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Computer Programming

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Session: Searching

Quick Recap of Relevant Topics

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- Sorting integers
  - Selection sort
  - Merge sort
  - Counting “basic” steps in sorting an array
- Sorting strings and other data types
  - Same techniques apply
  - Appropriate comparison operator needed

Overview of This Lecture

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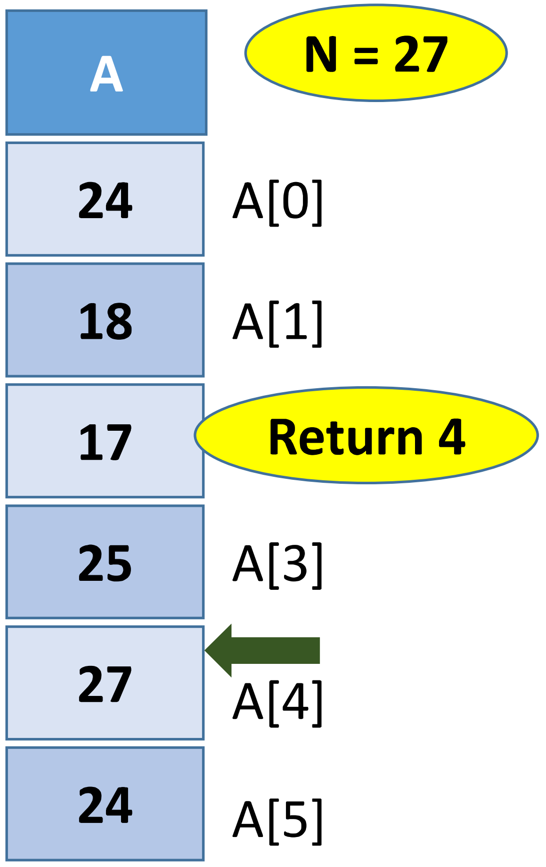
- Searching integers
  - Linear search
  - Binary search
- Searching strings and other data types

The Searching Problem



Given an array A of integers and a candidate integer N

Is N present in A? **Yes/No question**

More interesting

If N is present in A, return its index in A else return -1

[Yes/No answer can be derived]

The Searching Problem

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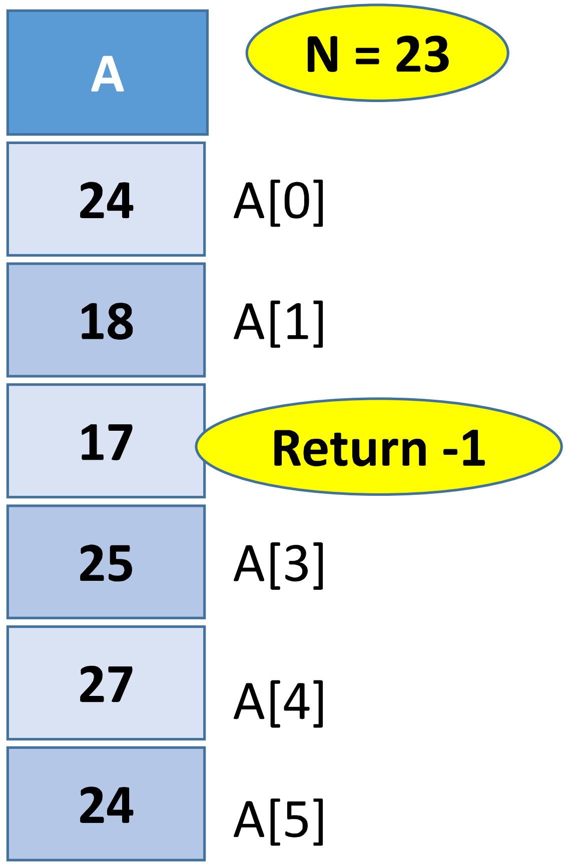

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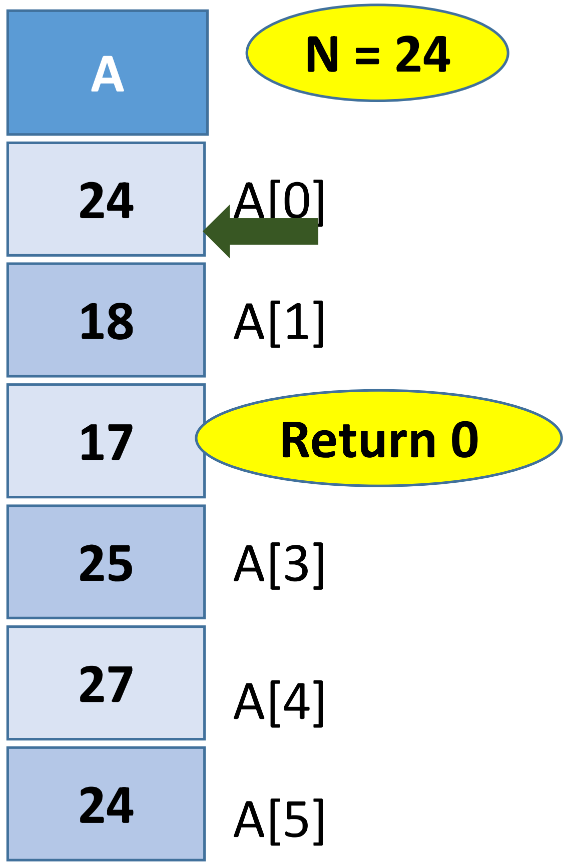

