5.1
One-dimensional Arrays

Why Learning Arrays?

- Most programming languages provide array data structure as built-in data structure.
- An array is a list of values with the **same** data type that can be used to organize and store related data items. If not using array, you will need to define many variables instead of just **one** array variable.
- Python provides the **list** structure, which has two major differences from the array data structure in C:
  - Arrays have only limited operations while lists have many operations.
  - Size of arrays cannot be changed while lists can grow and shrink.
- In arrays, we can categorize them as one-dimensional arrays and two-dimensional (or multi-dimensional) arrays. In this lecture, we focus on discussing one-dimensional arrays.

One-dimensional Arrays

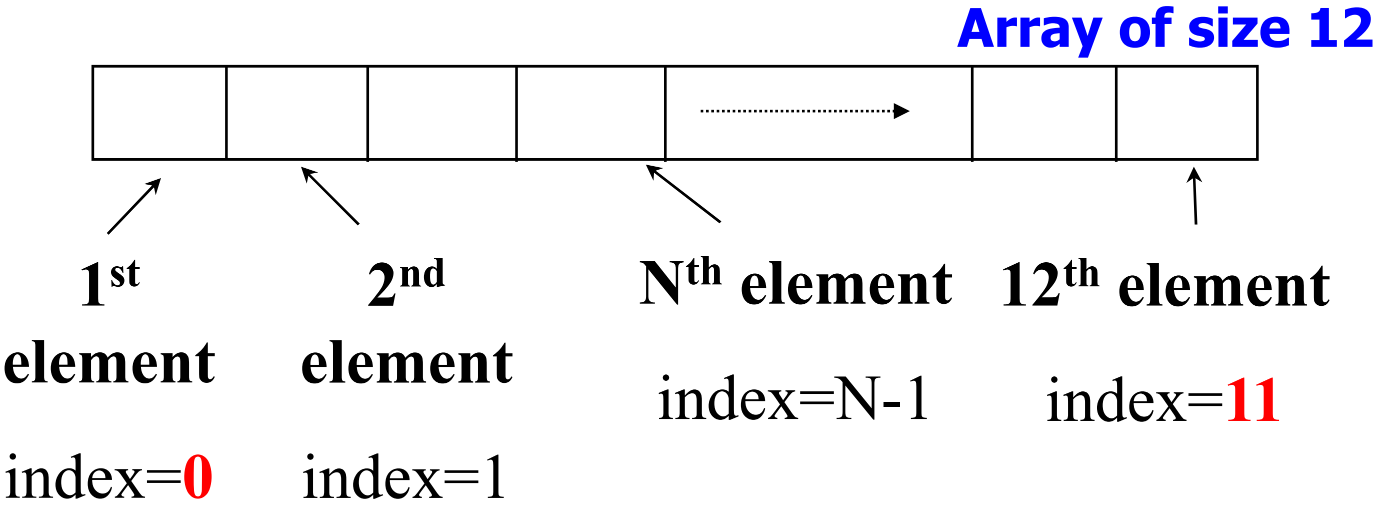
- **Array Declaration, Initialization and Operations**
- Pointers and Arrays
- Arrays as Function Arguments

Types of Variables

- Data (or values) stored in variables are mainly in two forms:
  - **Primitive Variables**: Variables that are used to store **values**. They are mainly variables of primitive data types, such as int, float and char. Later on, you will learn **Structure**, which is used to store a record of data (values).
  - **Reference (or Pointer) Variables**: Variables that are used to store **addresses**, such as **pointer variables, array variables** and **string variables**.

What is an Array?

- An **array** is a **list of values** with the **same data type**. Each value is stored at a specific, numbered position in the array.
- An array uses an **integer** called **index** to reference an element in the array.
- The **size** of an array is **fixed** once it is created. Could the size be created dynamically? Yes by using **malloc()**, you will learn that later in data structures.
- Index always starts with **0** **(zero)**.



Array Declaration

- Declaration of arrays **without initialization**:

```
char name[12];          /* array of 12 characters */
float sales[365];       /* array of 365 floats */
int states[50];         /* array of 50 integers */
int *pointers[5];       /* array of 5 pointers to integers */
```

- When an array is declared, some **consecutive memory** locations are allocated by the compiler for the whole array (**2 or 4** bytes will be allocated for an integer depending on machine):

  total_memory = **sizeof**(type_specifier)*array_size;

  e.g. char name[12]; - total_memory = 1*12 = 12 bytes

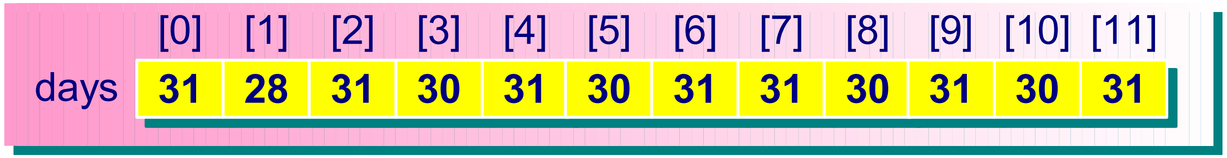
- The size of array must be integer constant or constant expression in declaration:

```
e.g.    char name[i];      // i is a variable  ==> illegal
        int states[i*6];   // i is a variable  ==> illegal
```

Initialization of Arrays

- **Initialize array variables** at declaration:

```
int days[12]={31,28,31,30,31,30,31,31,30,31,30,31};
```

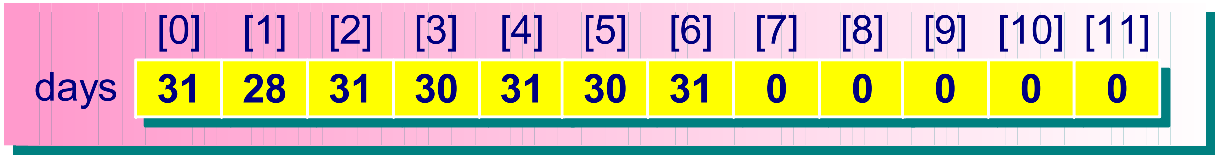


	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
days	31	28	31	30	31	30	31	31	30	31	30	31

