MASTER OF COMPUTER APPLICATIONS

SEMESTER 1

PROGRAMMING & PROBLEM-SOLVING USING C

Unit 8

Pointers

Table of Contents

1. INTRODUCTION

In the previous unit, you studied about the arrays and strings. You studied how the arrays and strings are declared and manipulated in making C a more easy and powerful programming language. In this unit, you will study about pointer which is another useful topic that makes C a most powerful programming language. You will study about the basics of pointer and pointer arithmetic.

A pointer is a variable that points at, or refers to, another variable. That is, if we have a pointer variable of type "pointer to int, "it might point to the int variable i, or to any one of the locations of the int array a. Given a pointer variable, we can ask questions like, "what's the value of the variable that this pointer points to?".

Why would we want to have a variable that refers to another variable? Why not just use that other variable directly? Pointers are used frequently in C, as they have number of useful applications. For example, pointers can be used to pass information back and forth between a function and its reference point. In particular, pointers provide a way to return multiple data items from a function via function arguments. Pointers also permit references to other functions to be specified as arguments to a given function. This has the effect of passing functions as arguments to the given function.

Pointers are also closely associated with the arrays and therefore provide an alternate way to access individual array elements. Pointers make the program efficient when we use pointers for accessing the individual array elements. In this unit, you will study about the basics of pointers and its usage in one dimensional array. In this unit, you will read about null pointers and how pointers can be used to manipulate a string along with the usage of pointers in two dimensional arrays. You will also read about arrays of pointers briefly.

1.1 Objectives

After studying this unit, you should be able to:

- *implement pointers in your program*
- *write a program related to arrays and using a pointer with it*
- *solve and illustrate the use of pointer arithmetics in C*
- *point out the similarities between pointers and one dimensional arrays*

2. BASICS OF POINTERS

A pointer is a variable which contains the address in memory of another variable. We can have a pointer to any variable type. Before studying pointers, you should mind certain symbols that are frequently used in implementing the pointers. We use the symbol **&** that gives the "address of a variable" and is known as the **unary** or **monadic** operator. We use other symbol * that gives the "contents of an object ***pointed to*** by a pointer" and we call it the **indirection** or **dereference** operator.

The first things to do with pointers are to declare a pointer variable, set it to point somewhere, and finally manipulate the value that it points to. A simple pointer declaration has the following general format:

*datatype *variablename*

where *datatype* represents the type of the data to which the pointer *variablename* points to. In simple terms, the *variablename* holds the address of the value of type *datatype*.

For example,

```
int *ip;
```

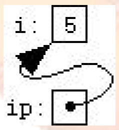
This declaration looks like our earlier declarations, with one obvious difference: that is the asterisk. The asterisk means that ip, the variable we're declaring, is not of type int, but rather of type pointer-to-int. (Another way of looking at it is that *ip, which as we'll see is the value pointed to by ip, will be an int.)

We may think of setting a pointer variable to point to another variable as a two-step process: first we generate a pointer to that other variable, and then we assign this new pointer to the pointer variable. We can say (but we have to be careful when we're saying it) that a pointer variable has a value, and that its value is "pointer to that other variable". This will make more sense when we see how to generate pointer values.

Pointers (that is, pointer values) are generated with the "address-of" operator &, which we can also think of as the "pointer-to" operator. We demonstrate this by declaring (and initializing) an int variable i, and then setting ip to point to it:

```
int i = 5;
ip = &i;
```

The assignment expression ip = &i; contains both parts of the "two-step process": &i generates a pointer to i, and the assignment operator assigns the new pointer to (that is, places it "in") the variable ip. Now ip "points to" i, which we can illustrate with this picture:



i is a variable of type int, so the value in its box is a number, 5. ip is a variable of type pointer-to-int, so the "value" in its box is an arrow pointing at another box. Referring once again back to the "two-step process" for setting a pointer variable: the & operator draws us the arrowhead pointing at i's box, and the assignment operator =, with the pointer variable ip on its left, anchors the other end of the arrow in ip's box.

We discover the value pointed to by a pointer using the "contents-of" operator, *. Placed in front of a pointer, the * operator accesses the value pointed to by that pointer. In other words, if ip is a pointer, then the expression *ip gives us whatever it is that's in the variable or location pointed to by ip. For example, we could write something like

```
printf("%d\n", *ip);
```

which would print 5, since ip points to i, and i is (at the moment) 5.