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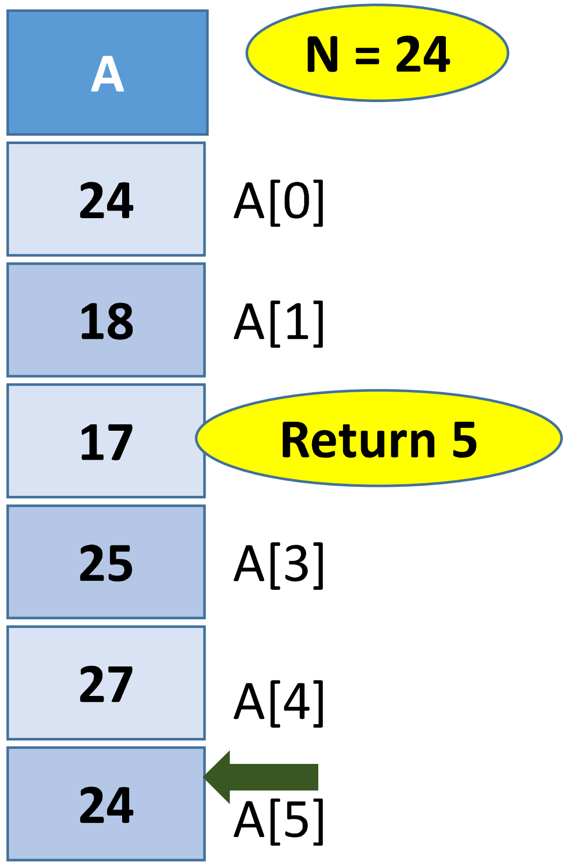

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[Yes/No answer can be derived]

The Searching Problem

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A	N = 24
24	A[0]
18	A[1]
17	A[2]
25	A[3]
27	A[4]
24	A[5]

Given an array A of integers and a candidate integer N

In case of multiple matches, index of any one can be returned

n A

else return -1

[Yes/No answer can be derived]

Linear Search

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- Check each element of the array
- Stop on finding first match and output index
- If array exhausted and no match found, return -1

Linear Search in C++

```
int main() {
  int i, n, A[100];  // Declarations
  cout << “Give size of array: “; cin >> n; // Read and validate inputs
  if ((n > 100) || (n <= 0)) { cout << “Invalid input!” << endl; return -1; }
  cout << “Give “ << n << “ positive integers in array.” << endl;
  for (i = 0; i < n; i++) {cin >> A[i]; } // Read elements of array A
   ... Code to search ...
  return 0;
}
```

Linear Search in C++

```
int main() {
  … Declarations, reading inputs and validation …
  int srchElement, index;
  do {
    cout << “Give element to search (-1 to exit): “; cin >> srchElement;
    if (srchElement == -1) break;
    index = linearSearch(A,  n,  srchElement);
    if (index == -1) { cout << srchElement << “ not present!” << endl;}
    else { cout <<  srchElement << “present at index “ << index << endl;}
  }  while (true);
  return 0;
}
```

Linear Search in C++

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int main() {
  … Declarations, reading inputs and validation …
  int srchElement, index;
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    else { cout <<  srchElement << "present at index " << index << endl;}
  }  while (true);
  return 0;
}
```

Linear Search in C++

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```
int linearSearch(int A[], int n, int srchElement) {
   int i;
   for (i = 0; i < n; i++) {
     if (A[i] == srchElement) { return i; }
   }
   return -1;
}
```

“Basic” Steps In Searching

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- Comparing an element of array A with the searched element and incrementing index
- Count of “basic” steps
  - At most n “basic” steps to search in an array of size n
- Can we do better?