- **Partial array initialization**: E.g. (initialize first 7 elements)

```
int days[12]={31,28,31,30,31,30,31};
```

/* **remaining** elements are initialized to **zero** */



	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
days	31	28	31	30	31	30	31	0	0	0	0	0

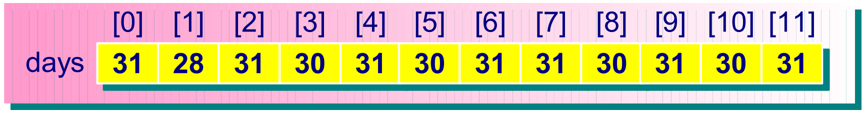
Operations on Arrays

- **Accessing** array elements:

  sales[0] = 143.50; **// using array index**
  if (sales[23] == 50.0) ...

- **Subscripting**: The element indices range from **0** to **n-1** where n is the declared size of the array.

  char name[12];
  name[**12**] = 'c'; **// index out of range – common error**

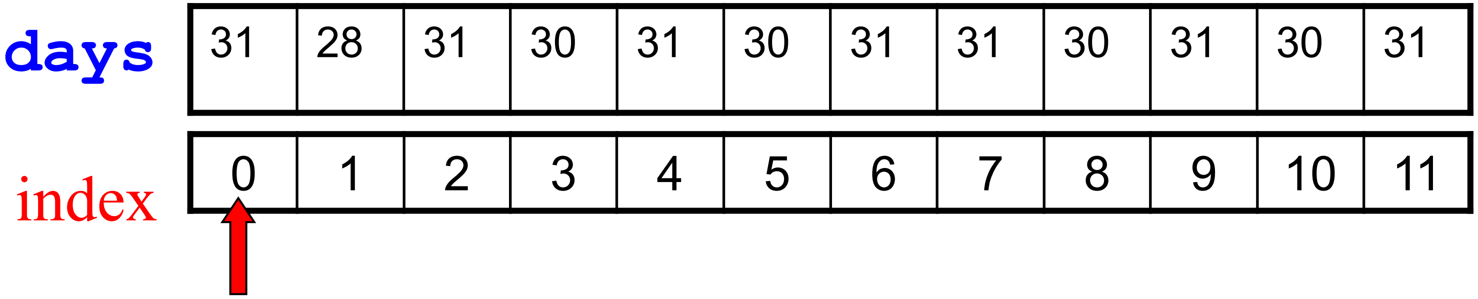


	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
days	31	28	31	30	31	30	31	31	30	31	30	31

- Working on array values:
  (1) days[1] = 29; - OK ??
  (2) days[2] = days[2] + 4; - OK ??
  (3) days[3] = days[2] + days[3]; - OK ??
  (4) days[1] = {2,3,4,5,6}; - OK? NOT OK!!

Traversing an Array – Using Array Index

- One of the **most common actions** in dealing with arrays is to examine every array element in order to perform an operation or assignment.
- This action is also known as **traversing** an array.
- Example:
  - Traverse the **days[ ]** array using a **for** or **while** loop to access each array element individually with array index, and then process each array element's content accordingly.



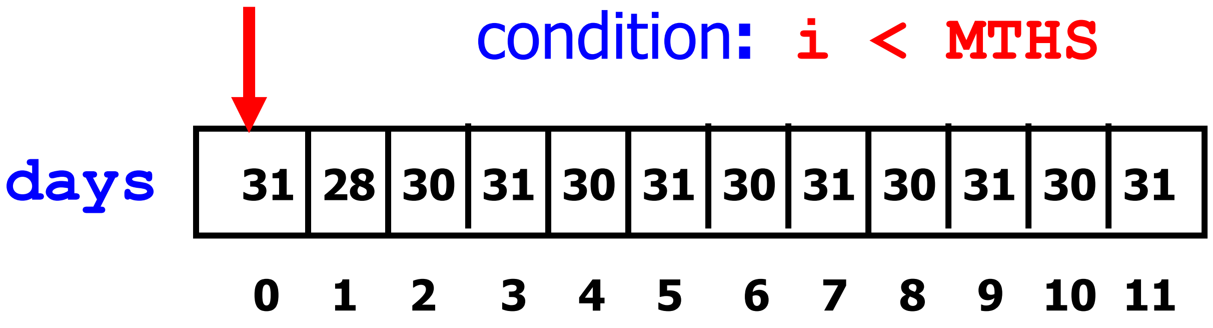
days	31	28	31	30	31	30	31	31	30	31	30	31
index	0	1	2	3	4	5	6	7	8	9	10	11

Example 1: Printing Values

```
#include <stdio.h>
#define MTHS 12              /* define a constant */
int main( )
{
    int i;
    int days[MTHS] = {31,28,31,30,31,30,31,31,30,31,30,31};

    /* print the number of days in each month */
    for (i = 0 ;   i < MTHS ;    i++ )
        printf("Month %d has %d days\n", i+1, days[i]);
    return 0;
}
```

Output

```
Month 1 has 31 days.
Month 2 has 28 days.
…
Month 12 has 31 days.
```



condition: i < MTHS

days	31	28	30	31	30	31	30	31	30	31	30	31
	0	1	2	3	4	5	6	7	8	9	10	11

Example 2: Searching for a Value

```
#include <stdio.h>
#define SIZE 5          /* define a constant */
int main ( )
{
    char myChar[SIZE] = {‘b’, ‘a’, ‘c’, ‘k’, ‘s’};
    int i;
    char searchChar;
    // Reading in user’s input to search
    printf("Enter a char to search: ");
    scanf(“%c”, &searchChar);
    // Traverse myChar array and output character if found
    for  (i = 0;    i < SIZE;    i++) {
        if (myChar[i] == searchChar){
            printf (“Found %c at index %d”, myChar[i], i);
            break;      //break out of the loop
        }
    }
    return 0;
}
```

