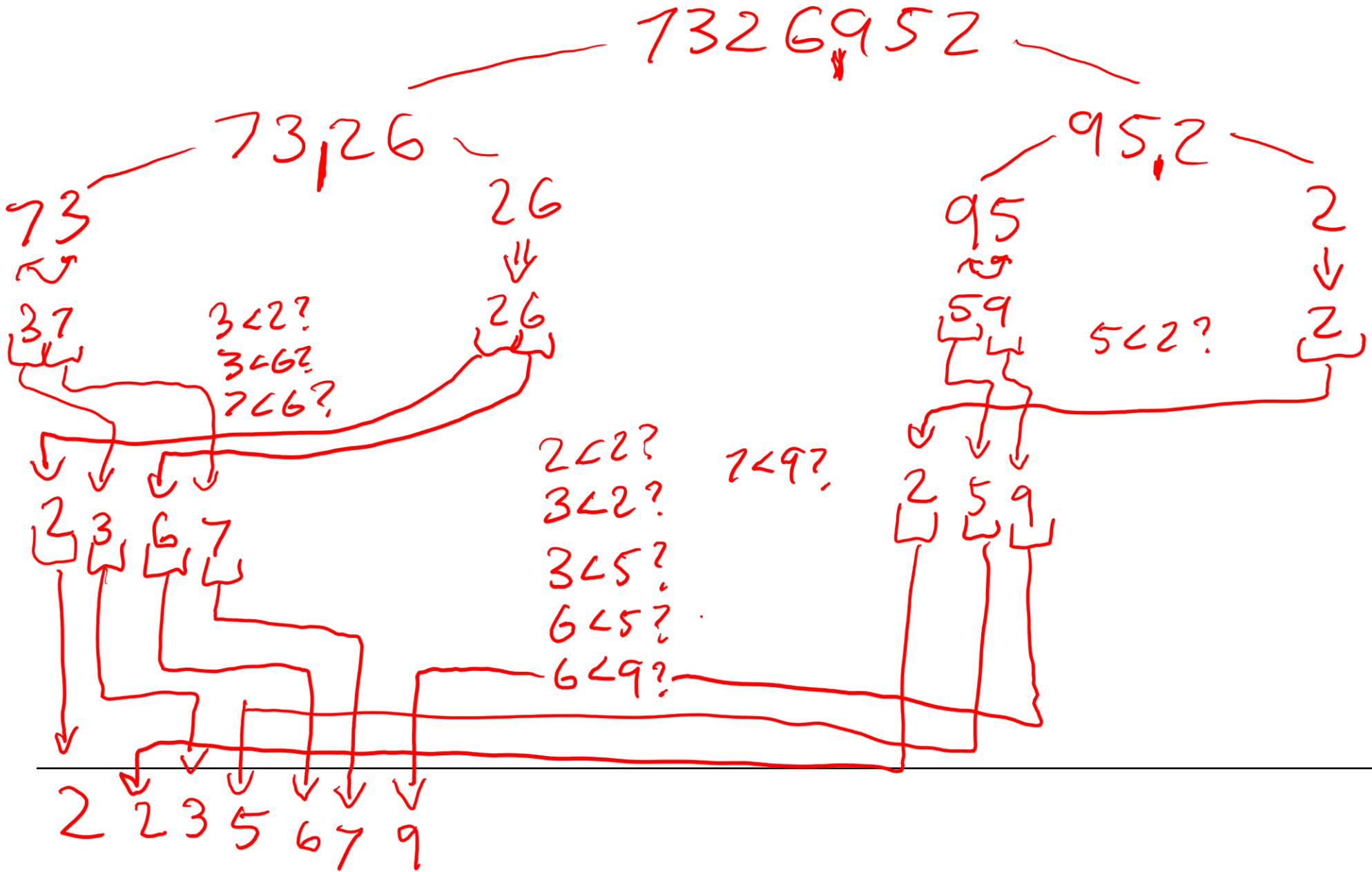
Quick


2 8 3 5 9 6 4
2 3 4
8 9 6
8 6
2
4
6
6 8
2 3 4
6 8 9
2 3 4 5 6 8 9

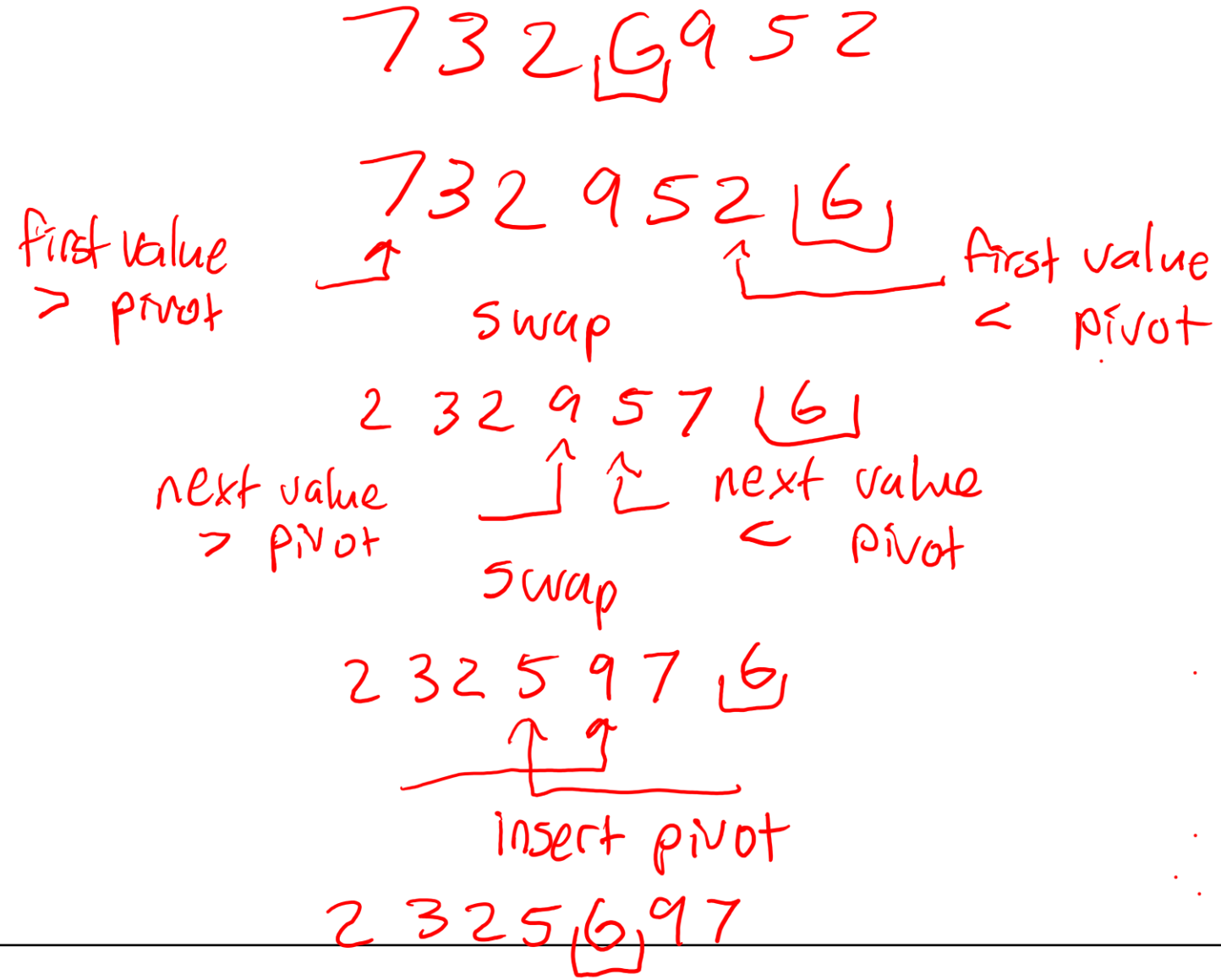
SORTING ALGORITHMS CONTINUED

- Merge sort
  - Usually done recursively
  - Divide array into two halves
  - As base case, sort the two remaining values
  - Upon exiting the recursive call, poll items from each half in order
- Quick sort
  - Pick a pivot
  - Reposition items so all items less than pivot will appear to its left and all greater items will appear on the right
  - Continue on smaller and smaller portions until the list is sorted

