

Procedure Programming

Arrays

Instructor: Jeeho Ryoo

Arrays

Collections or groups of the same data type

Can be multi-dimensional (arrays of arrays)

1D, 2D, 3D

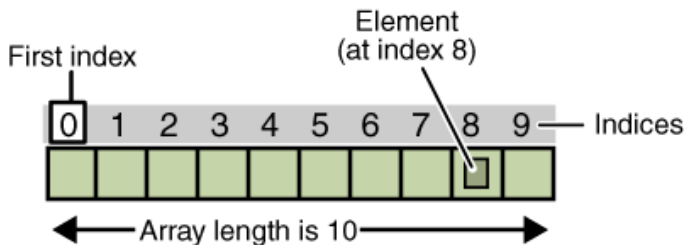
Variable name is followed by one pair
of square brackets

Ex: Regular integer variable declaration: *int x*;

Array of integers variable declaration: *int x[]*;

Arrays

- Arrays are referenced using indexes
- Indexes of arrays always start at 0



Declaring an Array

The length of the array can be declared by putting the length in the square bracket []

```
int x[3];
```

We can load the array with values when we declare it as well

```
int x[5] = {4, 6, 7};
```

Declaring an Array

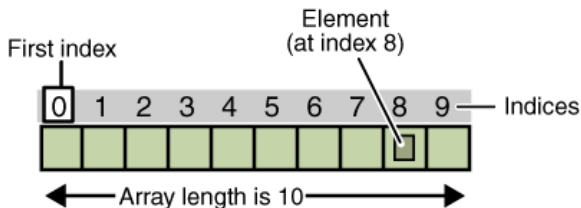
We can declare and load the array with values without setting it's length

```
int y[] = {4, 5, 3, 8, 9, 12, 45};
```

Accessing elements in an Array

We access elements in the array by using an index number
In this example we assign the 8th element of the array to *y*

```
int x[10] = {4, 6, 8, 6, 55, 6, 8, 10, 4, 0};  
int y = x[8];
```



Accessing elements in an Array (Example)

Write a program that prints the 6th element of an Array

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

```
int main() {  
    int z[] = {6, 5, 8, 10, 67, 43, 200};  
    printf ("%d", z[5]);  
    return 0;  
}
```

Using Arrays (Example 1)

What will be displayed in console?

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

```
int main() {  
    int x[7] = {0, 1, 5, 2, 3, 8, 6};  
    int y = x[2]*x[4];  
    printf ("%d", y);  
    return 0;  
}
```


Using Arrays (Example 2)

What will z have to equal so 8 is displayed in console?

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

```
int main() {  
    int x[] = {9, 4, 1, 8, 34, 6, 8, 56, 87};  
    int z = ?;  
    int y = z - (x[2]*x[4]);  
    printf ("%d", y);  
    return 0;  
}
```

2d Arrays

2d arrays are also known as an array of 1d arrays

Declared by providing more than one set of square brackets

```
int x[3][3];
```

2d Arrays (Cont.)

Typically the first dimension is the number of rows and second dimension is the number of columns

Visualizing: `int x[3][3];`

	Column 0	Column 1	Column 2
Row 0	<code>x[0][0]</code>	<code>x[0][1]</code>	<code>x[0][2]</code>
Row 1	<code>x[1][0]</code>	<code>x[1][1]</code>	<code>x[1][2]</code>
Row 2	<code>x[2][0]</code>	<code>x[2][1]</code>	<code>x[2][2]</code>

Declaring 2d Arrays

Typically you declare and load a 2d array by grouping the { }

```
int x[2][2] = { {4, 5}, {8, 2} }; or  
int x[2][2] = {4, 5 ,8 ,2 };
```

2d arrays can also be loaded without providing a length for the first square bracket []

```
int x[][2] = { {4, 5}, {8, 2} };
```

Declaring 2d arrays (cont.)