Output

```
Enter a char to
search: a
Found a at index 1
```

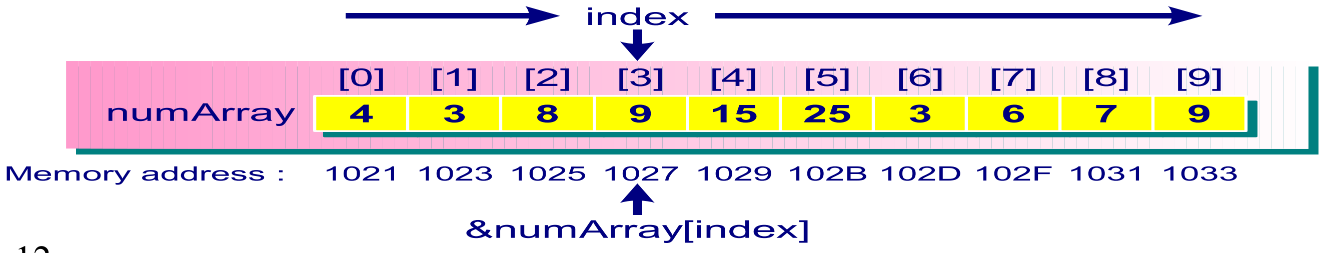
Example 3: Finding the Maximum Value

This example shows how to find the largest value in an array of numbers.

```
#include <stdio.h>
int main( )
{
    int index, max, numArray[10];
    max = -1; printf(“Enter 10 numbers: \n”);
    for (index = 0; index < 10; index++)
          scanf(“%d”, &numArray[index]);
    // Find maximum from array data
    for (index = 0;   index < 10;    index++) {
          if (numArray[index] > max)
               max = numArray[index];
     }
    printf(“The max value is %d.\n”, max);
    return 0;
}
```

Output

```
Enter 10 numbers:
4 3 8 9 15 25 3 6 7 9
The max value is 25.
```



	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
numArray	4	3	8	9	15	25	3	6	7	9
Memory address :	1021	1023	1025	1027	1029	102B	102D	102F	1031	1033

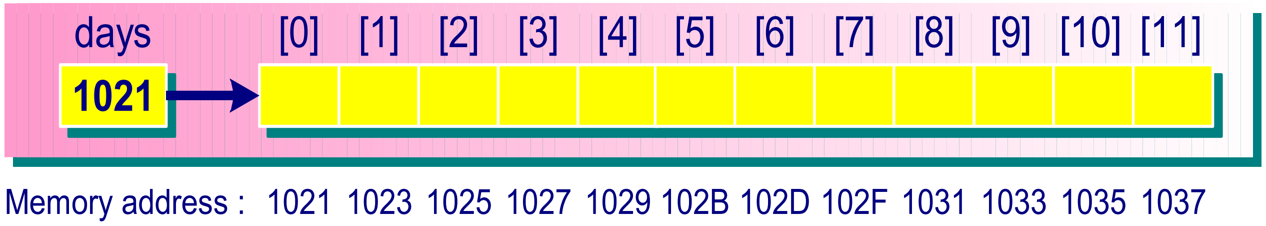
One-dimensional Arrays

– Array Declaration, Initialization and Operations
– **Pointers and Arrays**
– Arrays as Function Arguments

Pointer Constants

- The **array name** is actually a ***pointer constant***.

  e.g. int **days**[12]; // **days** – **pointer constant**



days

1021

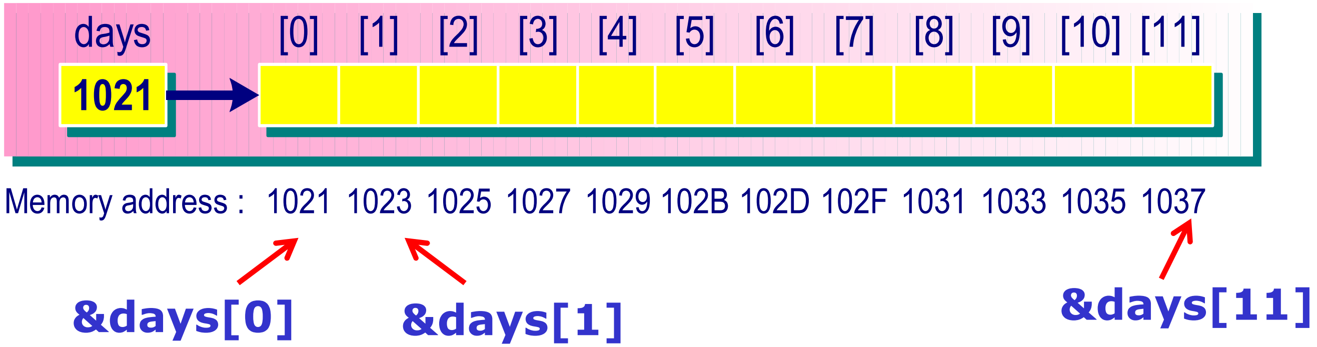
[0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11]

Memory address : 1021 1023 1025 1027 1029 102B 102D 102F 1031 1033 1035 1037

- The array **days** begins at memory location 1021. Here, we use 2 bytes to represent an integer value (for older machines) for illustration purpose. Note that most current systems represent an integer using 4 bytes.

Pointer Constants (Cont'd.)