(You may wonder how the asterisk * can be the pointer contents-of operator when it is also the multiplication operator. There is no ambiguity here: it is the multiplication operator when it sits between two variables, and it is the contents-of operator when it sits in front of a single variable. The situation is analogous to the minus sign: between two variables or expressions it's the subtraction operator, but in front of a single operator or expression it's the negation operator. Technical terms you may hear for these distinct roles are *unary* and *binary*: a binary operator applies to two operands, usually on either side of it, while a *unary* operator applies to a single operand.)

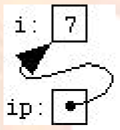
The contents-of operator * does not merely fetch values through pointers; it can also set values through pointers. We can write something like

```
*ip = 7;
```

which means "set whatever ip points to 7." Again, the * tells us to go to the location pointed to by ip, but this time, the location isn't the one to fetch from

-- we're on the left-hand sign of an assignment operator, so *ip tells us the location to store to. (The situation is no different from array subscripting expressions such as a[3] which we've already seen appearing on both sides of assignments.)

The result of the assignment *ip = 7 is that i's value is changed to 7, and the picture changes to:



If we called printf("%d\n", *ip) again, it would now print 7.

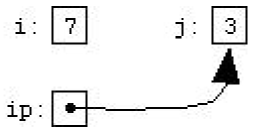
At this point, you may be wonder, if we wanted to set i to 7, why didn't we do it directly? We'll begin to explore that next, but first let's notice the difference between changing a pointer (that is, changing what variable it points to) and changing the value at the location it points to. When we wrote *ip = 7, we changed the value pointed to by ip, but if we declare another variable j:

```
int j = 3;
```

and write

```
ip = &j;
```

we've changed ip itself. The picture now looks like this:



We have to be careful when we say that a pointer assignment changes "what the pointer points to." Our earlier assignment

```
*ip = 7;
```

changed the value pointed to by ip, but this more recent assignment

```
ip = &j;
```

has changed what variable ip points to. It's true that "what ip points to" has changed, but this time, it has changed for a different reason. Neither i (which is still 7) nor j (which is still 3) has changed. (What has changed is ip's value.) If we again call

```
printf("%d\n", *ip);
```

this time it will print 3.

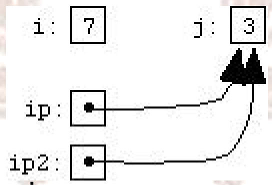
We can also assign pointer values to other pointer variables. If we declare a second pointer variable:

```
int *ip2;
```

then we can say

```
ip2 = ip;
```

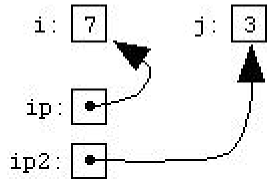
Now ip2 points where ip does; we've essentially made a "copy" of the arrow:



Now, if we set ip to point back to i again:

```
ip = &i;
```

the two arrows point to different places:



We can now see that the two assignments

```
ip2 = ip;
```

and

```
*ip2 = *ip;
```

do two very different things. The first would make ip2 again point to where ip points (in other words, back to i again). The second would store, at the location pointed to by ip2, a copy of the value pointed to by ip; in other words (if ip and ip2 still point to i and j respectively) it would set j to i's value, or 7.

It's important to keep very clear in your mind the distinction between a *pointer* and *what* it points to. You can't mix them. You can't “set ip to 5” by writing something like

```
ip = 5;                    /* WRONG */
```

5 is an integer, but ip is a pointer. You probably wanted to “set *the value pointed to by* ip to 5,” which you express by writing

```
*ip = 5;
```

Similarly, you can't “see what ip is” by writing

```
printf("%d\n", ip);          /* WRONG */
```

Again, ip is a pointer-to-int, but %d expects an int. To print *what* ip *points to*, use

```
printf("%d\n", *ip);
```

Finally, a few more notes about pointer declarations. The * in a pointer declaration is related to, but different from, the contents-of operator *. After we declare a pointer variable

```
int *ip;
```

the expression

```
ip = &i
```

sets what ip points to (that is, which location it points to), while the expression

```
        *ip = 5
```

sets the value of the location pointed to by ip. On the other hand, if we declare a pointer variable and include an initializer:

```
        int *ip3 = &i;
```

we're setting the initial value for ip3, which is where ip3 will point, so that initial value is a pointer. (In other words, the * in the declaration int *ip3 = &i; is not the contents-of operator, it's the indicator that ip3 is a pointer.)

