CSE 130
Introduction to Programming in C

Arrays and Pointers

Spring 2018

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http://www3.cs.stonybrook.edu/~cse230/

Definition: Arrays

- A collection of elements of the *same type* stored contiguously in memory under one name
  - can be of any data type, e.g., integer, long integer, float, double, character etc.
  - even collection of arrays!
  - Arrays of structure, union, pointer etc. are also allowed

- Advantages:
  - For ease of access to any element of an array
  - Passing a group of elements to a function

Array Representation

- A sample one-dimensional integer array

Conceptual Picture

2	5	1	7	3	10
[0]	[1]	[2]	[3]	[4]	[5]

- A collection of integer type elements
- Each element is associated with a location index
- In C, array index starts from zero

Actual Picture

Memory Address	content
1000	2
1002	5
1004	1
1006	7
1008	3
1010	10

Arrays: Declaration & Initialization

- **Declaration:** `int A[6];`
  - An array of 6 integers
  - `A[0], A[1], A[2], …, A[6]`
- If array is declared within a function it contains garbage, if not initialized
- If array is globally declared it contains zeros
- **Initialization:**
  `int A[6] = {2,5,1,7,3,10};`
  - First index is 0, and Last index is array `size-1`
- Accessing array element at index `i`: `A[i]`

Arrays: Characteristics

- The storage class of arrays may be automatic, external, or static, but not register
- If external or static arrays are not initialized they are by default initialized to zero
- If an array is declared without a size and is initialized to a series of values, it implicitly given the size of the number of initializers.

  ```
  int A[] = {2,5,1,7,3,10};
  ```

  size of array `A` is 6 here

Arrays: Characteristics (cont.)

- Character arrays:

```
char c[] = {‘a’,‘b’,‘c’,‘\0’};
```

Null character, represents end of string

- Alternatively:

