What we have learned so far

- Straight forward statements
- Conditional statements (branching)
- Repeated statements (loops)
- Grouping statements in a subprogram (functions)

Adding Comments

- Why is it important to write comments?
  - Some programmers are not very smart and write ugly codes!!

Two types of Comments

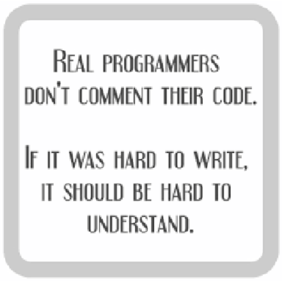
- Multi line comments

```
/*
   Addition Of Two Numbers
   By Bill Gates
   © Microsoft Corporation
*/
```

- Single line comment

```
int a=5; //initialization
```

However…..



REAL PROGRAMMERS DON'T COMMENT THEIR CODE.

IF IT WAS HARD TO WRITE, IT SHOULD BE HARD TO UNDERSTAND.

Arrays

One variable many data

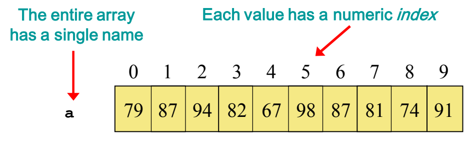
Problem:
Read 10 numbers from the keyboard and store them

Problem:
Read 10 numbers from the keyboard and store them

```
// solution #1
int a, b, c, d, e, f, g, h, i, j;

printf("Enter a number: ");
scanf(" %d", &a);

printf("Enter a number: ");
scanf(" %d", &b);

//…

printf("Enter a number: ");
scanf(" %d", &j);
```

Arrays

- An *array* is an ordered list of values

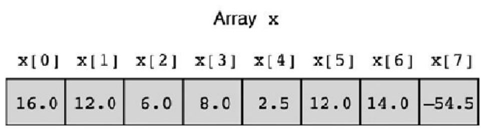

The entire array has a single name
Each value has a numeric *index*
0 1 2 3 4 5 6 7 8 9
a
79 87 94 82 67 98 87 81 74 91

An array of size N is indexed from zero to N-1

This array holds 10 values that are indexed from 0 to 9

An array with 8 elements of type double

```
double x[8];
```



Arrays

- The values held in an array are called *array elements*
- An array stores multiple values of the same type – the *element type*
- The element type can be a primitive type
- Therefore, we can create an array of integers, an array of floats, an array of `doubles`.

Declaring Arrays

```
data_type array_name[size];

For example:

        int a[10];

a is an array of 10 integers.

        float prices[3];

prices is an array of 3 floats.

        char c[6];

c is an array of 6 characters.
```

How to assign values?

There are 3 ways.

How to assign values?

First way

- It is possible to initialize an array when it is declared:

```
float prices[3] = {1.0, 2.1, 2.0};
```

How to assign values?

First way (Continue)

- Declaring an array of characters of size 3:

```
char letters[3] = {'a', 'b', 'c'};
```

- Or we can skip the 3 and leave it to the compiler to estimate the size of the array:

```
char letters[] = {'a', 'b', 'c'};
```

How to assign values?

Second way:

- Use assignment operator

```
int a[6];

a[0]=3;

a[1]=6;
```

How to assign values?

Third way:

- Use scanf to input in the array:

```
int a[6];

scanf("%d", &a[0]);

scanf("%d", &a[1]);

   …….

   ….
```

How to assign values?

Third way (continue):

- Use scanf to input in the array:

```
int a[6];

for(i= 0; i < 6; i++){

     scanf("%d", &a[1]);

}
```

Arrays: Some easy examples

- Example 1: Suppose an array has 5 students marks. Find average mark.

  How to accommodate N students where N will be input to your program?

- Example 2: Suppose an array has N students marks. Find grade of each student.

- Example 3: Take N numbers as input and store them in array. Print all odd numbers in the array.