Declaration needs to be loaded if first square bracket is empty

```
int x[][2];
```

```
int x[][2] = { {4, 5}, {8, 2} };
```

Accessing elements in a 2d array

Elements of 2d arrays are accessed using the index number of the row or column

In this example we give the 1st row of the 2nd column a value of 8.

```
int x[2][2];  
x[0][1] = 8;
```

	Column 0	Column 1	Column 2
Row 0	x[0][0]	x[0][1]	x[0][2]
Row 1	x[1][0]	x[1][1]	x[1][2]
Row 2	x[2][0]	x[2][1]	x[2][2]

Accessing elements in a 2d Array (Example)

Write a program that prints the 3rd element of the 2nd row

```
#include <stdio.h>

int main() {
    int z[][3] = { {6, 5, 8}, {10, 6, 3}, {5, 7, 1} };
    printf ("%d", z[1][2]);

    return 0;
}
```

Using 2d arrays (Example 1)

What will be displayed in console?

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

```
int main() {  
    int x[4][2] = { {4, 7}, {2, 8}, {8, 4}, {9, 0} };  
    printf ("%d", x[0][0]);  
    return 0;  
}
```


Using 2d arrays (Example 2)

What will be displayed in console?

```
#include <stdio.h>
int main() {
    int x[][4] = { {0, 1, 5, 7}, {3, 8, 6, 9} };
    int y = x[0][1] * x[1][3];
    printf ("%d", y);
    return 0;
}
```

Determining the size of an array

Best way to get the length of an array is to use the *sizeof* operator

sizeof operator returns the size in bytes

Example:

```
int x[2];
```

```
int y = sizeof(x);
```

Y equals '8', because the array is 8 bytes in size

Determining the length of an array

Each element in array is equal in size because they are same types (int, float, char, etc)

Note the value can be different, but size will be the same

You can divide the array size by the size of just one element

```
int x[2];  
int y = sizeof(x) / sizeof(x[0]);
```

Returns 2, which is the length of the array

Bounds checking with arrays

In other languages bounds checking is better handled than in C

In C you can easily create issues without realizing it

Consider this 2d array:

```
int x[3][3] = { {2, 3, 6}, {2, 6, 6}, {2, 6, 8, 7} };
```

The **7** is outside the declared scope of the array

Bounds checking with arrays (cont.)

Accessing elements outside the array bounds can also cause issues

Consider this:

```
int x[3][3] = { {2, 3, 8}, {2, 6, 6}, {2, 6, 8} };  
int y = x[2][50];
```

The arrays length does not support this index
Could be some other value you are accessing

Multi-dimensional arrays extra

```
int x[2][2] = { {4, 5}, {6, 7} };
```

To get the number 7 in the second row we normally write:

```
x[1][1];        (recommended)
```

This will work to:

```
x[0][3];        (Not recommended)
```

This is because of the assigned memory for the array

Examples

`int A[10]`

- An array of ten integers
- `A[0], A[1], ..., A[9]`

`double B[20]`

- An array of twenty long floating point numbers
- `B[0], B[1], ..., B[19]`

Arrays of **structs**, **unions**, **pointers**, etc., are also allowed

Array indexes *always* start at zero in C

Examples

`int C[]`

- An array of an unknown number of integers (allowable in a parameter of a function)
- `C[0], C[1], ..., C[max-1]`

`int D[10][20]`

- An array of ten rows, each of which is an array of twenty integers
- `D[0][0], D[0][1], ..., D[1][0], D[1][1], ..., D[9][19]`
- *Not used so often as arrays of pointers*

Two-dimensional Arrays

```
int D[10][20]
```

- A *one-dimensional array* with 10 elements, each of which is an array with 20 elements

```
i.e., int D[10][20]    /*[row][col]*/
```

Last subscript varies the fastest

- I.e., elements of last subscript are stored contiguously in memory

Also, three or more dimensions

Array Elements (continued)

Array elements are commonly used in loops

E.g.,

```
for(i=0; i < max; i++)
```

```
    A[i] = i*i;
```

```
for(sum = 0, j=0; j < max; j++)
```

```
    sum += B[j];
```

```
for (count=0; rc!=EOF; count++)
```

```
    rc=scanf("%f", &A[count]);
```

Caution! Caution! Caution!