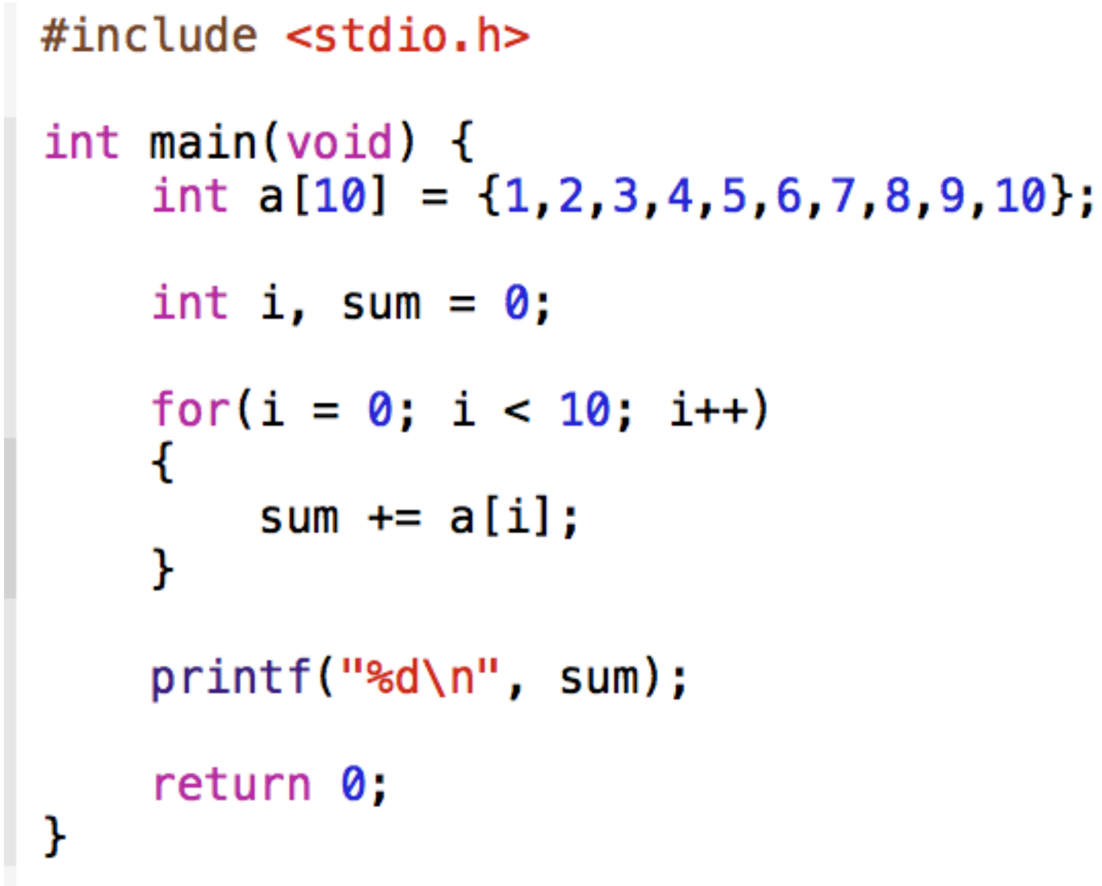
```
char c[] = “abc”;
```

- These two representations are equivalent

- **string** is a sequence of **characters** that is treated as a single data item and terminated by null **character** '\0' . **C** does not support **strings** as a data type. A **string** is actually one-dimensional **array** of **characters in C.**

Array Usage: Example

- Sum all the elements of an array



```c
#include <stdio.h>

int main(void) {
    int a[10] = {1,2,3,4,5,6,7,8,9,10};

    int i, sum = 0;

    for(i = 0; i < 10; i++)
    {
        sum += a[i];
    }

    printf("%d\n", sum);

    return 0;
}
```

Errors in array usage

1. If `i` has a value outside the range `[0,size-1],` no compiler error. Run-time error will occur when `A[i]` is accessed.

– Overrunning the bounds of an array is a common programming error

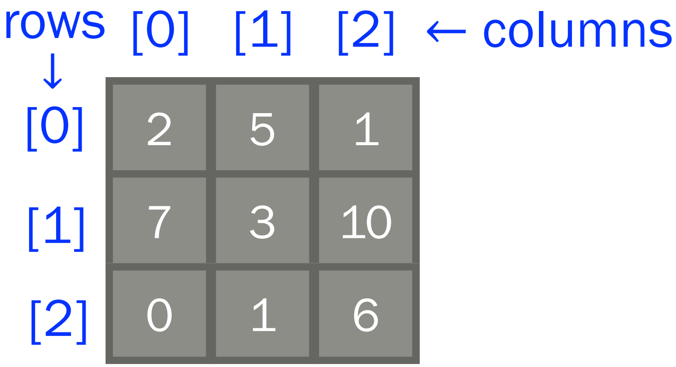
– The effect of the error is system-dependent

– Often the value of some unrelated variable will be returned

2. If local array is used before initialization garbage value will be processed

2-dimensional array

- A 2D 3-by-3 integer array
  - 2D square array
  - not always necessary to have equal number of columns and rows

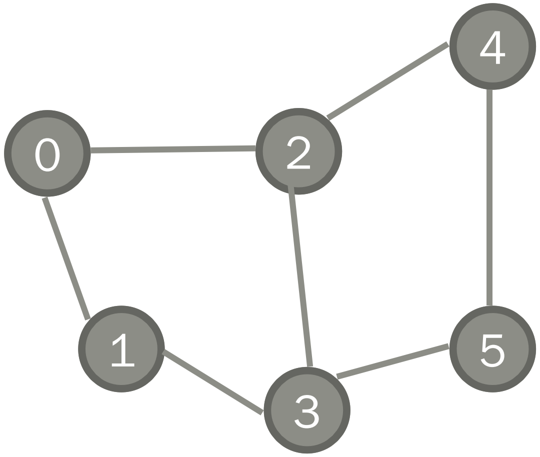


rows ↓	[0]	[1]	[2] ← columns
[0]	2	5	1
[1]	7	3	10
[2]	0	1	6

- Declaration: `int A[3][3];`
- Initialization: `int A[3][3] = {{2,5,1},{7,3,10},{0,1,6}};`
- Applications:
  - Matrix representation, e.g, graph adjacency matrix

2D Array for Graph Adjacency Matrix

-
  ```
  int A[6][6] =
  {{0,1,1,0,0,0},
  {1,0,0,1,0,0},
  {1,0,0,1,1,0},
  {0,1,1,0,0,1},
  {0,0,1,0,0,1},
  {0,0,0,1,1,0}};
  ```



Undirected unweighted plain graph

2D Arrays in Memory

- In the computer **memory**, all elements are stored linearly using contiguous addresses.
- In order to store a **two-dimensional** matrix , **two dimensional** address space must be mapped to one-dimensional address space.
- In the computer's **memory** matrices are stored in either Row-major order or Column-major order form.