The Searching Problem

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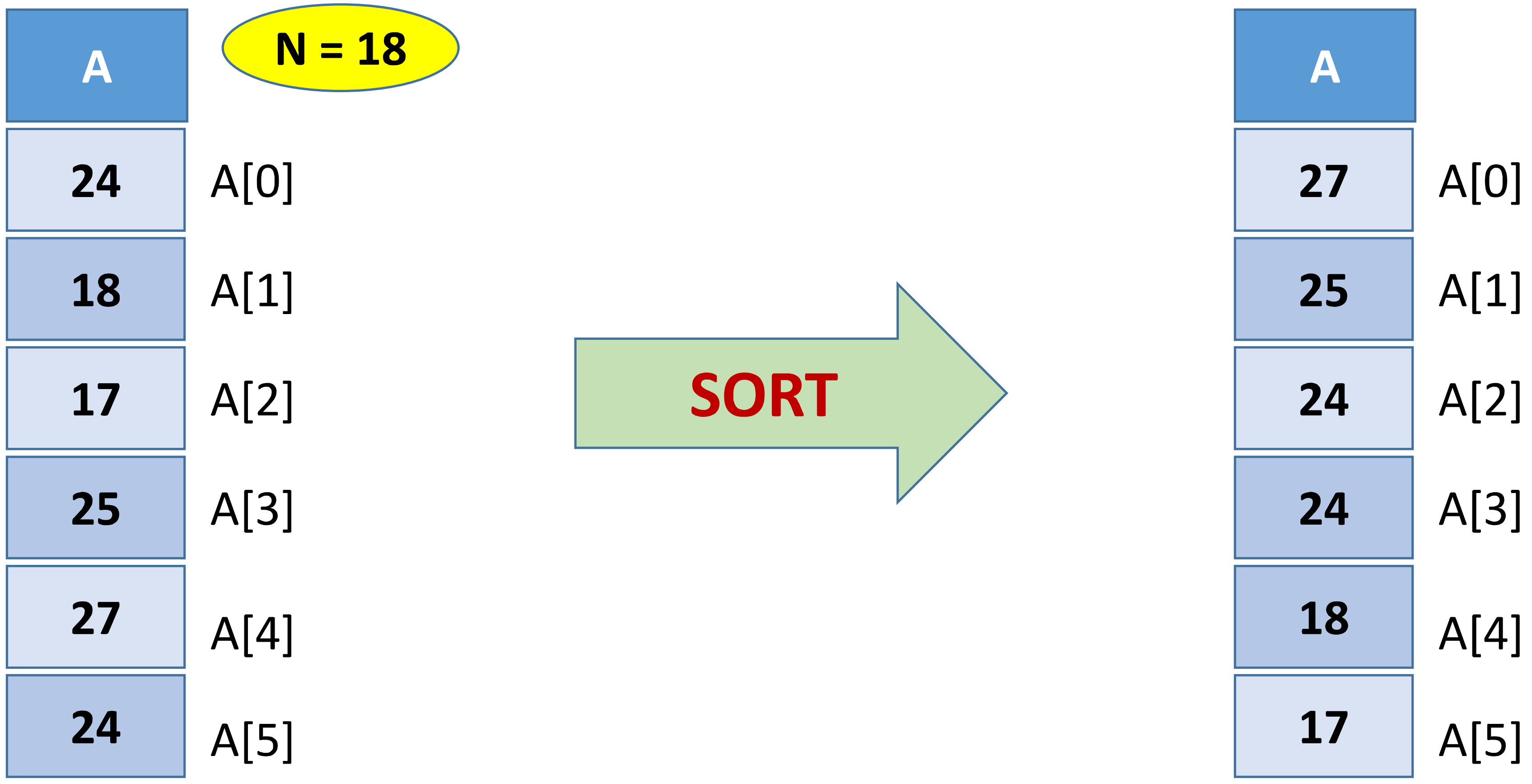
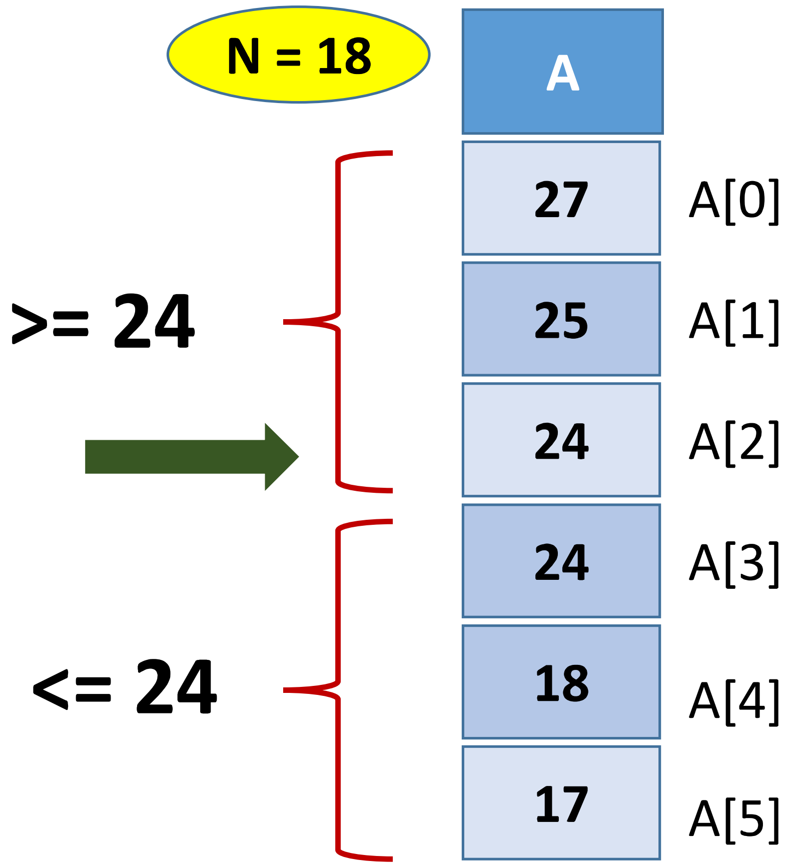