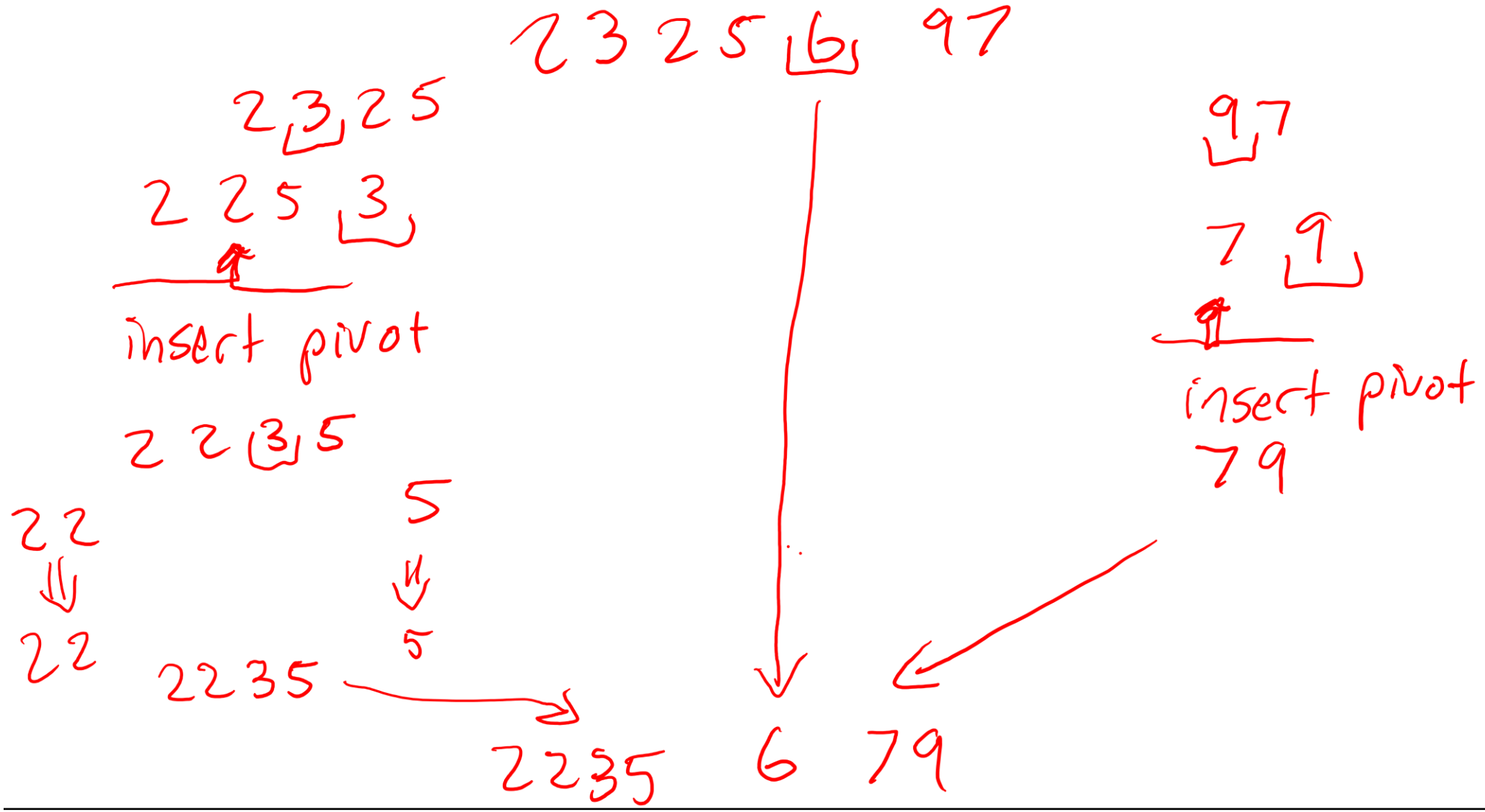
Merge sort


7326952
7326
952
73
26
95
2
7 ? 3
3 < 2 ?
3 < 6 ?
7 < 6 ?
2 6
9 5
5 < 2 ?
2 < 2 ?
3 < 2 ?
3 < 5 ?
6 < 5 ?
6 < 9 ?
7 < 9 ?
2 3 6 7
2 5 9
2 2 3 5 6 7 9