- Address of an array element:


days
1021
[0]
[1]
[2]
[3]
[4]
[5]
[6]
[7]
[8]
[9]
[10]
[11]
Memory address : 1021 1023 1025 1027 1029 102B 102D 102F 1031 1033 1035 1037
&days[0]
&days[1]
&days[11]

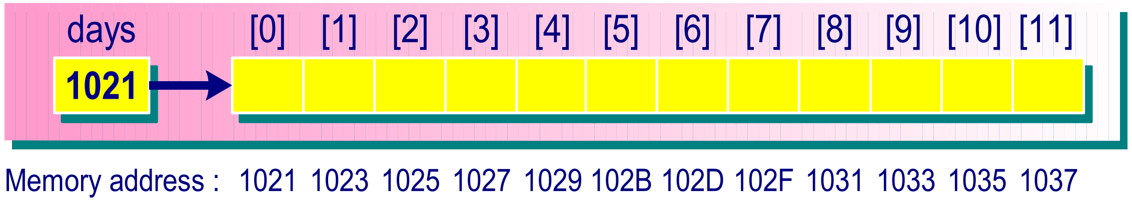
&days[0] - is the **address** of the **1st** element [i.e. 1021]

&days[1] - is the **address** of the **2nd** element [i.e. 1023]

&days[i] - is the **address** of the **(i+1)th** element

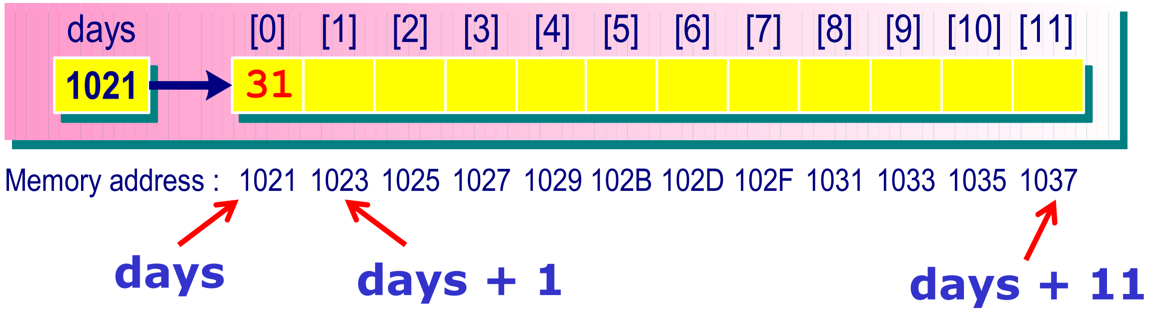
Pointer Constants (Cont'd.)

- **days** - is the **address (or pointer)** of the **1st element of the array**



- Note:
  - Array variable: **days** – contains a pointer constant (i.e. 1021) (the value cannot be changed)
  - Array with index: **days[0]**, days[1], etc. – contains the array value at that index location
  - Array element address: **&days[0] (i.e. 1021)**, &days[1], etc. - days[0] has the address of 1021, days[1] has the address of 1023, etc.
- Can we use the pointer **days** for accessing each array element?

Pointer Constants (Cont'd.)


days
[0]
[1]
[2]
[3]
[4]
[5]
[6]
[7]
[8]
[9]
[10]
[11]
1021
31
Memory address : 1021 1023 1025 1027 1029 102B 102D 102F 1031 1033 1035 1037
days
days + 1
days + 11

- To do that, we need to know two important concepts:

(1) **array_name** (i.e. pointer constant)

days == &days[0] (i.e. 1021)

days + i == &days[i]

(2) ***array_name (dereferencing)**

***days** == days[0] (i.e. 31)

***(days + i)** == days[i]

Note: You may also use ***days** to refer to the content stored at **days[0]**, etc.

- But, you <u>cannot</u> change the array <u>base pointer</u>:

```
days += 5;    // i.e. days = days+5;    not valid
days++;       // i.e. days = days+1;    not valid
```

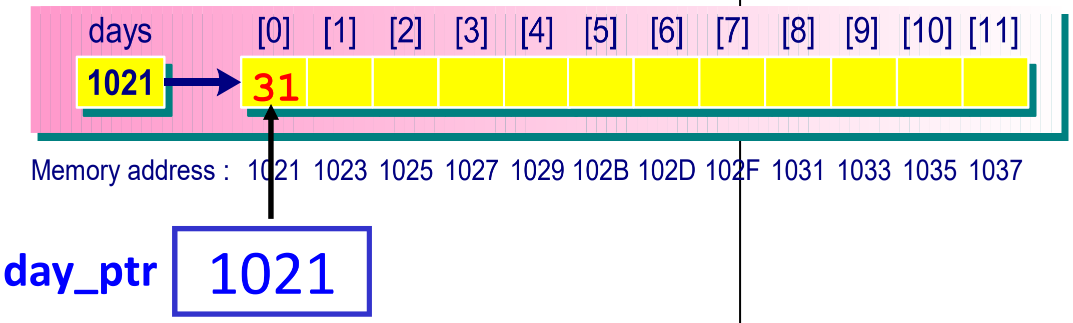
Pointer Variables

- A ***pointer variable*** can take on **different addresses**.

```
/* pointer arithmetic */
#define MTHS 12
int main()
{
    int days[MTHS]=  {31,28,31,30,31,30,31,31,30,31,30,31};
    int *day_ptr;

1. day_ptr = days;
```

Pointer constant

Pointer variable


days
[0]
[1]
[2]
[3]
[4]
[5]
[6]
[7]
[8]
[9]
[10]
[11]
1021
31
Memory address : 1021 1023 1025 1027 1029 102B 102D 102F 1031 1033 1035 1037
day_ptr
1021

```
     printf("First element = %d\n", *day_ptr);
}
```

Output

First element = 31

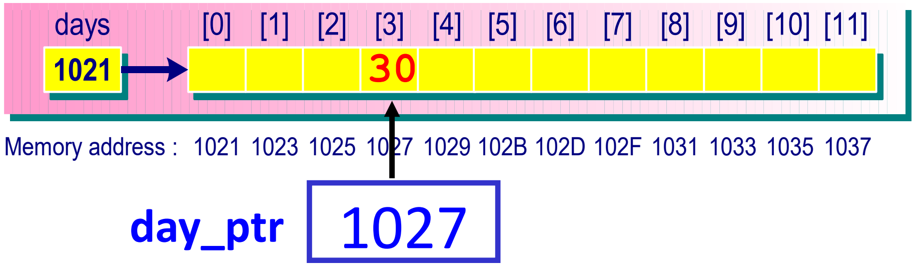
Pointer Variables (Cont'd.)