The Searching Problem



The Searching Problem

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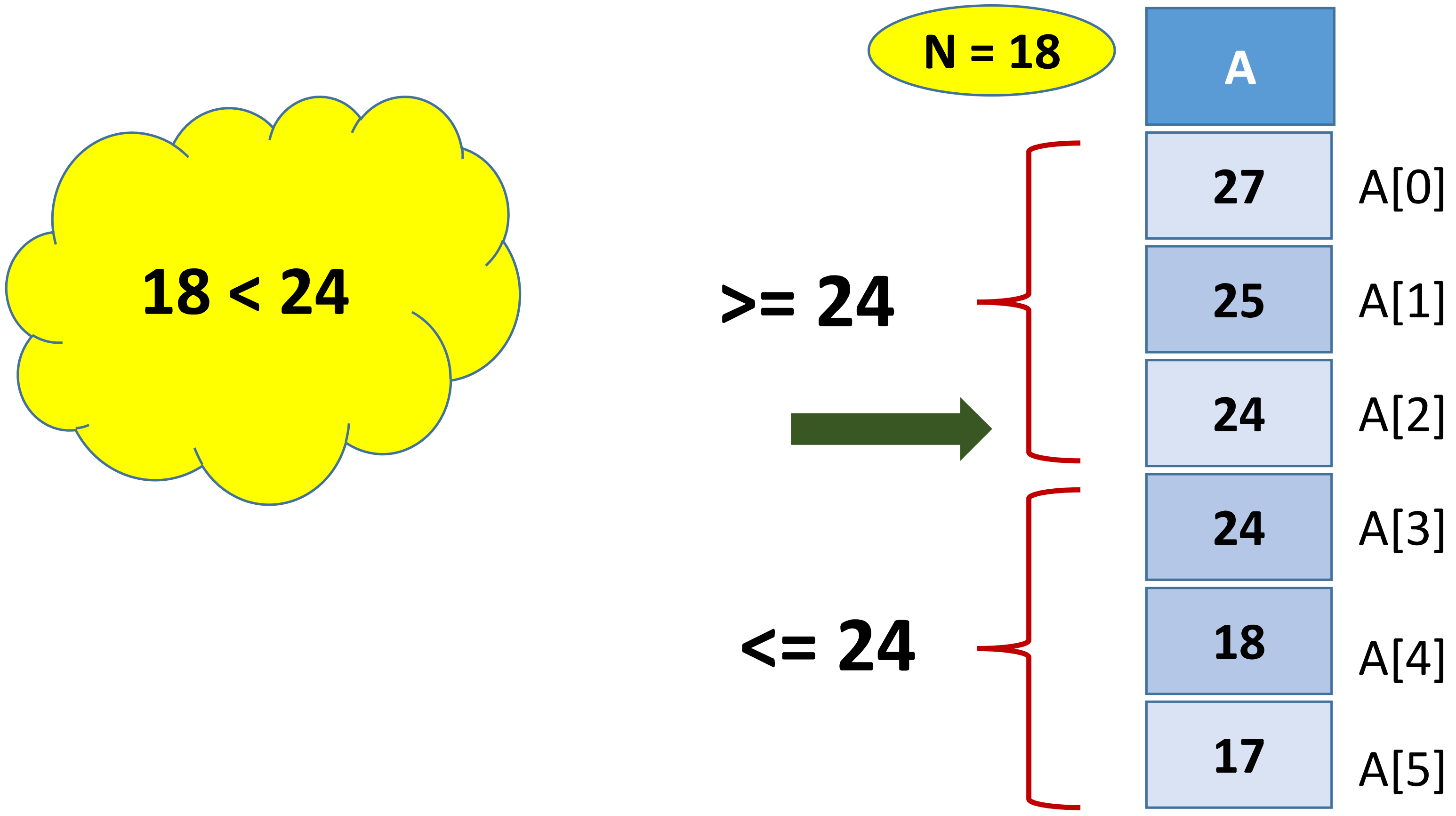

The Searching Problem

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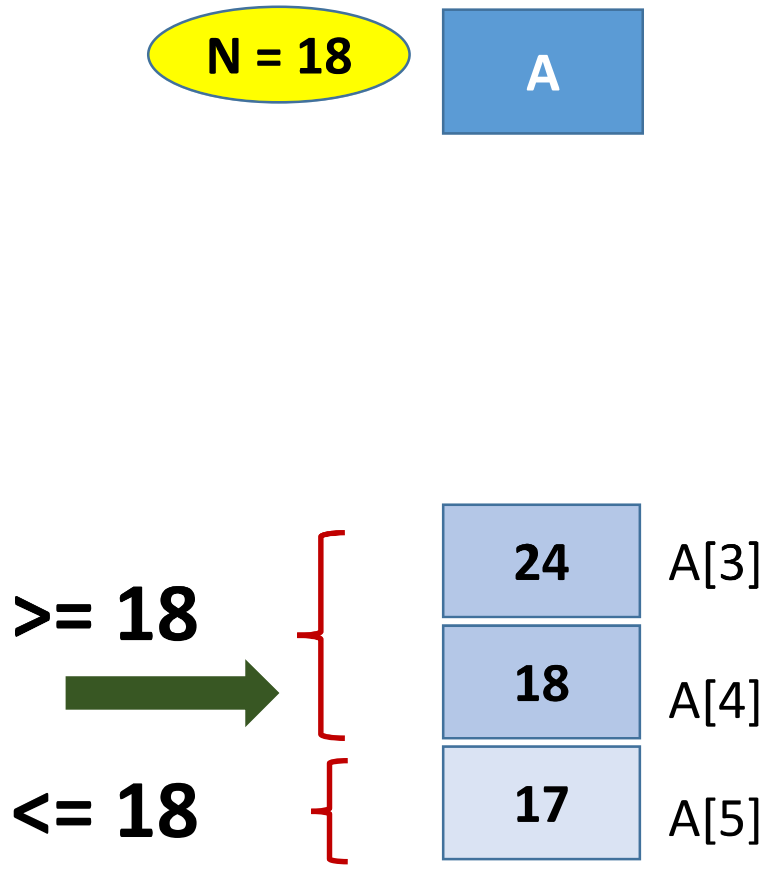
18 = 18

