Quick Sort

CMPT 125
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SFU Computing Science
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Lecture 16

Today:

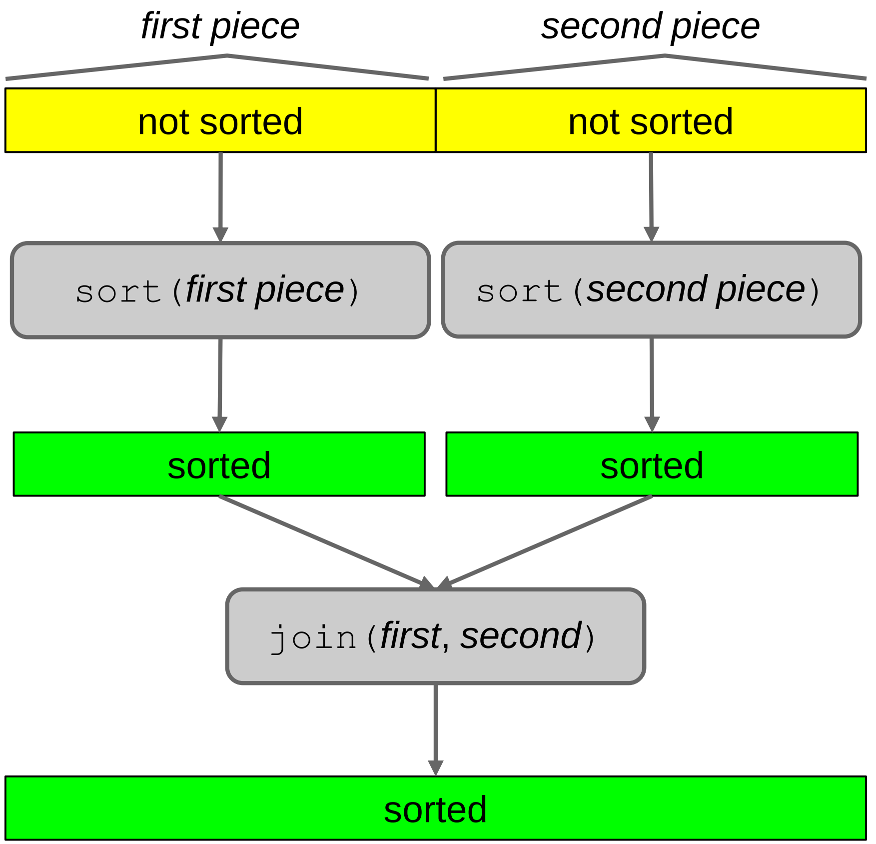
- Quick sort
- Introduction to Generics
- Library Sorting

Sorting by Recursion (Review)

Use Divide and Conquer to sort recursively.

1. Split the array into two roughly equal pieces.
2. Recursively sort each half.
   - This works because each piece is *smaller*.
3. Join the two pieces together to make one sorted array.