Example 4:
Find the minimum number in an array of unsorted integers

find_minimum.c

```
#include <stdio.h>
#include <stdlib.h>

#define N 12
int main()
{
   int a[N] = { 14, 21, 36, 14, 12, 9, 8, 22, 7, 81, 77, 10};
   int i;

   // Find The Minimum Element

   int min=a[0]; // pick the first number as the current minimum
   for(i=1; i< N; i++)
   {
        if(a[i] < min)
        {
             min=a[i];
        }
   }

   printf("The minumum value in the array is %d.\n\n", min);
}
```

Example 5:
Find the minimum number (and its index) in an array of unsorted integers

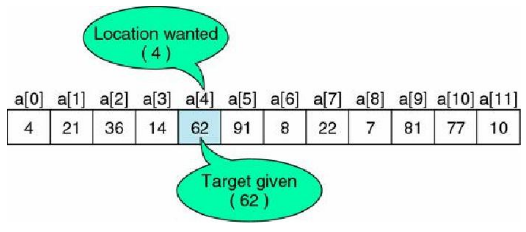
find_minimum_and_index.c

```
#include <stdio.h>
#include <stdlib.h>
#define N 12
int main()
{
   int a[N] = { 14, 21, 36, 14, 12, 9, 8, 22, 7, 81, 77, 10};
   int i, min;

   // Find The Minimum Element and it index
   min= a[0];  // initial guess: a[0] is the minimum value
   int idx=0;  // initial guess: the minimum value is at index 0

   for(i=0; i< N; i++)
   {
        if(a[i] < min)
        {
                min=a[i];
                idx=i;
        }
   }
   printf("The minumum value in the array is %d.\n\n", min);
   printf("It is located at index: %d \n\n",  idx);
}
```

Some Harder Examples

- Print largest and second largest element of an array.
- Left rotate all elements of an array
- Print number of distinct elements in an array which is already sorted in ascending order
- Print number of distinct elements in an unsorted array

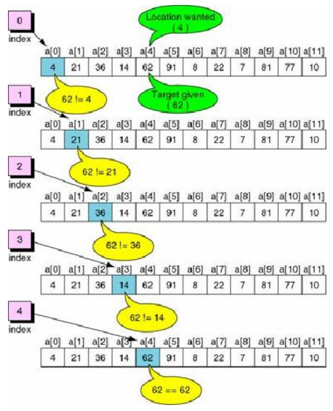
Search



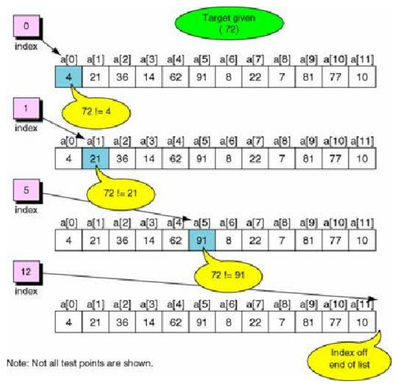
Linear Search

- The most basic
- Very easy to implement
- The array DOESN'T have to be sorted
- All array elements must be visited if the search fails
- Could be very slow

Example: Successful Linear Search



Example: Failed Linear Search



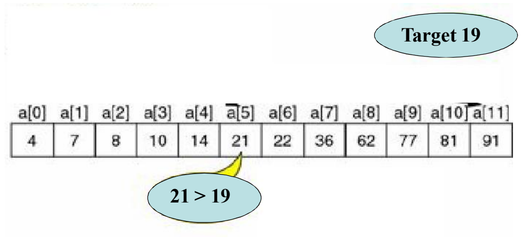
Problem: Find the index of a number in an unsorted array of integers

linear_search.c

Linear_Search.c

```
#include <stdio.h>
#include <stdlib.h>
#define N 12
int main()
{
   int a[N] = { 4, 21, 36, 14, 62, 91, 8, 22, 7, 81, 77, 10};
   int i;

   int target = 62;  //int target = 72; // Try this next
   int idx=-1;
   for(i=0; i< N; i++)
   {
        printf(".\n");
        if(a[i] == target)
        {
                idx=i;
                break;
        }
   }
   if(idx == -1)
        printf("Target not found.\n\n");
   else
        printf("Target found at index: %d \n\n", idx);
}
```

Linear Search in a Sorted Array



Target 19
a[0] a[1] a[2] a[3] a[4] a[5] a[6] a[7] a[8] a[9] a[10] a[11]
4 7 8 10 14 21 22 36 62 77 81 91
21 > 19