We are done!



General Idea

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- Sort the array (A[0] … A[n-1]) in increasing order
- Check search element (m) with element at A[n/2]
- If m equals A[n/2], we are done (return n/2)
- If m < A[n/2], search for m in A[0] … A[n/2 - 1]
- If m > A[n/2], search for m in A[n/2] … A[n-1]
- If A has 1 element and m does not match that, return -1

Termination Case

Termination Case

Recursion

Recursion

General Idea

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- Sort the array (A[0] … A[n-1]) in increasing order
- Check searc /2]
- If m equals
- If m < A[n/
- If m > A[n/]
- If A has 1 el , return -1

BINARY SEARCH

Binary Search In Action

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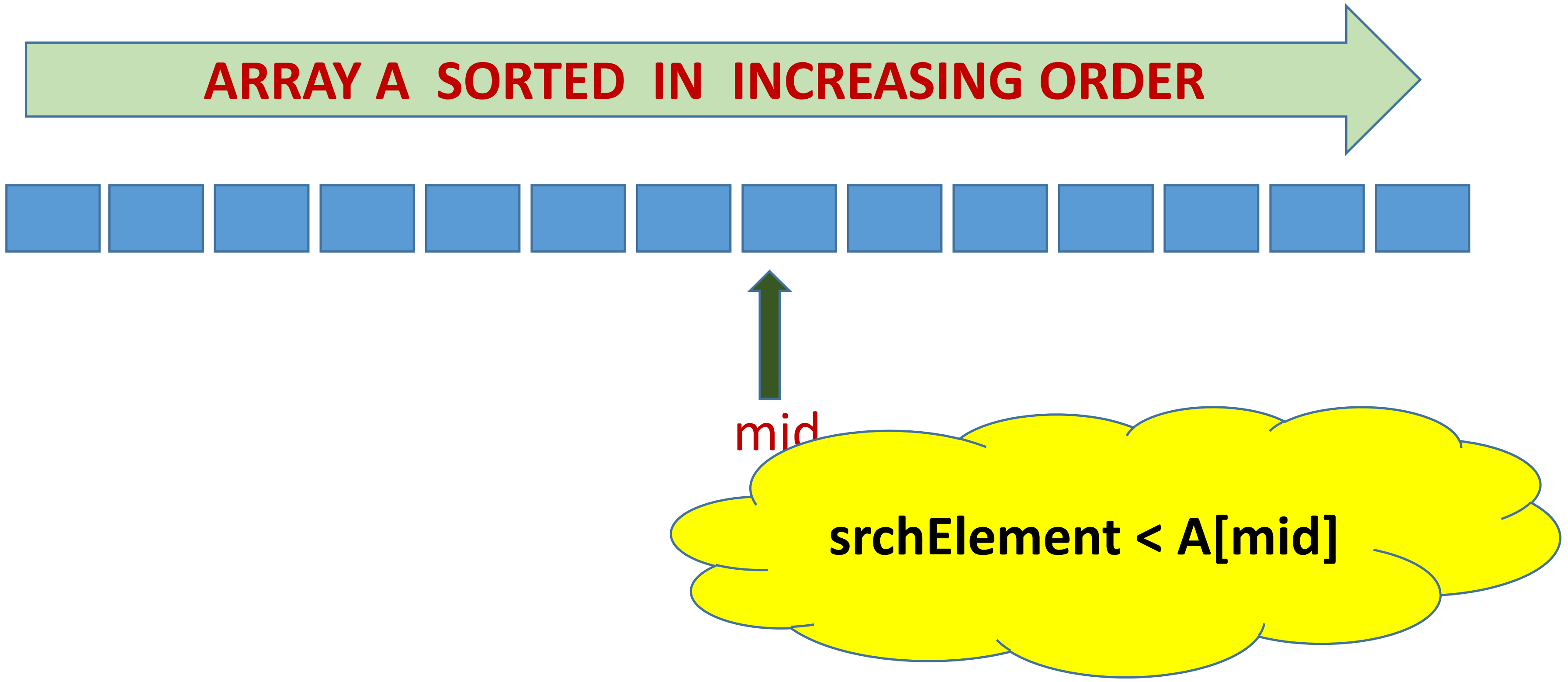
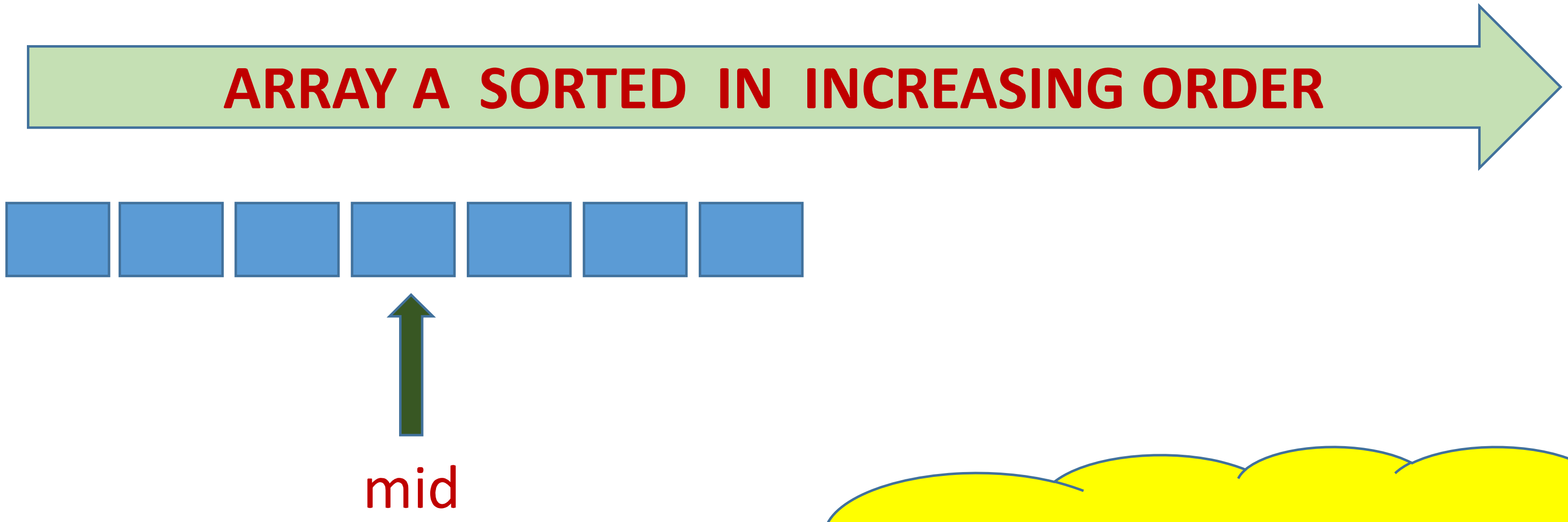
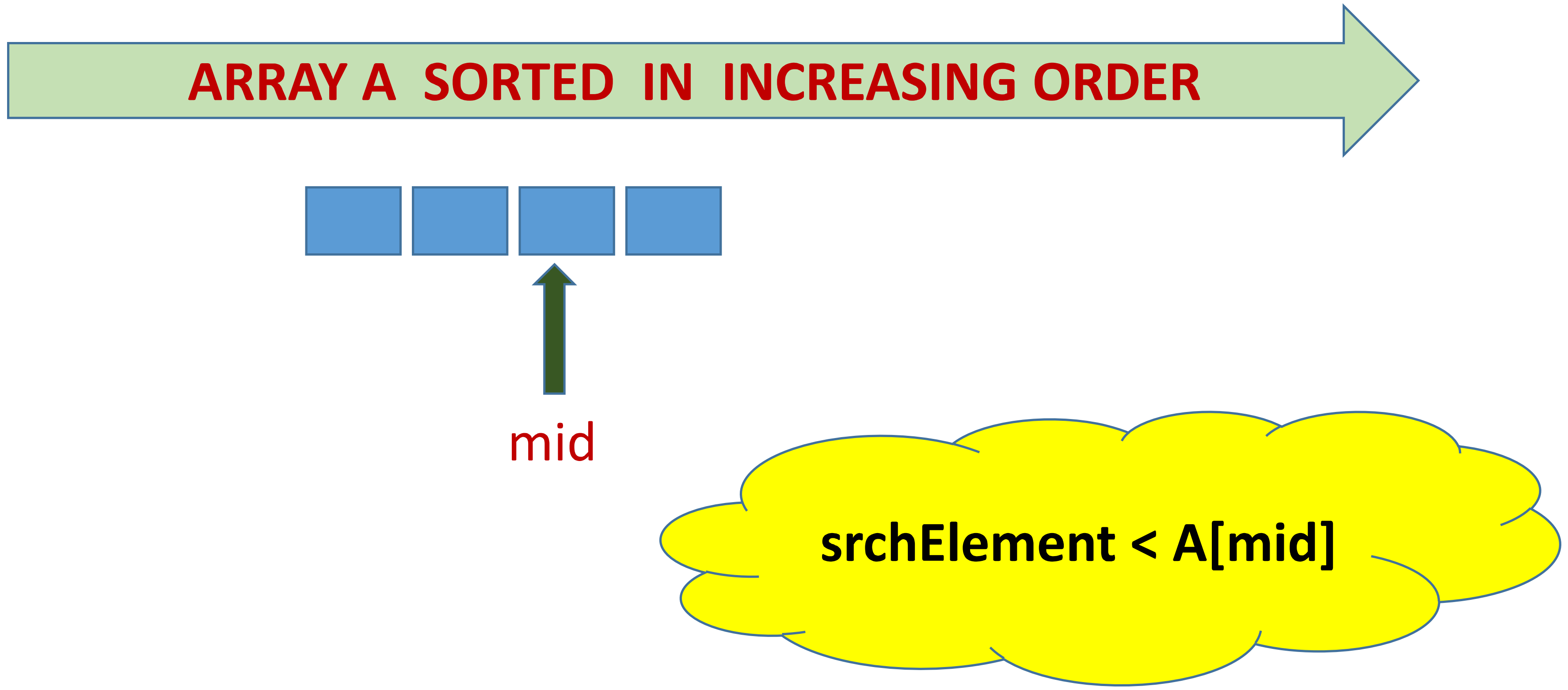