- A ***pointer variable*** can take on **different addresses**.

```
/* pointer arithmetic */
#define MTHS 12
int main()
{
    int days[MTHS]=  {31,28,31,30,31,30,31,31,30,31,30,31};
    int *day_ptr;
    day_ptr = days;
    printf("First element = %d\n", *day_ptr);

2 . day_ptr = &days[3]; /* points to the fourth element */
```

Pointer constant

Pointer variable

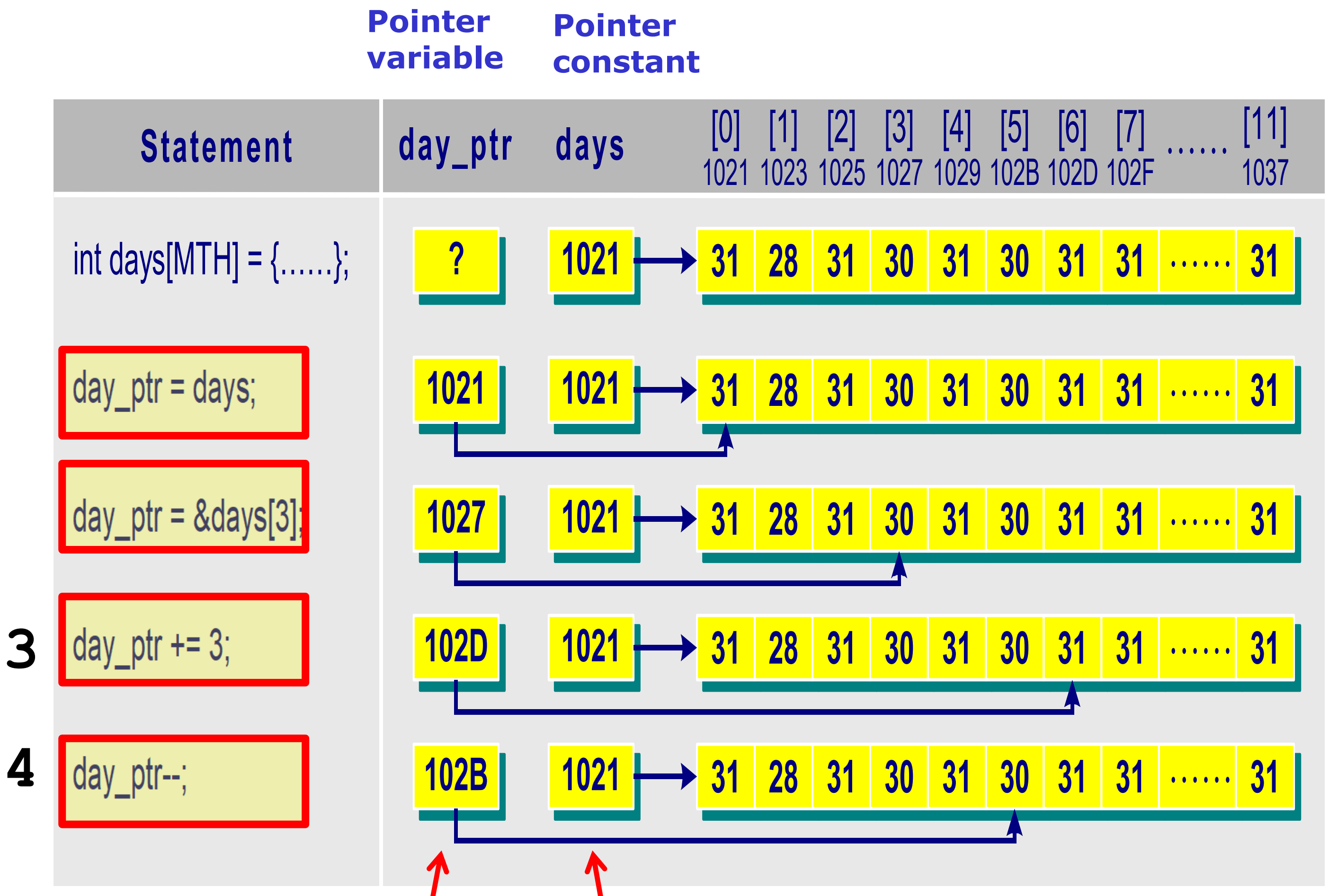

days
[0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11]
1021
30
Memory address : 1021 1023 1025 1027 1029 102B 102D 102F 1031 1033 1035 1037
day_ptr
1027

```
    printf("Fourth element = %d\n", *day_ptr);
}
```

Output

```
First element = 31
Fourth element = 30
```

Pointer Variables (Cont'd.)