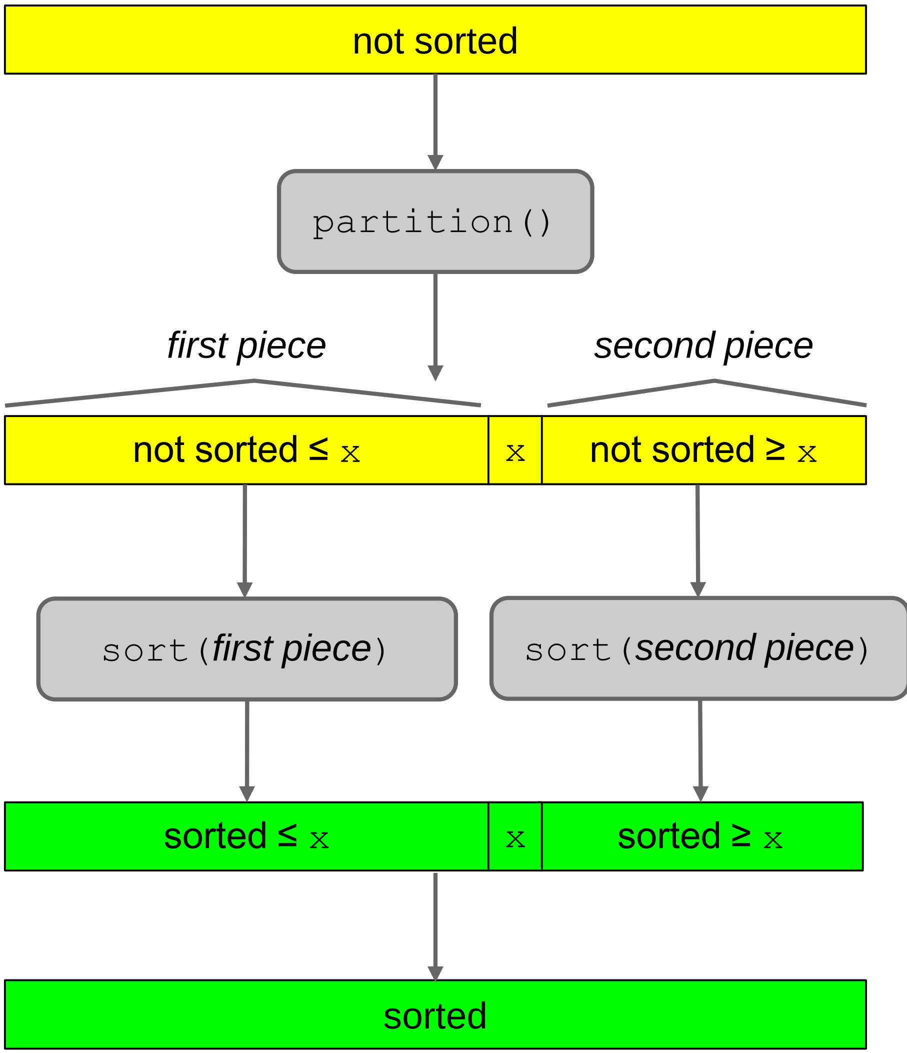
Two famous sorts behave this way: *mergesort* and *quicksort*.