If you have a pointer declaration containing an initialization, and you ever have occasion to break it up into a simple declaration and a conventional assignment, do it like this:

```
int *ip3;
ip3 = &i;
```

Don't write

```
int *ip3;
*ip3 = &i;
```

or you'll be trying to mix pointer and the value to which it points

Also, when we write

```
    int *ip;
```

although the asterisk affects ip's type, it goes with the identifier name ip, not with the type int on the left. To declare two pointers at once, the declaration looks like

```
int *ip1, *ip2;
```

Some people write pointer declarations like this:

```
    int* ip;
```

This works for one pointer, because C essentially ignores whitespace. But if you ever write

```
    int* ip1, ip2;    /* PROBABLY WRONG */
```

it will declare one pointer-to-int ip1 and one plain int ip2, which is probably not what you meant.

What is all of this good for? If it was just for changing variables like i from 5 to 7, it would not be good for much. What it's good for, among other things, is when for various reasons we don't know exactly which variable we want to change.

Program 8.1: A simple program to illustrate the relationship between two integer variables, their corresponding addresses and their associated pointers.

```
#include<stdio.h>
main()
{
        int x=5;
        int y;
        int *px;            /* pointer to an integer */
        int *py;            /* pointer to an integer */
        px=&x;             /* assign address of x to px */
        y=*px;             /* assign value of x to y */
        py=&y;             /* assign address of y to py */
        printf("\nx=%d     &x=%u px=%u *px=%d", x, &x, px, *px);
        printf("\ny=%d     &y=%u py=%u *py=%d", y, &y, py, *py);
}
```

Execute this program and observe the result.

SELF-ASSESSMENT QUESTIONS – 1

1. Dereference operator is also known as ________________.
2. Pointer is a variable containing address of another variable. (True/False)
3. State whether the following statements are correct: (Correct/Incorrect) int a, b; b=&a;
4. The contents-of operator * does not merely fetch values through pointers; it can also set values through pointers. (True/False)

2.1 Null Pointers

We said that the value of a pointer variable is a pointer to some other variable. There is one other value a pointer may have: it may be set to a null pointer. A null pointer is a special pointer value that is known not to point anywhere. What this means that no other valid pointer, to any other variable or array cell or anything else, will ever compare equal to a null pointer.

The most straightforward way to "get'' a null pointer in your program is by using the predefined constant NULL, which is defined for you by several standard header files, including <stdio.h>, <stdlib.h>, and <string.h>. To initialize a pointer to a null pointer, you might use code like

```
#include <stdio.h>
int *ip = NULL;
```

and to test it for a null pointer before inspecting the value pointed to, you might use code like

```
if(ip != NULL)
printf("%d\n", *ip);
```

It is also possible to refer to the null pointer by using a constant 0, and you will see some code that sets null pointers by simply doing

```
int *ip = 0;
```

(In fact, NULL is a preprocessor macro which typically has the value, or replacement text, 0.)

Furthermore, since the definition of “true'' in C is a value that is not equal to 0, you will see code that tests for non-null pointers with abbreviated code like

```
if(ip)
printf("%d\n", *ip);
```

This has the same meaning as our previous example; if(ip) is equivalent to if(ip != 0) and to if(ip != NULL).

All of these uses are legal, and although the use of the constant NULL is recommended for clarity, you will come across the other forms, so you should be able to recognize them.

You can use a null pointer as a placeholder to remind yourself (or, more importantly, to help your program remember) that a pointer variable does not point anywhere at the moment and that you should not use the “contents of'' operator on it (that is, you should not try to inspect what it points to, since it doesn't point to anything). A function that returns pointer values can return a null pointer when it is unable to perform its task. (A null pointer used in this way is analogous to the EOF value that functions like getchar return.)

As an example, let us write our own version of the standard library function strstr, which looks for one string within another, returning a pointer to the string if it can, or a null pointer if it cannot.