Binary Search In Action



srchElement > A[mid]

Binary Search In Action



Binary Search In Action

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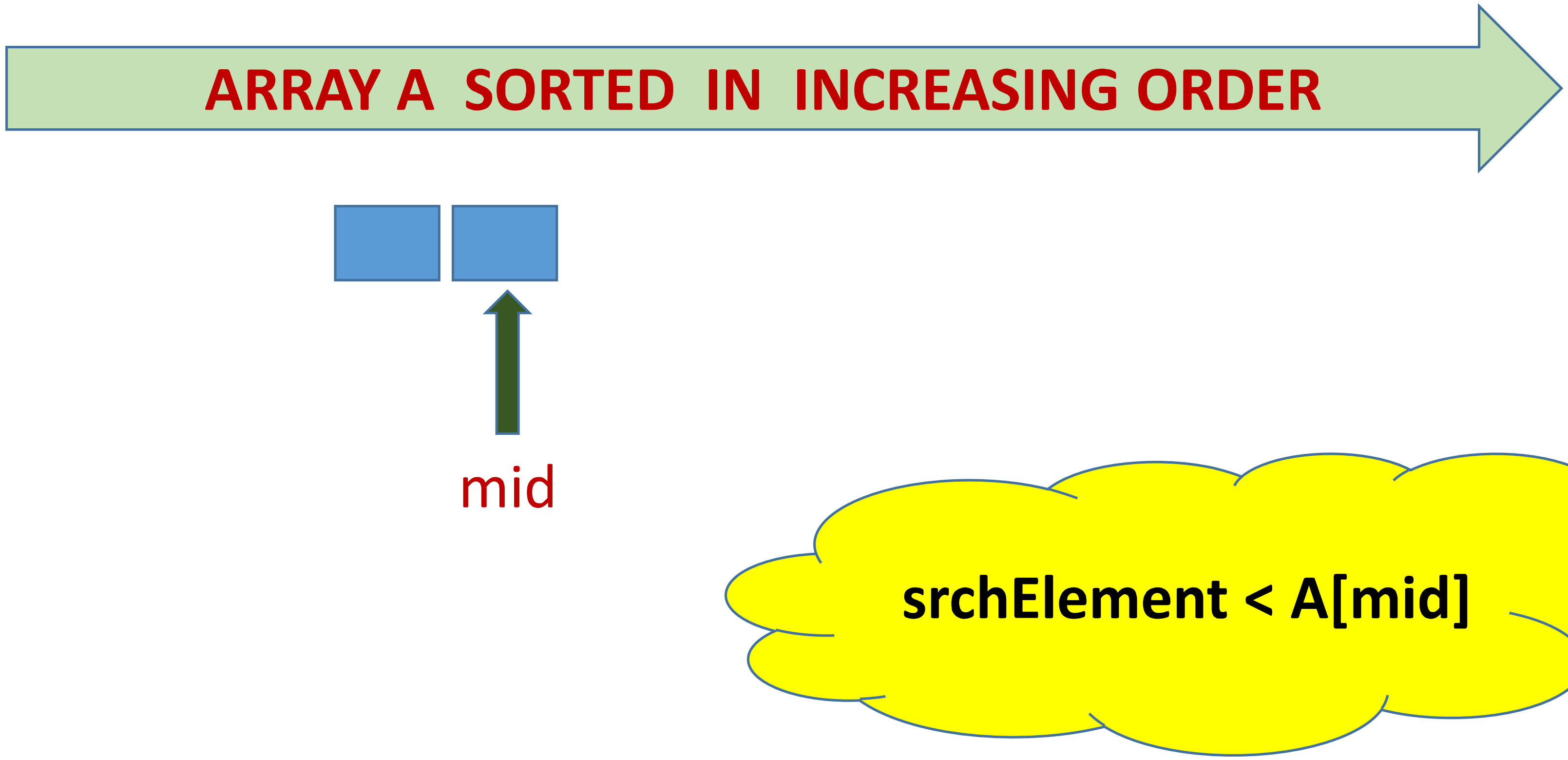