It is the programmer's responsibility to avoid indexing off the end of an array

- *Likely* to corrupt data
- May cause a *segmentation fault*
- Could expose system to a *security hole!*

C does **NOT** check *array bounds*

- I.e., whether index points to an element within the array
- Might be high (beyond the end) or negative (before the array starts)

Declaring Arrays

Static or automatic

Array size may be determined explicitly or implicitly

Array size may be determined at run-time

Declaring Arrays (continued)

Outside of any function – always static

```
int A[13];
```

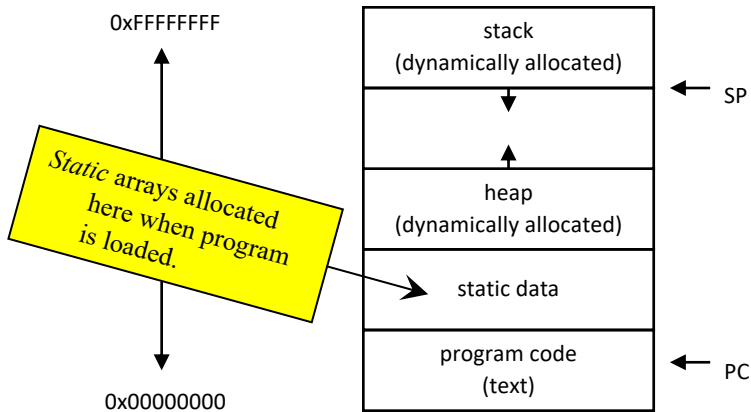
```
#define CLASS_SIZE 73  
double B[CLASS_SIZE];
```

```
const int nElements = 25  
float C[nElements];
```

```
static char D[256];
```

Static \Rightarrow retains
values across
function calls

Static Data Allocation

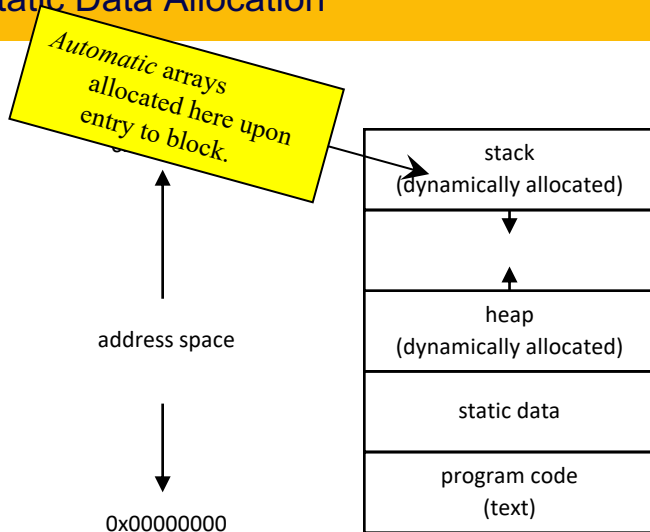


Declaring Arrays (continued)

Inside function or compound statement – usually automatic

```
void f( ...) {  
    int A[13];  
  
    #define CLASS_SIZE 73  
    double B[CLASS_SIZE];  
  
    const int nElements = 25  
    float C[nElements];  
  
    static char D[256]; /*static, not  
    visible outside function */  
  
}    //f
```

Static Data Allocation



Dynamic Array Size Determination

gcc supports the following:-

```
void func(<other parameters>, const int n)
{
    double arr[2*n];
} //func
```

i.e., array size is determined by evaluating an expression at run-time

Automatic allocation on *The Stack*

Not in C88 ANSI standard

Part of C99 and C++

Implicit Array Size Determination

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

Array is created with as many elements as initial values

In this case, 12 elements

Values must be compile-time constants (for static arrays)

Values may be run-time expressions (for automatic arrays)