Example 8.1: Here is the function, using the obvious brute-force algorithm: at every character of the input string, the code checks for a match there of the pattern string:

```
#include <stddef.h>
char *mystrstr(char input[], char pat[])
{
char *start, *p1, *p2;
for(start = &input[0]; *start != '\0'; start++)
{ /* for each position in input string... */
p1 = pat; /* prepare to check for pattern string there */
p2 = start;
while(*p1 != '\0')
{
```

```
if(*p1 != *p2) /* characters differ */
break;
p1++;
p2++;
}
if(*p1 == '\0') /* found match */
return start;
}
return NULL;
}
```

The start pointer steps over each character position in the input string. At each character, the inner loop checks for a match there, by using p1 to step over the pattern string (pat), and p2 to step over the input string (starting at start). We compare successive characters until either (a) we reach the end of the pattern string (*p1 == '\0'), or (b) we find two characters which differ. When we're done with the inner loop, if we reached the end of the pattern string (*p1 == '\0'), it means that all preceding characters matched, and we found a complete match for the pattern starting at start, so we return start. Otherwise, we go around the outer loop again, to try another starting position. If we run out of those (if *start == '\0'), without finding a match, we return a null pointer.

Notice that the function is declared as returning (and does in fact return) a pointer-to-char.

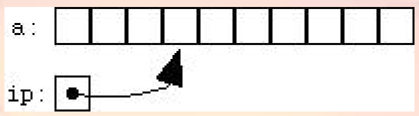
In general, C does not initialize pointers to null for you, and it never tests pointers to see if they are null before using them. If one of the pointers in your programs points somewhere some of the time but not all of the time, an excellent convention to use is to set it to a null pointer when it doesn't point anywhere valid, and to test to see if it's a null pointer before using it. But you must use explicit code to set it to NULL, and to test it against NULL. (In other words, just setting an unused pointer variable to NULL doesn't guarantee safety; you also have to check for the null value before using the pointer.) On the other hand, if you know that a particular pointer variable is always valid, you don't have to insert a paranoid test against NULL before using it.

3. POINTERS AND ONE-DIMENSIONAL ARRAYS

Pointers do not have to point to single variables. They can also point at the cells of an array. For example, we can write

```
int *ip;
int a[10];
ip = &a[3];
```

and we would end up with ip pointing at the fourth cell of the array a (remember, arrays are 0-based, so a[0] is the first location). We could illustrate the situation like this:



We'd use this ip just like the one in the previous section: *ip gives us what ip points to, which in this case will be the value in a[3].

3.1 Pointer Arithmetic

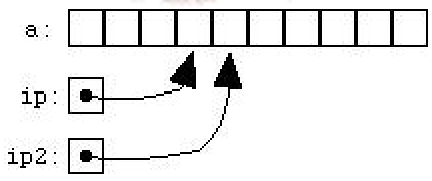
Once we have a pointer pointing into an array, we can start doing *pointer arithmetic.* Given that ip is a pointer to a[3], we can add 1 to ip:

```
ip + 1
```

What does it mean to add one to a pointer? In C, it gives a pointer to the cell one farther on, which in this case is a[4]. To make this clear, let's assign this new pointer to another pointer variable:

```
ip2 = ip + 1;
```

Now the picture looks like this:



If we now do

```
*ip2 = 4;
```

we've set a[4] to 4. But it's not necessary to assign a new pointer value to a pointer variable in order to use it; we could also compute a new pointer value and use it immediately:

```
        *(ip + 1) = 5;
```

In this last example, we've changed a[4] again, setting it to 5. The parentheses are needed because the unary "contents of'' operator * has higher *precedence* (i.e., binds more tightly than) the addition operator. If we wrote *ip + 1, without the parentheses, we'd be fetching the value pointed to by ip, and adding 1 to that value. The expression *(ip + 1), on the other hand, accesses the value one past the one pointed to by ip.

Given that we can add 1 to a pointer, it's not surprising that we can add and subtract other numbers as well. If ip still points to a[3], then

```
*(ip + 3) = 7;
```

sets a[6] to 7, and

```
*(ip - 2) = 4;
```

sets a[1] to 4.