Binary Search In Action

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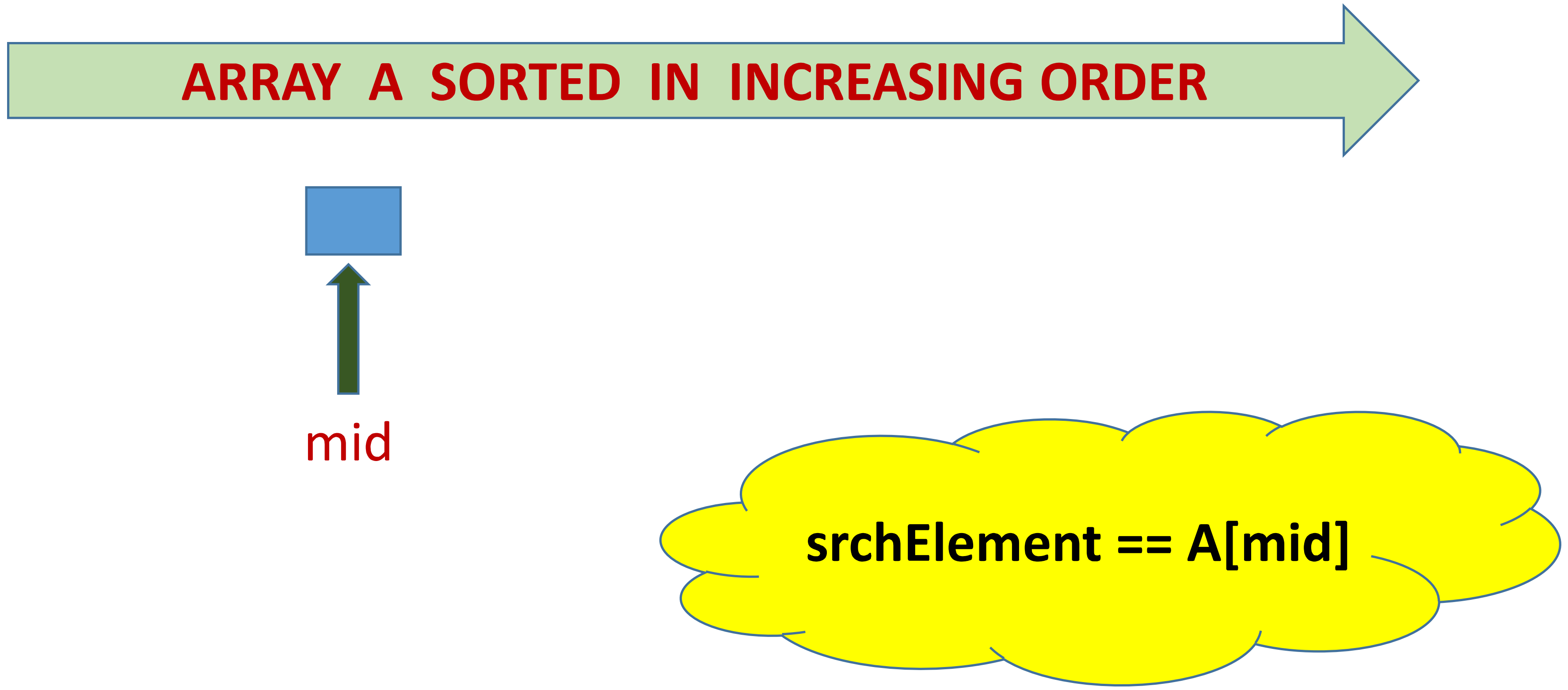

Binary Search in C++

```
// PRECONDITION:  A[start] … A[end – 1] sorted in increasing order
int binarySearch(int A[], int start, int end, int srchElement) {
  if (end == start + 1) { // Array A has exactly 1 element
      if (A[start] == srchElement) { return start; }
     else { return -1; }
  }
  int mid = (start + end)/2;
  if (A[mid] == srchElement) { return mid; }
  else {  if (A[mid] < srchElement) { return binarySearch(A, mid, end, srchElement); }
           else  { return binarySearch(A, start, mid, srchElement); }
  }
}
// POSTCONDITION: If srchElement in A[start] … A[end-1], return its index, else -1
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          else  { return binarySearch(A, start, mid, srchElement); }
  }
}
// POSTCONDITION: If srchElement in A[start] … A[end-1], return its index, else -1
```

What About Searching Other Data Types

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- Exactly same technique
- Sort array
  - Use an appropriate comparison operator
  - lexEarlier(s1, s2) for strings
  - Custom comparison operator for other data types
- Use same comparison operator for searching
  - Decide which half of array to recurse on based on output of comparison operator

Count Of “Basic” Steps

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- Let T_n be maximum count of steps when searching in array of size n
- $T_n = T_{n/2} + 1; \quad T_1 = 1$
- Solution: $T_n \approx \lceil \log_2 n \rceil$

Summary

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- Searching in an array of integers
  - Linear search
  - Binary search
  - Sorting helps searching
  - Counting “basic” steps in searching
- Searching in an array of other data types