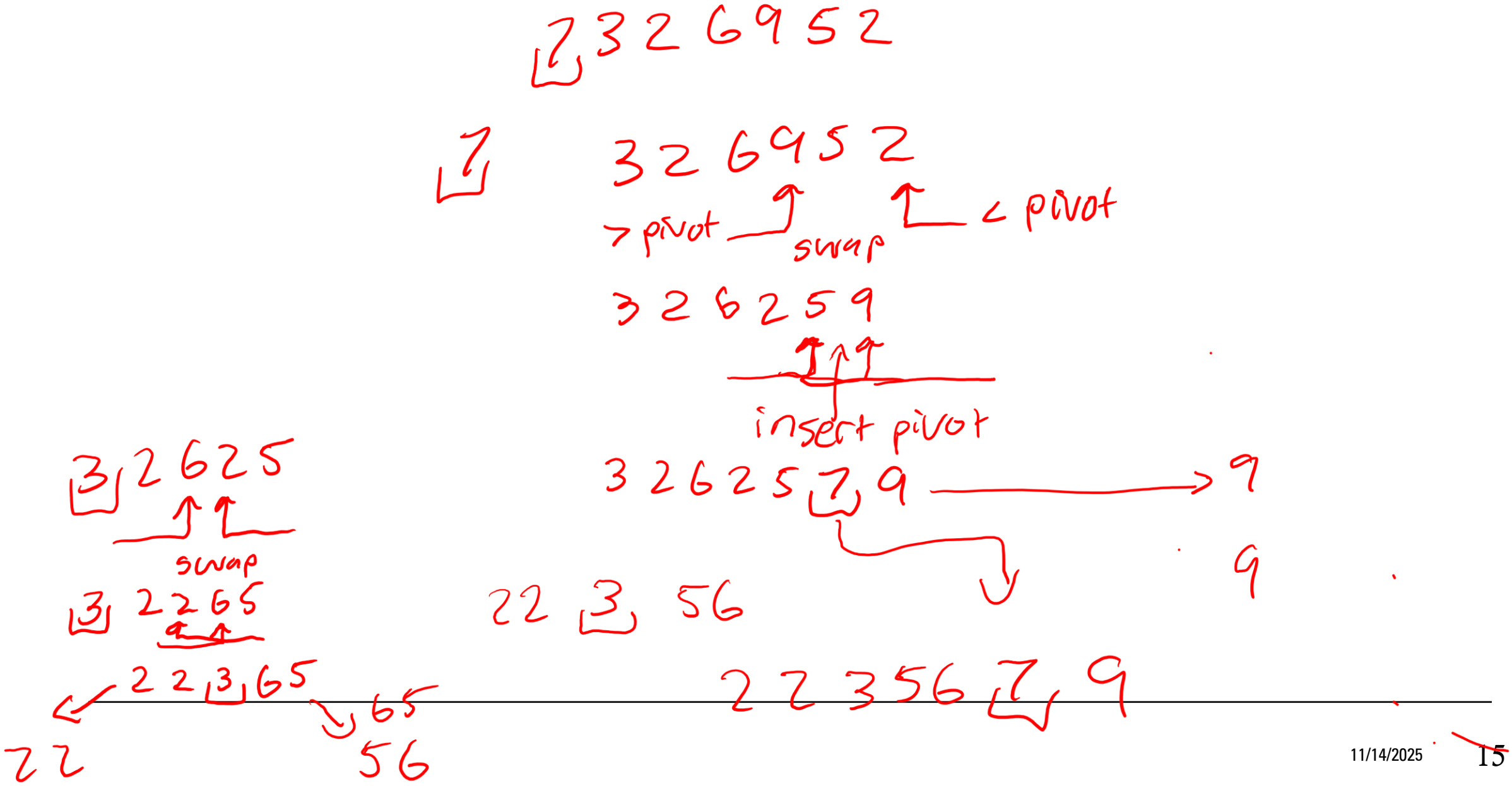
Quick Sort (central pivot)



Quick Sort Continued



Quicksort (first pivot)



BIG-O

- How long an algorithm takes to run in relation to the input
- Function can be simplified by:
  - Removing any constant coefficients
  - Removing all but the highest order term
- Example:
  - $5^n + 7n^2 + 3$ becomes…
  - 5^n

COMMON RATES OF GROWTH (BY MAGNITUDE)

- $O(1)$ – constant
- $O(\log n)$ – logarithmic
- $O(n)$ – linear
- $O(n * \log n)$ – log-linear
- $O(n^c)$ – polynomial
  - $O(n^2)$ – quadratic
  - $O(n^3)$ – cubic
  - Etc.
- $O(c^n)$ – exponential
  - $O(2^n)$
  - $O(3^n)$
  - Etc.
- $O(n!)$ – factorial

https://www.desmos.com/calculator/jpskgp3y7a

SORTING ALGORITHMS AND THEIR COMPLEXITY

• Selection	• $O(n^2)$
• Insertion	• $O(n^2)$
• Bubble	• $O(n^2)$
• Merge	• $O(n \log(n))$
• Quick	• $O(n^2)$