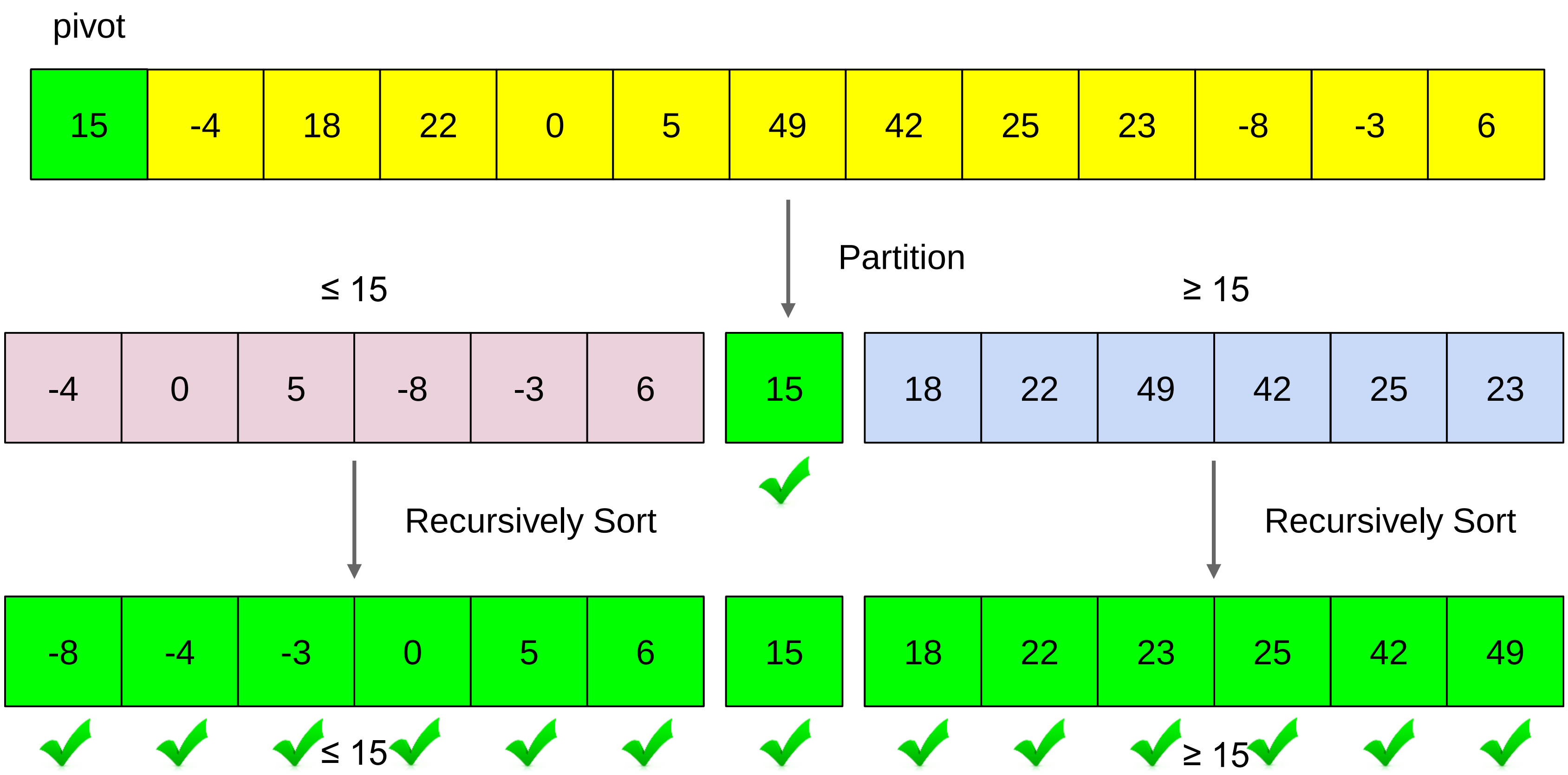
Quick Sort

Strategy: Divide and Conquer

1. Split the array into two roughly equal pieces.
   - partition by a *pivot* element, `x`
2. Recursively sort each half.
   - two recursive calls to `sort()`
   - assume smaller cases are sorted correctly
3. Join the two pieces together to make one sorted array.
   - trivial



Example



pivot
15
-4
18
22
0
5
49
42
25
23
-8
-3
6
Partition
≤ 15
≥ 15
-4
0
5
-8
-3
6
15
18
22
49
42
25
23
Recursively Sort
Recursively Sort
-8
-4
-3
0
5
6
15
18
22
23
25
42
49
≤ 15
≥ 15

Quick Sort Code

```
//  Post:  arr[first..last] are sorted
void quickSort(int arr[], int first, int last) {
```

- Base case
  - return if fewer than 2 elements

- Split array into two roughly equal pieces
  - partition around a pivot element
  - pivot element in correct position → `mid`

```
    //  Recursively sort
```