2D Arrays in Memory (cont.)

Conceptual Picture

	[0]	[1]	[2]
[0]	2	5	1
[1]	7	3	10
[2]	0	1	6

Actual Picture

Address	Content	Index
1000	2	(0, 0)
1002	5	(0, 1)
1004	1	(0, 2)
1006	7	(1, 0)
1008	3	(1, 1)
1010	10	(1, 2)
1012	0	(2, 0)
1014	1	(2, 1)
1016	6	(2, 2)

Row Major Order

Example is given for row major order only

2D Array Usage: Example

- Matrix multiplication code for matrix a and b

```
int i, j, k;
for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        double sum = 0;
        for (k = 0; k < n; k++) {
            sum += a[i][k] * b[k][j];
        }
        c[i][j] = sum;
    }
}
```

Pointers

Introduction

- A variable in a program is stored in a certain number of bytes at a particular memory location or address.
- Pointers are used to access memory and manipulate address.
- If *v* is a variable, then *&v* gives its memory address
  - Address operator & is an unary operator

Pointers: Declaration

- Example Declaration: `int *p;`
  - `p` is a pointer to integer
  - The indirection or dereferencing operator * is unary
- Its range of values include a special address 0 and a set of positive integers that represent machine addresses.
- Example assignment to pointer `p`

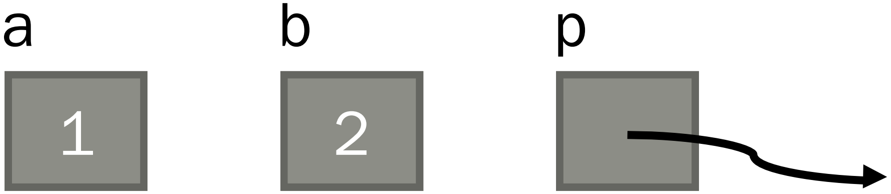
```
p = 0;
p = Null; // same as p = 0
p = &i; // pointing to i
p = (int *)1776; /* absolute address
*/
```

Pointers: Characteristics

- If `p` is a pointer then `*p` is the value of the variable of which `p` is the address.
- Direct value of p is an address of a memory location, and `*p` is indirect value of `p`, which is the value stored in that memory location.
- In a certain sense `*` is the inverse operator of `&`