Getting Size of Implicit Array

sizeof operator – returns # of bytes of memory required by operand

Examples:–

sizeof (int) – # of bytes per **int**

sizeof (float) – # of bytes per **float**

sizeof days – # of bytes in array **days** (previous slide)

of elements in **days** = **(sizeof days) / sizeof(int)**

Must be able to be determined at compile time

Getting size of dynamically allocated arrays not supported

Getting Size of Implicit Array

sizeof operator – returns # of bytes of memory required by operand

Examples:–

sizeof (int) – # of bytes per **int**

sizeof (float) – #

sizeof days – # of bytes (from previous slide)
of elements in **days** = $18 / \text{sizeof}(\text{int})$

Must be able to be determined at compile time

Getting size of dynamically allocated arrays not supported

sizeof with parentheses
is size of the *type*

sizeof – no parentheses
means size of the
object

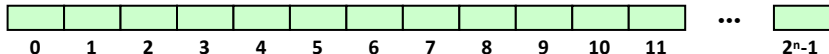
Initializing a Two-Dimensional Array

```
static char daytab[2][12] = {  
    {31,28,31,30,31,30,31,31,30,31,30,31},  
    {31,29,31,30,31,30,31,31,30,31,30,31}  
}; //daytab
```

OR

```
static char daytab[2][12] = {  
    31,28,31,30,31,30,31,31,30,31,30,31,  
    31,29,31,30,31,30,31,31,30,31,30,31  
}; //daytab
```

Digression – Memory Organization



All modern processors have memories organized as sequence of *numbered bytes*

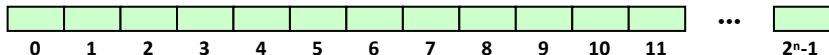
Many (but not all) are linear sequences

Definitions:—

Byte: an 8-bit memory cell capable of storing a value in range 0 ... 255

Address: number by which a memory cell is identified

Memory Organization (continued)



Larger data types are sequences of bytes – e.g.,

short int – 2 bytes

int – 2 or 4 bytes

long – 4 or 8 bytes

float – 4 bytes

double – 8 bytes

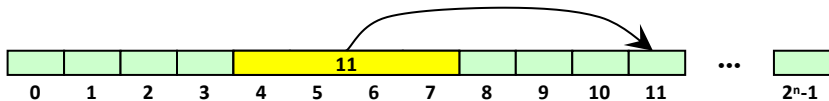
(Almost) always aligned to multiple of size in bytes

Address is “first” byte of sequence (i.e., byte zero)

May be low-order or high-order byte

Big endian or Little endian

Definition – *Pointer*



A *value* indicating the *number* of (the first byte of) a data object

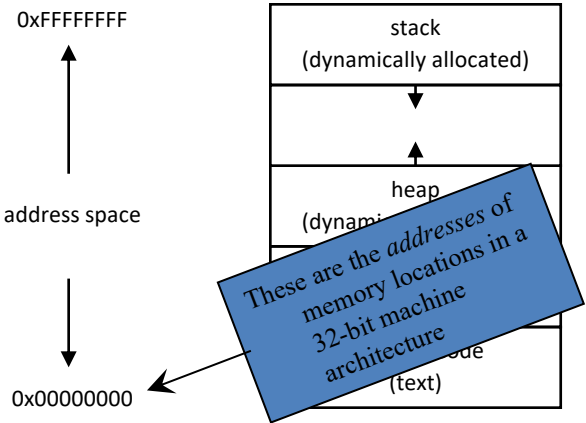
Also called an *Address* or a *Location*

Used in machine language to identify which data to access

E.g., *stack pointer* is address of most recent entry of *The Stack*

Usually 2, 4, or 8 bytes, depending upon machine architecture

Memory Addressing



Pointers in C

Used *everywhere*

- For building useful, interesting, data structures

- For returning data from functions

- For managing arrays

'&' unary operator generates a *pointer* to **x**

- E.g., `scanf("%d", &x);`

- E.g., `p = &c;`

- Operand of '&' must be an *l-value* — i.e., a legal object on left of assignment operator ('=')