- Recursively sort each piece

```
}
```

Quick Sort Code

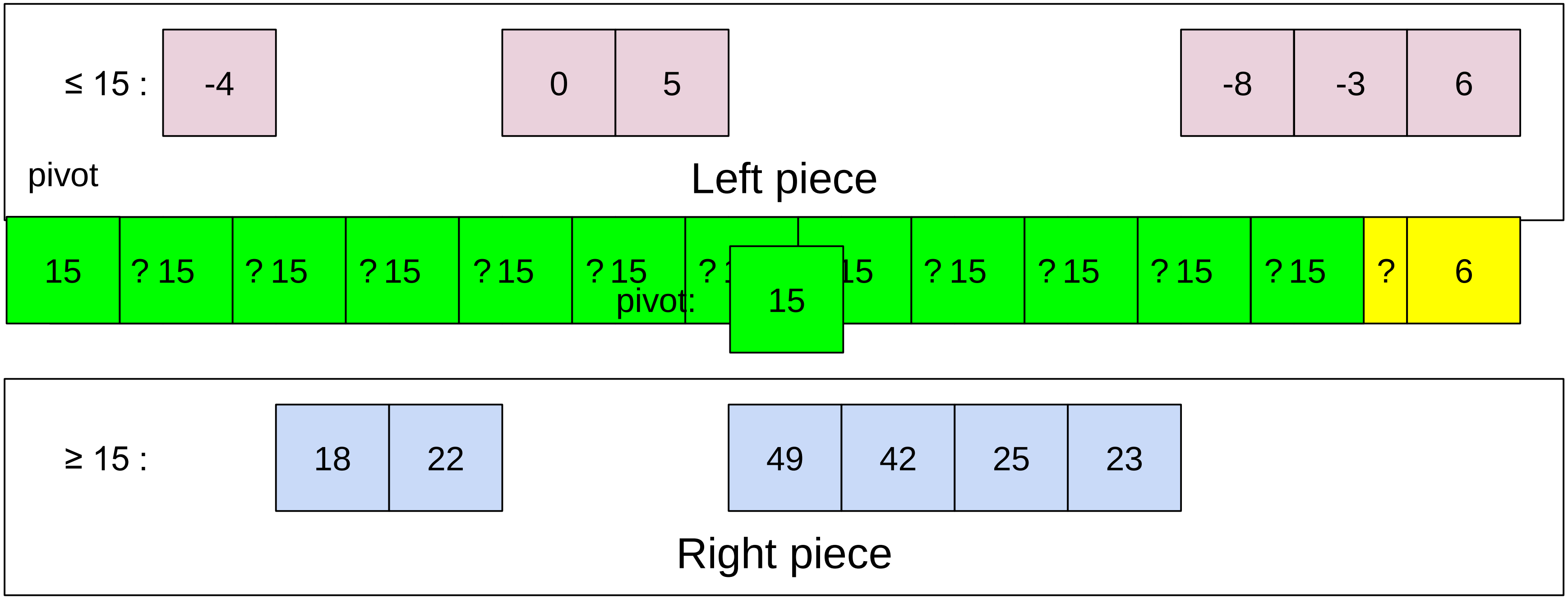
```
//  Post:  arr[first..last] are sorted
void quickSort(int arr[], int first, int last) {
    //  Base case
    if (last <= first) return;

    //  Split array
    int mid = partition(arr, first, last);

    //  Recursively sort
    quickSort(arr, first, mid-1);
    quickSort(arr, mid+1, last);
}
```

Partition

Q. How long does it take to partition N elements?



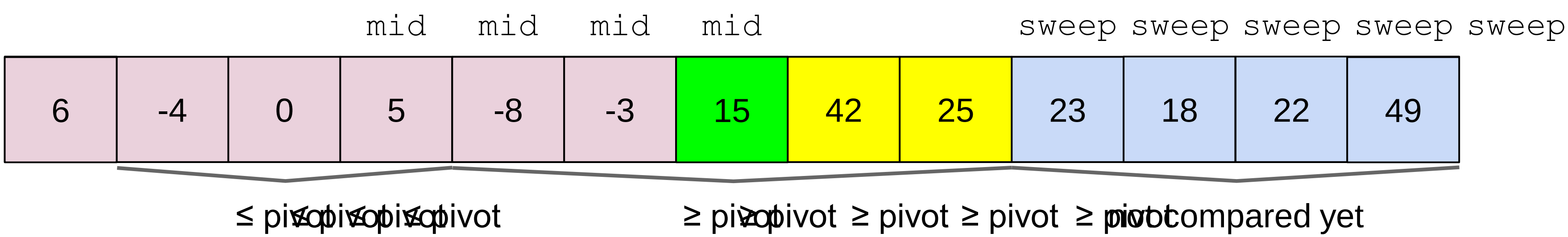
Strategy: Compare pivot with each element

- If less than pivot, put on left piece
- If greater than pivot, put on right piece

How to develop each piece?

There are many implementations of partition.

- To make our own, visualize a partially partitioned array:



Need two indices:

- index to scan through the array of indices (`sweep`)
  - marks end of the second piece
- index to mark end of the first piece (`mid`)

Algorithmic Strategy:

- if `arr[sweep]` > pivot then
  - add it to the second piece
  - (do nothing)
- if `arr[sweep]` < pivot then
  - add it to the first piece
  - swap with `arr[mid+1]`
  - `mid++`

Q. What's the last step?

- Place the pivot
- swap with `arr[mid]`

Running Time Analysis

What's the worst case running time?