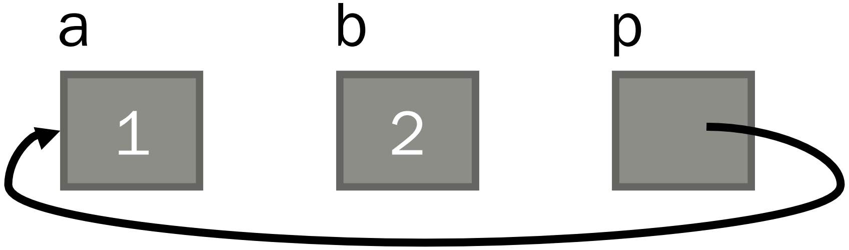
Pointers: Example

- `int a = 1, b = 2, *p;`



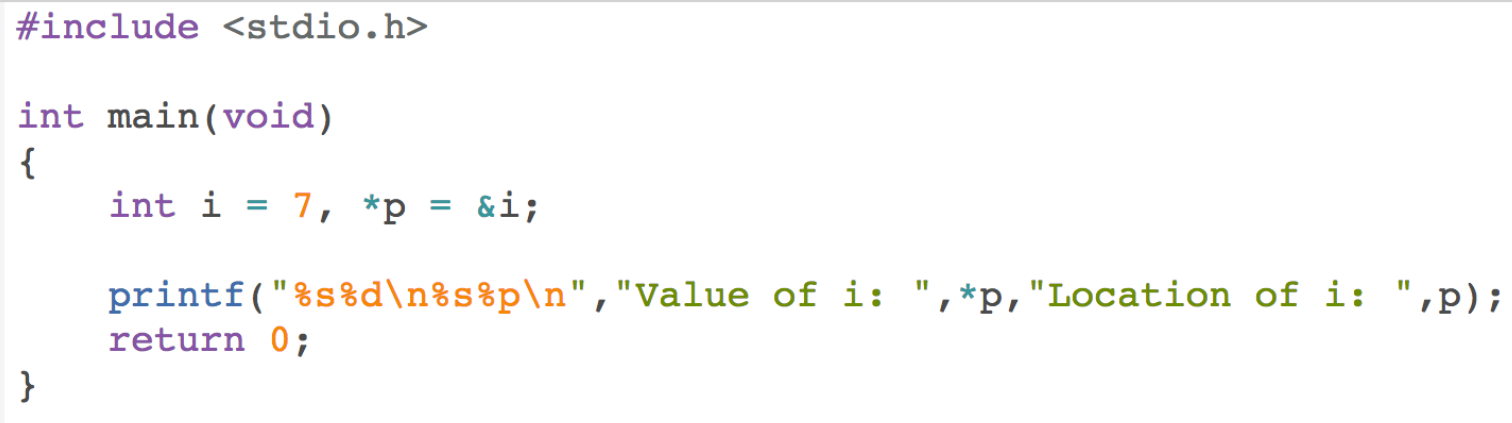
- Think of the pointer as an arrow, but it is not yet assigned a value. So, we do not know what it points to

- Next line: `p = &a`



- `b = *p;      b = ?`

Pointers: Example Code



```c
#include <stdio.h>

int main(void)
{
    int i = 7, *p = &i;

    printf("%s%d\n%s%p\n","Value of i: ",*p,"Location of i: ",p);
    return 0;
}
```

```
Value of i: 7
Location of i: effffb24
```

- A pointer can be initialized in a declaration.
    - The variable `p` is of type `int` and its initial value is `&i`.
    - The declaration of `i` must occur before we take its address.

Pointers: Declaration and Initialization

Declaration and Initialization		

int i=3,j=5,*p=&i,*q=&j,*r;
double x;		

Expression	Equivalent Expression	Value
p == &i	p == (&i)	1
**&p	*(*(&p))	3
r = &x	r = (&x)	illegal
7* *p/ *q+7	((7*(*p))/(*q))+7	11
*(r=&j) *= *p	(*(r = (&j))) *= (*p)	15