	Statement	day_ptr	days	[0] 1021	[1] 1023	[2] 1025	[3] 1027	[4] 1029	[5] 102B	[6] 102D	[7] 102F	……	[11] 1037
	int days[MTH] = {……};	?	1021	31	28	31	30	31	30	31	31	……	31
	day_ptr = days;	1021	1021	31	28	31	30	31	30	31	31	……	31
	day_ptr = &days[3];	1027	1021	31	28	31	30	31	30	31	31	……	31
3	day_ptr += 3;	102D	1021	31	28	31	30	31	30	31	31	……	31
4	day_ptr--;	102B	1021	31	28	31	30	31	30	31	31	……	31

Output
First element = 31
Fourth element = 30
Seventh element = 31
Sixth element = 30

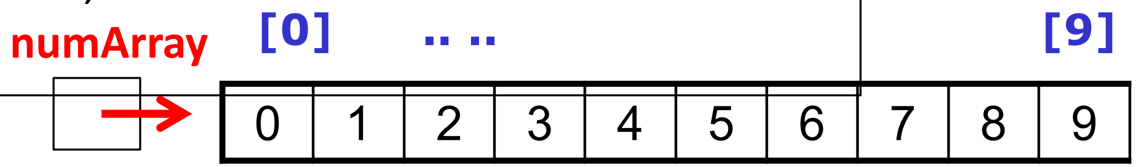
days - cannot be changed

day_ptr - can be updated

Finding Maximum: Using Pointer Constants

Pointer constant

```
#include <stdio.h>
int main( )
{
     int index, max, numArray[10];
     printf(“Enter 10 numbers: \n”);
     for (index = 0;   index < 10;   index++)
             scanf("%d", numArray + index);
     // Find maximum from array data
     max = *numArray;
     for (index = 1;   index < 10;   index++)
     {
             if (*(numArray + index) > max)
                 max = *(numArray + index);
     }
     printf("The max value is %d.\n", max);
     return 0;
}
```



0	1	2	3	4	5	6	7	8	9

Using index for reading input:

```
for (index = 0; index < 10; index++)
     scanf(“%d”, &numArray[index]);
```

Using index for processing:

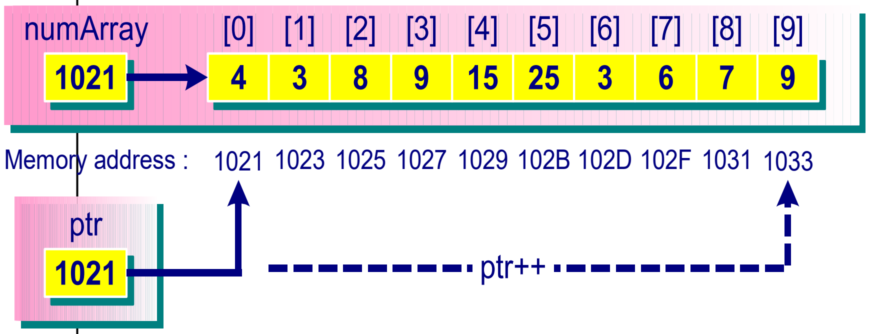
```
max = numArray[0];
for (index = 1;   index < 10;
                index++)
{
     if (numArray[index] > max)
          max = numArray[index];
}
```

Finding Maximum: Using Pointer Variables

```
#include <stdio.h>
int main( ){
      int index, max, numArray[10];
      int *ptr;
      ptr = numArray;
      printf("Enter 10 numbers: \n");
      for (index = 0; index < 10; index++)
                scanf("%d", ptr++);
       // Find maximum from array data
      ptr = numArray;
      max = *ptr;
      for (index = 0; index < 10; index++) {
                if (*ptr > max)
                         max = *ptr;
                ptr++;
      }
      printf("max is %d.\n", max);
      return 0;
}
```

Output

```
Enter 10 numbers:
4 3 8 9 15 25 3 6 7 9
max is 25.
```



Arrays and Pointers – Key Points

- Array is declared as **pointer constant**: In this case, we cannot change the base pointer address.
  - Example: int **numArray**[10];
  - Generally, we can use the **index notation** to access each element of the array, e.g. **numArray[0]** refers to the first element, etc.
  - We can also use the pointer constant to access each element of the array, e.g. *****(**numArray+1**) refers to **numArray[1]**, etc. in order to access each element of the array.

- In addition, we can also declare **pointer variables** to access the array.
  - Declare a pointer variable and assign the array to the pointer variable. Example: int ***ptr**; **ptr = numArray;**
  - Then we can use **ptr** to access each element of the array.
  - For example, by dereferencing the pointer variable, ***ptr** refers to the first element of the array **numArray[0]**, etc. By updating the pointer variable (**ptr++**) to point to the next array element, we can then access each element of the array.

One-Dimensional Arrays

- Array Declaration, Initialization and Operations
- Pointers and Arrays
- **Arrays as Function Arguments**

Arrays as Function Arguments: Function Header

Function header

```
void fn1(int table[ ], int size)
{
   ....
}
```

or

```
void fn2(int table[TABLESIZE])
{
   ....
}
```

or

```
void fn3(int *table, int size)
{
   ....
}
```

The **prototype** of the function:

```
void fn1(int table[ ], int size);
```

or

```
void fn2(int table[TABLESIZE]);
```

or

```
void fn3(int *table, int size);
```

Note: **size** and **TABLESIZE** are the **data size** to be processed in the array

Arrays as Function Arguments: Calling the Function

- Any dimensional array can be passed as a function argument, e.g. we can **call the function**:

  ```
  fn1(table, n);        /* calling a function */
  ```

  where **fn1()** is a function and **table** is an one-dimensional array, and **n** is the size of the array **table**.

- An **array table** is passed in using **call by reference** to a function.

- This means the **address** of the **first element** of the array is passed to the function.