Up above, we added 1 to ip and assigned the new pointer to ip2, but there's no reason we can't add one to a pointer, and change the same pointer:

```
    ip = ip + 1;
```

Now ip points one past where it used to (to a[4], if we hadn't changed it in the meantime). The shortcuts work for pointers, too: we could also increment a pointer using

```
ip += 1;
```

or

```
ip++;
```

Of course, pointers are not limited to ints. It's quite common to use pointers to other types, especially char.

Example 8.1: Here is a program segment to compare two strings, character by character using pointers.

```
char *p1 = &str1[0], *p2 = &str2[0];
while(1)
        {
        if(*p1 != *p2)
                return *p1 - *p2;
        if(*p1 == '\0' || *p2 == '\0')
                return 0;
        p1++;
        p2++;

        }
```

The auto increment operator ++ (like its companion, --) makes it easy to do two things at once. We've seen idioms like a[i++] which accesses a[i] and simultaneously increments i, leaving it referencing the next cell of the array a. We can do the same thing with pointers: an expression like *ip++ lets us access what ip points to, while simultaneously incrementing ip so that it points to the next element. The preincrement form works, too: *++ip increments ip, then accesses what it points to. Similarly, we can use notations like *ip-- and *--ip.

Example 8.2: Here is a program segment to copy a string to another using pointer:

```
char *dp = &dest[0], *sp = &src[0];
while(*sp != '\0')
        *dp++ = *sp++;

*dp = '\0';
```

(One question that comes up is whether the expression *p++ increments p or what it points to. The answer is that it increments p. To increment what p points to, you can use (*p)++.)

When you're doing pointer arithmetic, you have to remember how big the array the pointer points into is, so that you don't ever point outside it. If the array a has 10 elements, you can't access a[50] or a[-1] or even a[10] (remember, the valid subscripts for a 10-element array run from 0 to 9). Similarly, if a has 10 elements and ip points to a[3], you can't compute or access ip + 10 or ip - 5. (There is one special case: you can, in this case, compute, but not access, a pointer to the nonexistent element just beyond the end of the array, which in this case is &a[10]. This becomes useful when you're doing pointer comparisons, which we'll look at next.)

Program 8.2: Program to illustrate the relationship between an array and pointer.

```
#include<stdio.h>
main()
{
        int a[10];
        int i;
        for(i=0;i<10;i++)
                scanf("%d",&a[i]);
        for(i=0;i<10;i++)
printf("\ni=%d  a[i]=%d *(a+i)=%d &a[i]=%u a+i=%u", i, a[i], *(a+i), &a[i], a+i);

}
```

Execute this program and observe the result.

3.2 Pointer Subtraction and Comparison

As we've seen, you can add an integer to a pointer to get a new pointer, pointing somewhere beyond the original (as long as it is in the same array). For example, you might write
ip2 = ip1 + 3;

Applying a little algebra, you might wonder whether

    ip2 - ip1 = 3

and the answer is, yes. When you subtract two pointers, as long as they point into the same array, the result is the number of elements separating them. You can also ask (again, as long as they point into the same array) whether one pointer is greater or less than another: one pointer is "greater than" another if it points beyond where the other one points. You can also compare pointers for equality and inequality: two pointers are equal if they point to the same variable or to the same cell in an array, and are (obviously) unequal if they don't. (When testing for equality or inequality, the two pointers do not have to point into the same array.)

One common use of pointer comparisons is when copying arrays using pointers.

Example 8.3: Here is a code fragment which copies 10 elements from array1 to array2, using pointers. It uses an end pointer, endptr, to keep track of when it should stop copying.

```
int array1[10], array2[10];
int *ip1, *ip2 = &array2[0];
int *endptr = &array1[10];
for(ip1 = &array1[0]; ip1 < endptr; ip1++)
        *ip2++ = *ip1;
```

As we mentioned, there is no element array1[10], but it is legal to compute a pointer to this (nonexistent) element, as long as we only use it in pointer comparisons like this (that is, as long as we never try to fetch or store the value that it points to.)

Prorgam 8.3: In the following program, two different pointer variables point to the first and the last element of an integer array.

```
#include<stdio.h>
main()
{
        int *px, *py;
        int a[5]={1, 2, 3, 4, 5};
        px=&a[0];
        py=&a[4];
        printf("px=%u  py=%u", px, py);
        printf("\n\n py-px=%u", py-px);

}
```

Execute this program and observe the result.