Unary '*' operator *dereferences* a pointer

- i.e., gets value pointed to

- E.g. `*p` refers to value of **c** (above)

- E.g., `*p = x + y; *p = *q;`

Pointers in C

Used *everywhere*

For building useful, interesting, data structures

For returning data from functions

For managing arrays

'&' unary operator generates address of operand, i.e., pointer to **x**

E.g., `scanf ("%d", &x);`

E.g., `p = &c;`

Operand of '&' must be an *l-value* — i.e., a legal object on left of assignment operator ('=')

Unary '*' operator *dereferences* a pointer

i.e., gets value pointed to

E.g. `*p` refers to value of **c** (above)

E.g., `*p = x + y; *p = *q;`

Not the same as binary '&' operator (bitwise AND)

Declaring Pointers in C

`int *p;` — a pointer to an `int`
`double *q;` — a pointer to a `double`
`char **r;` — a pointer to a pointer to a `char`
`type *s;` — a pointer to an object of type `type`

Declaring Pointers in C (continued)

Pointer declarations:—read from *right* to *left*

```
const int *p;
```

- **p** is a pointer to an integer constant
- i.e., pointer can change, thing it points to cannot

```
int * const q;
```

- **q** is a constant pointer to an integer variable
- i.e., pointer cannot change, thing it points to can!

```
const int * const r;
```

- **r** is a constant pointer to an integer constant

Pointer Arithmetic

```
int *p, *q;
```

```
q = p + 1;
```

Construct a pointer to the next *integer* after ***p** and assign it to **q**

```
double *p, *r;
```

```
int n;
```

```
r = p + n;
```

Construct a pointer to a *double* that is **n doubles** beyond ***p**, and assign it to **r**

n may be negative

Pointer Arithmetic (continued)

```
long int *p, *q;
```

```
p++; q--;
```

Increment **p** to point to the next **long int**; decrement **q** to point to the previous **long int**

```
float *p, *q;
```

```
int n;
```

```
n = p - q;
```

n is the number of floats between ***p** and ***q**; i.e., what would be added to **q** to get **p**

Pointer Arithmetic (continued)

```
long int *p, *q;
```

```
p++; q--;
```

C never checks that the resulting pointer is valid

Increment **p** to point to the next **long int**; decrement **q** to point to the previous **long int**

```
float *p, *q;
```

```
int n;
```

```
n = p - q;
```

n is the number of floats between ***p** and ***q**; i.e., what would be added to **q** to get **p**

Why introduce pointers in the middle of a lesson ?

Arrays and pointers are *closely related* in C

In fact, they are essentially the same thing!

Esp. when used as parameters of functions

```
int A[10];
```

```
int *p;
```

- Type of **A** is **int ***
- **p = A;** and **A = p;** are legal assignments
- ***p** refers to **A[0]**
 ***(p + n)** refers to **A[n]**
- **p = &A[5];** is the same as **p = A + 5;**

Arrays and Pointers (continued)

double A[10]; vs. **double *A;**

Only difference:—

double A[10] sets aside *ten* units of memory, each large enough to hold a **double**, and **A** is initialized to point to the zeroth unit.

double *A sets aside *one* pointer-sized unit of memory, not initialized

- You are expected to come up with the memory elsewhere!

Note:— all pointer variables are the same size in any given machine architecture

- Regardless of what types they point to

Note

C does *not* assign arrays to each other

e.g,

```
double A[10];
```

```
double B[10];
```

```
A = B;
```

- assigns the pointer value **B** to the pointer value **A**
- Original contents of array **A** are untouched (and possibly unreachable!)

Arrays as Function Parameters

```
void init(float A[], int arraySize);  
void init(float *A, int arraySize);
```

- Are identical function prototypes!
- Pointer is passed by value
- i.e. caller copies the *value* of a pointer to `float` into the parameter `A`
- Called function can reference *through* that pointer to reach thing pointed to