- depends on the partition
- if it's an even split, then $O(N \log N)$ like Merge Sort.
- Q. What if it's a uneven split on every partition?
- $O(N^2)$ like Insertion Sort

It turns out that Quick Sort works well over all possible permutations of arrays

- $O(N \log N)$ in the average case
- Most implementations pick a random pivot

Generic Sorts

There is a function qsort() in <stdlib.h>

Parameters:

- a comparator function
- an arbitrary array of data

Remember that arrays are specified by:

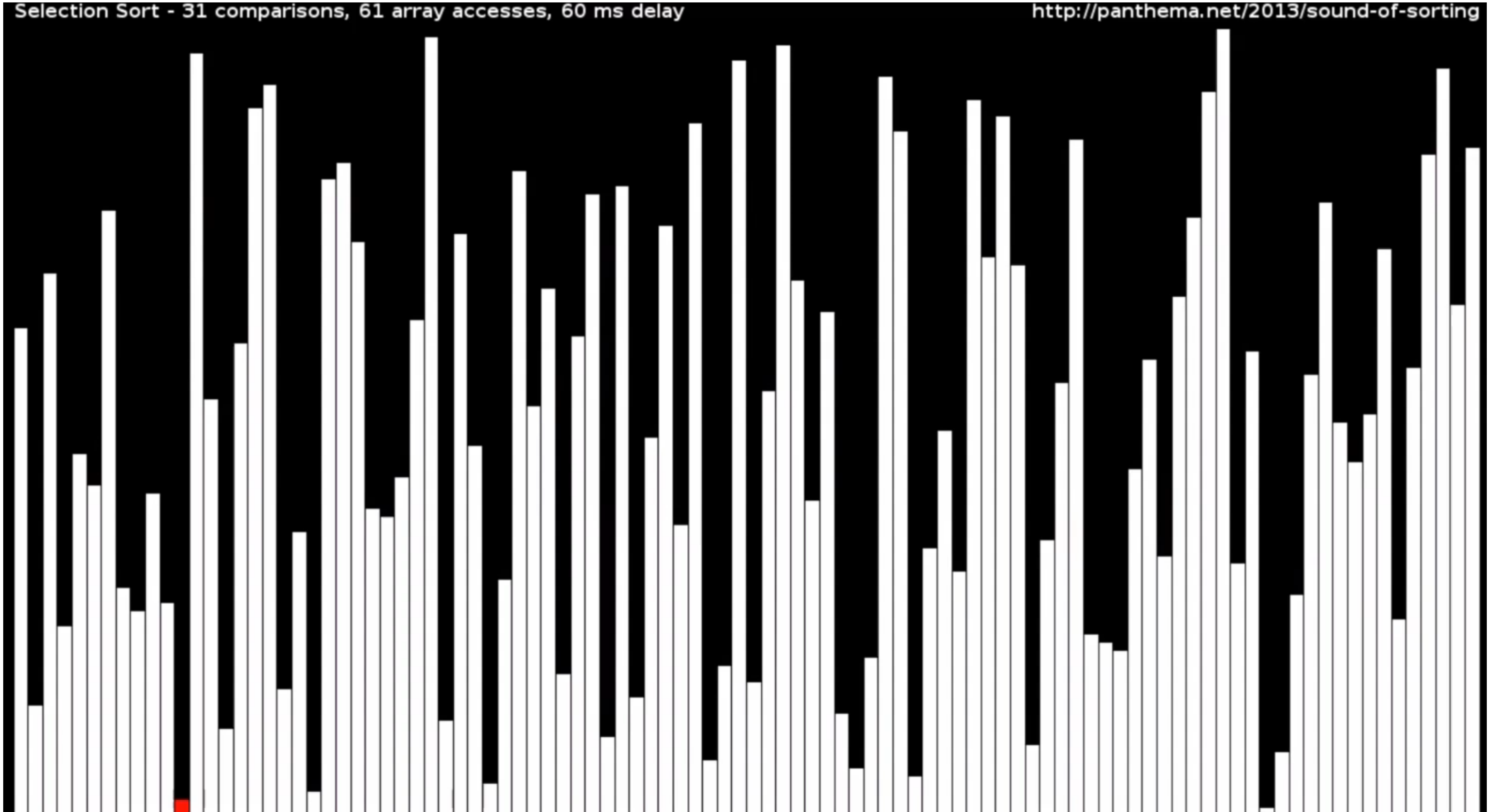
- base address
- type
- number of elements