3.3 Similarities between Pointers and One-dimensional Arrays

There are a number of similarities between arrays and pointers in C. If you have an array

```
int a[10];
```

you can refer to a[0], a[1], a[2], etc., or to a[i] where i is an int. If you declare a pointer variable ip and set it to point to the beginning of an array:

```
int *ip = &a[0];
```

you can refer to *ip, *(ip+1), *(ip+2), etc., or to *(ip+i) where i is an int.

There are also differences, of course. You cannot assign two arrays; the code

```
int a[10], b[10];

a = b;                          /* WRONG */
```

is illegal. As we've seen, though, you can assign two pointer variables:

```
int *ip1, *ip2;
ip1 = &a[0];
ip2 = ip1;
```

Pointer assignment is straightforward; the pointer on the left is simply made to point wherever the pointer on the right does. We haven't copied the data pointed to (there's still just one copy, in the same place); we've just made two pointers point to that one place.

The similarities between arrays and pointers end up being quite useful, and in fact C builds on the similarities, leading to what is called "the equivalence of arrays and pointers in C.'' When we speak of this "equivalence'' we do not mean that arrays and pointers are the same thing (they are in fact quite different), but rather that they can be used in related ways, and that certain operations may be used between them.

The first such operation is that it is possible to (apparently) assign an array to a pointer:

```
        int a[10];
        int *ip;
        ip = a;
```

What can this mean? In that last assignment ip = a, C defines the result of this assignment to be that ip receives a pointer to the first element of a. In other words, it is as if you had written

```
        ip = &a[0];
```

The second facet of the equivalence is that you can use the "array subscripting'' notation [i] on pointers, too. If you write ip[3]

it is just as if you had written

*(ip + 3)

So when you have a pointer that points to a block of memory, such as an array or a part of an array, you can treat that pointer “as if'' it *were* an array, using the convenient [i] notation. In other words, at the beginning of this section when we talked about *ip, *(ip+1), *(ip+2), and *(ip+i), we could have written ip[0], ip[1], ip[2], and ip[i]. As we'll see, this can be quite useful (or at least convenient).

The third facet of the equivalence (which is actually a more general version of the first one we mentioned) is that *whenever* you mention the name of an array in a context where the “value'' of the array would be needed, C automatically generates a pointer to the first element of the array, as if you had written &array[0]. When you write something like

```
int a[10];
int *ip;
ip = a + 3;
```

it is as if you had written

```
ip = &a[0] + 3;
```

which (and you might like to convince yourself of this) gives the same result as if you had written

```
ip = &a[3];
```

For example, if the character array

```
char string[100];
```

contains some string, here is another way to find its length:

```
        int len;
        char *p;
        for(p = string; *p != '\0'; p++)
        ;
        len = p - string;
```

After the loop, p points to the '\0' terminating the string. The expression p - string is equivalent to p - &string[0], and gives the length of the string. (Of course, we could also call strlen; in fact here we've essentially written another implementation of strlen.)

SELF-ASSESSMENT QUESTIONS – 2

5. You can perform any type of arithmetic operation on pointers. (True or False)
6. For an int array a[10], If you declare a pointer variable ip then you can set it to point to the beginning of an array by assigning: int *ip =__________________ .
7. One common use of pointer comparisons is when copying arrays using pointers. (True/False)
8. To increment what p points to, you can use the expression __________________.

4. POINTERS AND STRINGS

Because of the similarity of arrays and pointers, it is extremely common to refer to and manipulate strings as character pointers, or char *'s. It is so common, in fact, that it is easy to forget that strings are arrays, and to imagine that they're represented by pointers. (Actually, in the case of strings, it may not even matter that much if the distinction gets a little blurred; there's certainly nothing wrong with referring to a character pointer, suitably initialized, as a ''string.'') Let's look at a few of the implications:

Any function that manipulates a string will actually accept it as a char * argument. The caller may pass an array containing a string, but the function will receive a pointer to the array's (string's) first element (character).

The %s format in printf expects a character pointer.