Problem:
Find the index of a number in a sorted array of integers

LinearSearch_InSortedArray.c

LinearSearch_InSortedArray.c

```c
#include <stdio.h>
#include <stdlib.h>
#define N 12
int main()
{
   int a[N]= { 4, 7, 8, 10, 14, 21, 22, 36, 62, 77, 81, 91};

   int target = 62;    //int target = 72;// Try this target next
   int i, idx=-1;
   for(i=0; i< N; i++)
   {
        if(a[i] == target)
        {
                idx=i;
                break;
        }
        else if(a[i]>target)
                break; // we can stop here
   }
   if(idx == -1)
        printf("Target not found.\n\n");
   else
        printf("Target found at index: %d. \n\n", idx);
}
```

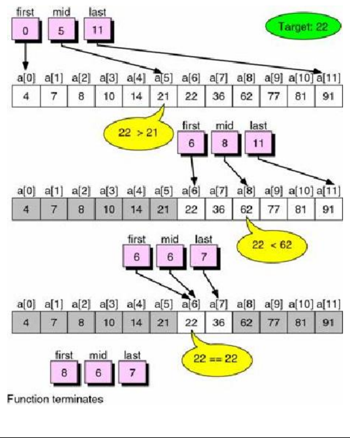
Analysis

- If the list is unsorted we have to search all numbers before we declare that the target is not present in the array.
- Because the list is sorted we can stop as soon as we reach a number that is greater than our target
- Can we do even better?

Binary Search

- At each step it splits the remaining array elements into two groups
- Therefore, it is faster than the linear search
- Works only on an already SORTED array
- Thus, there is a performance penalty for sorting the array

Example: Successful Binary Search



Example: BinarySearch.c

Binary_Search.c

```c
#include <stdio.h>
#include <stdlib.h>
#define N 12

int main()
{
     int a[N]= { 4, 7, 8, 10, 14, 21, 22, 36, 62, 77, 81, 91}; //sorted in increasing order
     int i;
     int target = 22;      //int target = 72; // Try this target next
     int idx=-1;           // if the target is found its index is stored here

     int first=0;          // initial values for the three search varaibles
     int last= N-1;
     int mid= (first + last)/2;

     while(last >= first)
     {
             if( a[mid] == target)
             {
                          idx=mid;  // Found it!
                          break;    // exit the while loop
             }
             else if(a[mid] > target)
             {
                          // don't search in a[mid] ... a[last]
                          last = mid-1;
             }
             else
             {
                          // don't search in a[first] ... a[mid]
                          first = mid +1;
             }

             // recalculate mid for the next iteration
             mid = (first + last)/2; // integer division!

     } // end of while loop

     if(idx == -1)
             printf("Target not found.\n\n");
     else
             printf("Target found at index: %d \n\n", idx);
}
```

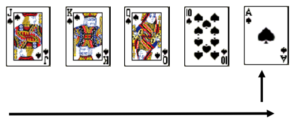
Problem:
Find the all occurrences of a number in an array and replace it with a new value.

search_and_replace.c

Linear_Search.c

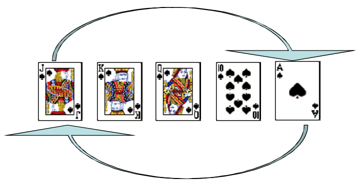
```c
#include <stdio.h>
#include <stdlib.h>
#define N 12
int main()
{
     int a[N] = { 4, 21, 36, 14, 62, 91, 8, 22, 7, 81, 62, 10};
     int i;
     int target = 62;
     int newValue = 65;

     int count=0;
     int idx[5];  // a helper array that keeps the indexes of all entries == target value
     int found=0;

     for(i=0; i< N; i++)
     {
             if(a[i] == target)
             {
                          found = 1;
                          idx[count] = i;
                          count++;
             }
     }

     if(found == 0)
             printf("Not found!\n\n");
     else
     {
             printf("Found it a total of %d times.\n", count);
             for(i=0; i< count; i++)
                          printf("\t Found @ index %d \n", idx[i]);
     }
     // Now replace all found occurences with a nother number
     for(i=0; i< count; i++)
             a[ idx[i] ] = newValue;

     system("pause");
}
```

Selection Sort
(Cards Example)

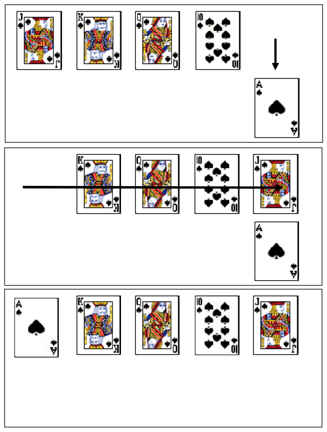


Initial Configuration

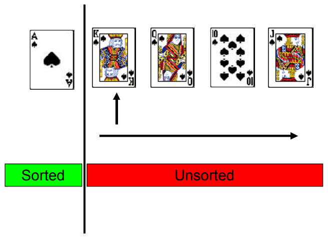
(search all cards and find the largest)