C++ uses the *template* construct to make generic typing easier

Generics promote code reuse by generalizing algorithms over different types

Sorting Algorithms: Summary

- For great sound effects: https://youtu.be/92BfuxHn2XE



Sorting Algorithms: Summary

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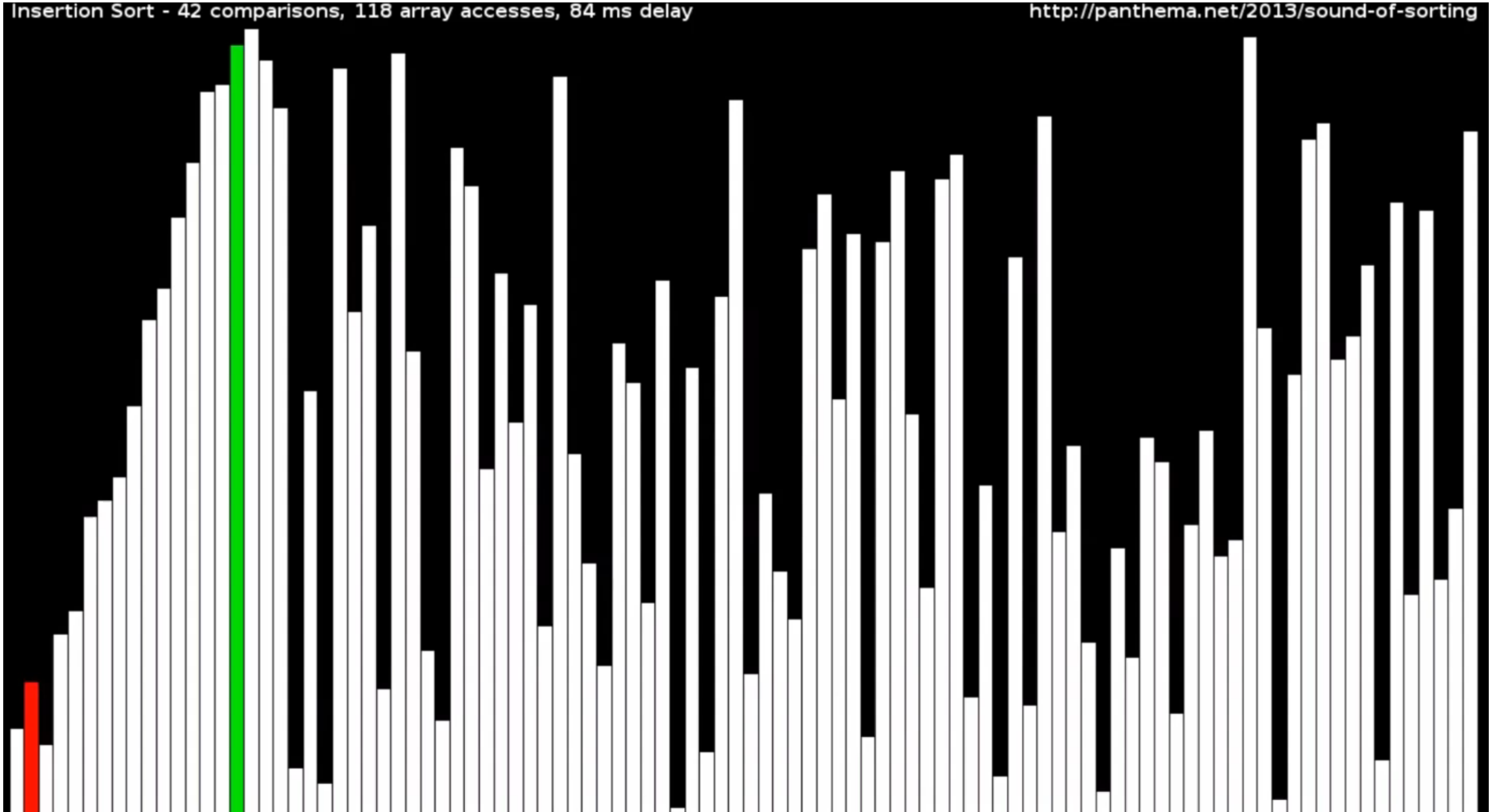

Sorting Algorithms: Summary

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Sorting Algorithms: Summary

- For great sound effects: https://youtu.be/9IqV6ZSjuaI

Sorting Algorithms: Summary

- https://youtu.be/ZZuD6iUe3Pc