Array as a Function Argument: Maximum

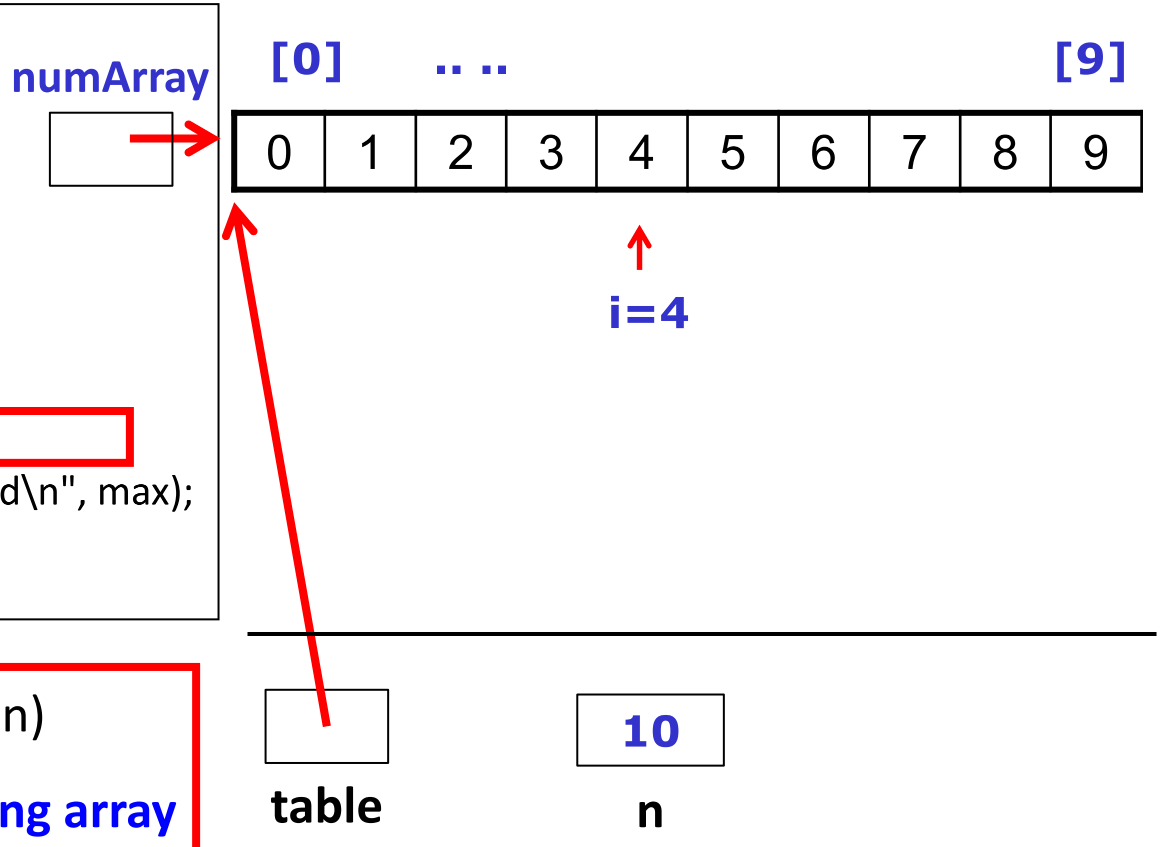
```
#include <stdio.h>
int maximum(int table[ ], int n);
int main( )
{
      int max, index, n;
      int numArray[10];   // Using index for input

      printf("Enter the number of values: ");
      scanf("%d", &n);
      printf("Enter %d values: ", n);
      for (index = 0; index < n; index++)
                scanf("%d", &numArray[index]);

      // find maximum              // Calling the function
      max = maximum(numArray, n);
      printf("The maximum value is %d\n", max);

     return 0 ;
}
```

Output

```
Enter the number of
values:  10
Enter 10 values: 0 1 2 3 4
5 6 7 8 9
The maximum value is 9
```

Implementing Maximum: (1) Using Array Indexing

```
#include <stdio.h>
int maximum(int table[ ], int n);
int main( )
{
      int max, index, n;
      int numArray[10];


      ....
      max = maximum(numArray, n);
      printf("The maximum value is %d\n", max);
     return 0 ;
}
```

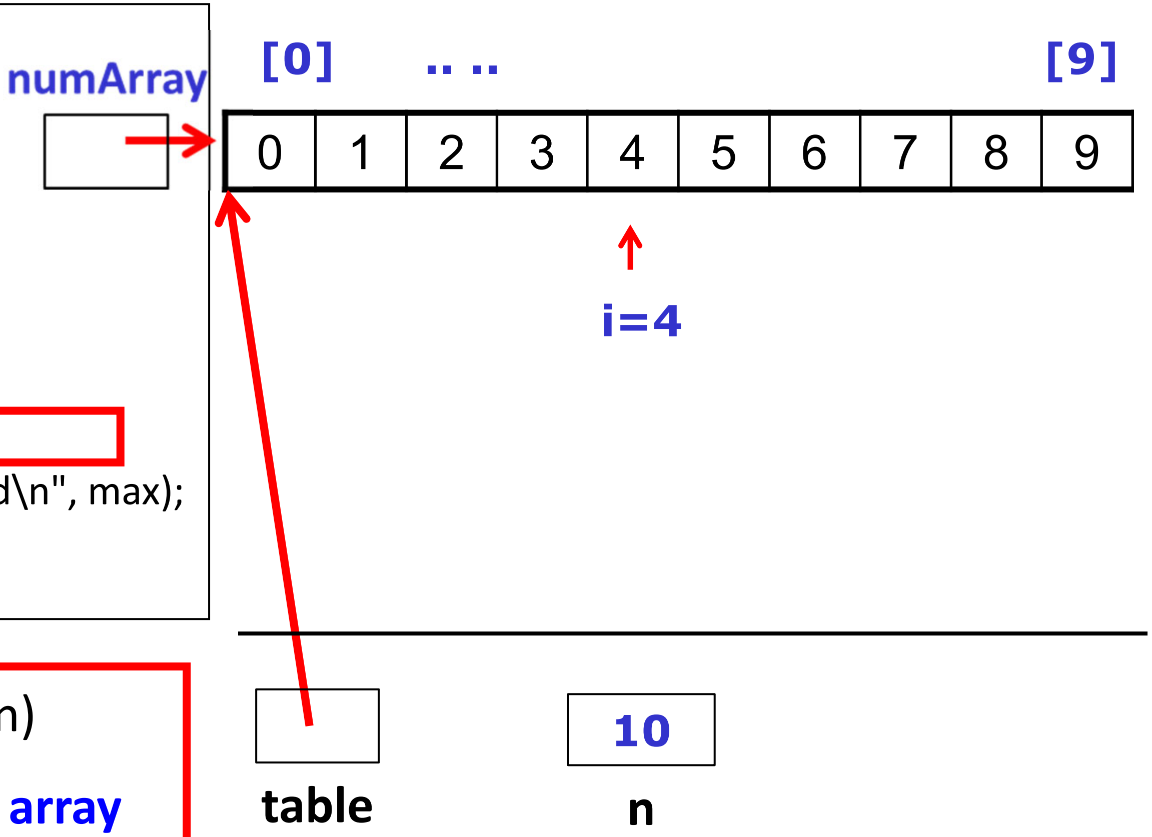


```
int maximum(int table[ ], int n)
{
      int i, max;

      max = table[0];
      for (i = 1; i < n; i++)
              if (table[i] > max)
                    max = table[i];
      return max;
}
```