Swap the two cards



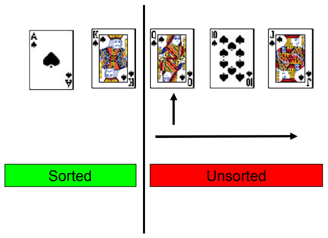
As before, the swap is performed in three steps.



Among the remaining cards the king is the largest.

It will remain in place.

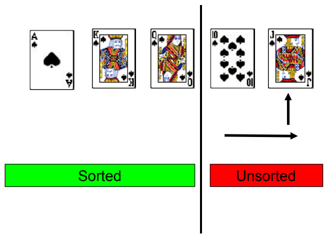
But the algorithm may perform Some empty operations (ie., swap it with itself in place)



Among the remaining cards the queen is the largest.

It will remain in place.

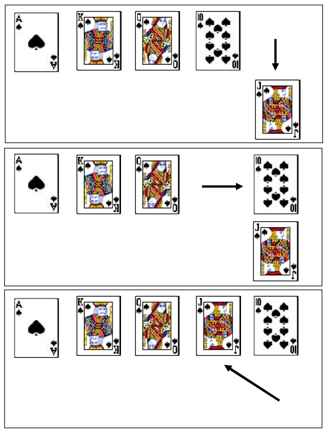
But the algorithm may perform Some empty operations (i.e., swap it with itself in place)



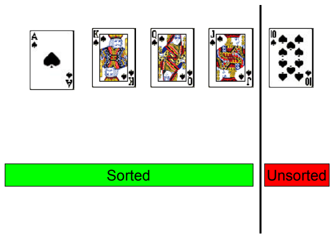
Among the remaining cards the Jack is the largest.

It will remain in place.

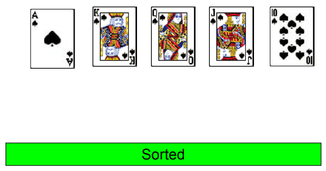
But the algorithm may perform Some empty operations (i.e., swap it with itself in place)



As before, the swap is performed in three steps.

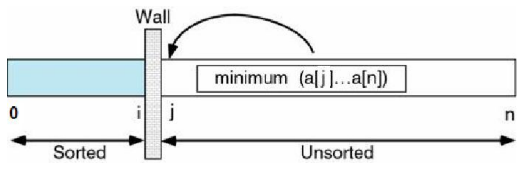


We are down to the last card.
Because there is only one and
Because we know that it is
Smaller than all the rest
We don't need to do anything
Else with it. This is why the
Algorithm goes up to < N-1

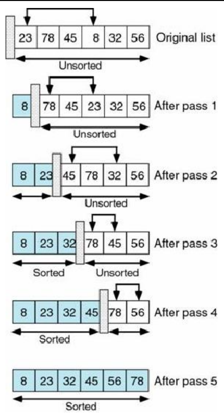


All cards are now sorted.

Selection Sort



Example: Selection Sort


23 78 45 8 32 56 Original list
Unsorted
8 78 45 23 32 56 After pass 1
Unsorted
8 23 45 78 32 56 After pass 2
Unsorted
8 23 32 78 45 56 After pass 3
Sorted
Unsorted
8 23 32 45 78 56 After pass 4
Sorted
8 23 32 45 56 78 After pass 5
Sorted

Example: SelectionSort.c

```
#include <stdio.h>
#define N 6
int main()
{
   int a[N]= { 23, 78, 45, 8, 32, 56};
   int i,j,tmp;
   // Sort the array using Selection Sort
   int idx,min;
   for(i=0; i < N-1; i++)
   {
        min=a[i];
        idx = i;
        for(j=i+1; j < N; j++)
        if(a[j] < min){
                idx = j;
                min = a[j];
              }
        tmp = a[i];
        a[i] = min;
        a[idx] = tmp;
   }
   for(i = 0; i < N; i++)
         printf("%d\n",a[i]);
}
```

Questions?