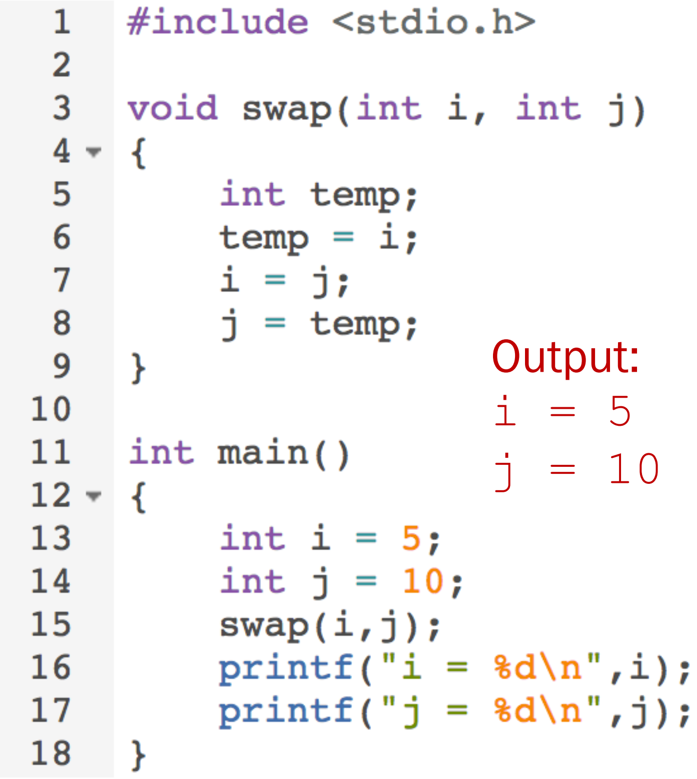
Constructs not to be pointed at

- Do not point at constants.
  - `&3 /* illegal */`
- Do not point at ordinary expressions.
  - `&(k + 99) /* illegal */`
- Do not point at register variables.
  - `register v;`
  - `&v /* illegal */`
- Address operator can be applied to variables and array elements.
  - If a is an array, expressions such as `&a[0]` and `&a[i+j+3]` make sense.

Call-by-reference

- "call-by-reference" is a way of passing addresses (references) of variables to a function that then allows the body of the function to make changes to the values of variables in the calling environment.

Call by value

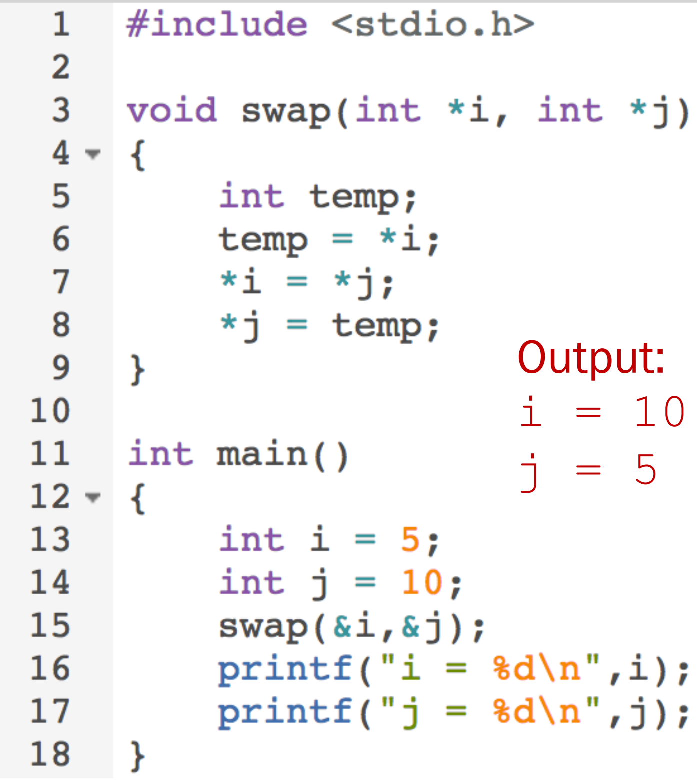


```c
#include <stdio.h>

void swap(int i, int j)
{
    int temp;
    temp = i;
    i = j;
    j = temp;
}

int main()
{
    int i = 5;
    int j = 10;
    swap(i,j);
    printf("i = %d\n",i);
    printf("j = %d\n",j);
}
```

Output:

```
i = 5
j = 10
```

Call by reference



```c
#include <stdio.h>

void swap(int *i, int *j)
{
    int temp;
    temp = *i;
    *i = *j;
    *j = temp;
}

int main()
{
    int i = 5;
    int j = 10;
    swap(&i,&j);
    printf("i = %d\n",i);
    printf("j = %d\n",j);
}
```

Output:

```
i = 10
j = 5
```

Relationship between Arrays and Pointers

- A pointer variable can take different addresses as values. In contrast, an array name is an address , or pointer, that is fixed. So following are illegal:

```
  a = p    ++a     a += 2
```

- Suppose `a` is an array and `i` is an `int`,

- `a[i]` is equivalent to `*(a+i)`

- Equivalent expressions:

```
#define N 100
int a[N], i, *p, sum = 0;
p = a     equivalent to p = &a[0]
p = a + 1 equivalent to p = &a[1]
```

Relationship between Arrays and Pointers

- Following 3 `for` loops are equivalent:

```
for(p = a; p < &a[N]; ++p)
    sum += *p;

for(i = 0; i < N; ++i)
    sum += *(a+i);

p=a;
for(i = 0; i < N; ++i)
    sum += p[i];
```