Using array indexing

Implementing Maximum: (2) Using Ar Base Address

```
#include <stdio.h>
int maximum(int table[ ], int n);
int main( )
{
      int max, index, n;
      int numArray[10];

      ....
      max = maximum(numArray, n);
      printf("The maximum value is %d\n", max);
     return 0 ;
}
```



```
int maximum(int table[ ], int n)
{
      int i, max;

      max = *table;
      for (i = 1; i < n; i++)
            if (*(table+i) > max)
                        max = *(table+i);
      return max;
}
```

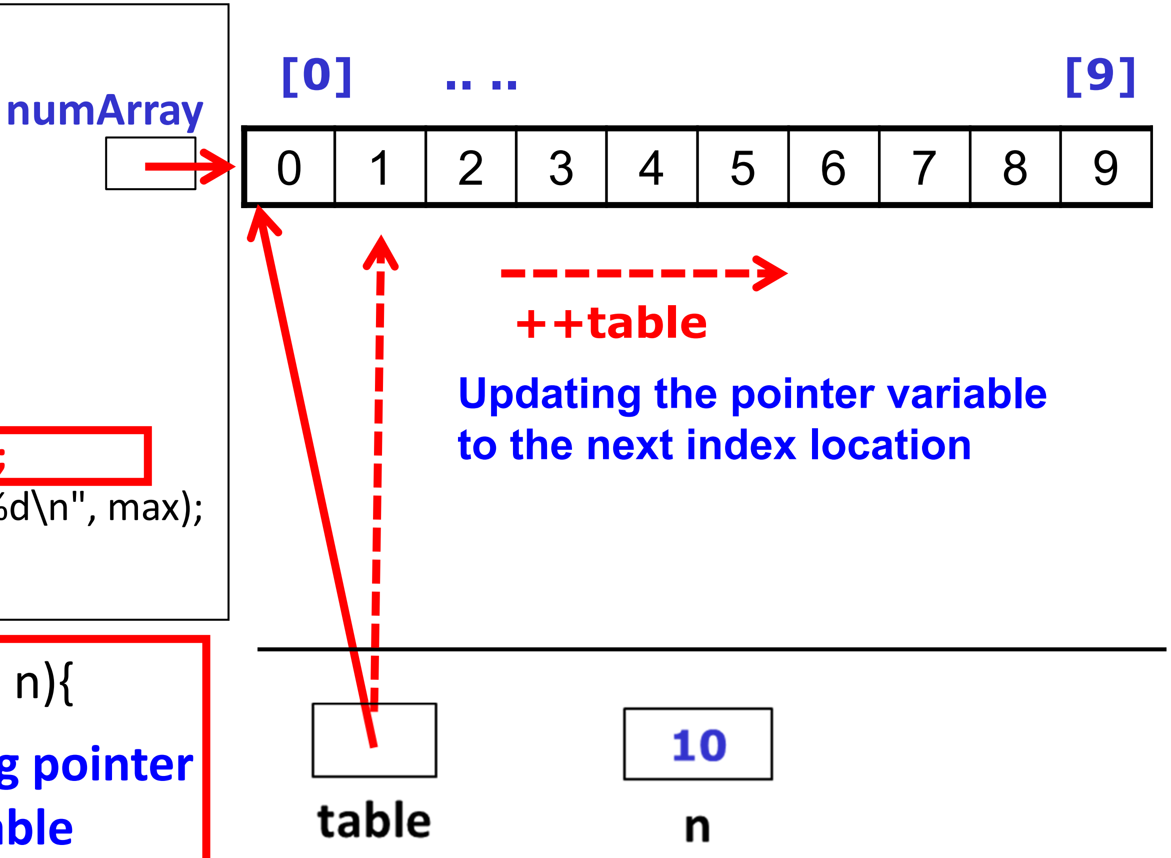
Using array base address

Implementing Maximum: (3) Using Pointer Variable

```
#include <stdio.h>
int maximum(int table[ ], int n);
int main( )
{
      int max, index, n;
      int numArray[10];

      ….
      max = maximum(numArray, n);
      printf("The maximum value is %d\n", max);
    return 0 ;
}
```

```
int maximum(int table[ ], int n){
   int i, max;
   max = *table;
   for (i = 0; i < n; i++) {
      if (*table > max)
         max = *table;
      ++table;
   }
   return max;
}
```

Using pointer variable



Updating the pointer variable to the next index location

Thank You!