Although you have to use strcpy to copy a string from one array to another, you can use simple pointer assignment to assign a string to a pointer. The string being assigned might either be in an array or pointed to by another pointer. In other words, given

```
char string[] = "Hello, world!";
char *p1, *p2;
```

both

```
p1 = string
```

and

```
p2 = p1
```

are legal. (Remember, though, that when you assign a pointer, you're making a copy of the pointer but *not* of the data it points to. In the first example, p1 ends up pointing to the string in string. In the second example, p2 ends up pointing to the same string as p1. In any case, after a pointer assignment, if you ever change the string (or other data) pointed to, the change is “visible'' to both pointers.

Many programs manipulate strings exclusively using character pointers, never explicitly declaring any actual arrays. As long as these programs are careful to allocate appropriate memory for the strings, they're perfectly valid and correct.

When you start working heavily with strings, however, you have to be aware of one subtle fact.

When you initialize a character array with a string constant:

```
char string[] = "Hello, world!";
```

you end up with an array containing the string, and you can modify the array's contents to your heart's content:

```
string[0] = 'J';
```

However, it's possible to use string constants (the formal term is *string literals*) at other places in your code. Since they're arrays, the compiler generates pointers to their first elements when they're used in expressions, as usual.

That is, if you say

```
char *p1 = "Hello";
int len = strlen("world");
```

it's almost as if you'd said

```
char internal_string_1[] = "Hello";
char internal_string_2[] = "world";
char *p1 = &internal_string_1[0];
int len = strlen(&internal_string_2[0]);
```

Here, the arrays named internal_string_1 and internal_string_2 are supposed to suggest the fact that the compiler is actually generating little temporary arrays every time you use a string constant in your code. *However*, the subtle fact is that the arrays which are “behind'' the string constants are not necessarily modifiable. In particular, the compiler may store them in read-only-memory. Therefore, if you write

```
char *p3 = "Hello, world!";
p3[0] = 'J';
```

your program may crash, because it may try to store a value (in this case, the character 'J') into nonwritable memory.

The moral is that whenever you're building or modifying strings, you have to make sure that the memory you're building or modifying them in is writable. That memory should either be an array you've allocated, or some memory which you've dynamically allocated. Make sure that no part of your program will ever try to modify a string which is actually one of the unnamed, unwritable arrays which the compiler generated for you in response to one of your string constants. (The only exception is array initialization, because if you write to such an array, you're writing to the array, not to the string literal which you used to initialize the array.)

Example 8.3: Breaking a Line into "Words''
First, break lines into a series of whitespace-separated words. To do this, we will use an *array of pointers to char,* which we can also think of as an "array of strings,'' since a string is an array of char, and a pointer-to-char can easily point at a string. Here is the declaration of such an array:

```
char *words[10];
```

This is the first complicated C declaration we've seen: it says that words is an array of 10 pointers to char. We're going to write a function, getwords, which we can call like this:

```
int nwords;
nwords = getwords(line, words, 10);
```

where line is the line we're breaking into words, words is the array to be filled in with the (pointers to the) words, and nwords (the return value from getwords) is the number of words which the function finds. (As with getline, we tell the function the size of the array so that if the line should happen to contain more words than that, it won't overflow the array).

Here is the definition of the getwords function. It finds the beginning of each word, places a pointer to it in the array, finds the end of that word (which is signified by at least one whitespace character) and terminates the word by placing a '\0' character after it. (The '\0' character will overwrite the first whitespace character following the word.) Note that the original input string is therefore modified by getwords: if you were to try to print the input line after calling getwords, it would appear to contain only its first word (because of the first inserted '\0').

```
#include <stddef.h>
#include <ctype.h>
getwords(char *line, char *words[], int maxwords)
{
char *p = line;
int nwords = 0;
while(1)
{
while(isspace(*p))
p++;
if(*p == '\0')
return nwords;
words[nwords++] = p;
while(!isspace(*p) && *p != '\0')
p++;
if(*p == '\0')
return nwords;
*p++ = '\0';
if(nwords >= maxwords)

return nwords;
}
}
```

Each time through the outer while loop, the function tries to find another word. First it skips over whitespace (which might be leading spaces on the line, or the space(s) separating this word from the previous one). The isspace function is new: it's in the standard library, declared in the header file <ctype.h>, and it returns nonzero (“true'') if the character you hand it is a space character (a space or a tab, or any other whitespace character there might happen to be).

When the function finds a non-whitespace character, it has found the beginning of another word, so it places the pointer to that character in the next cell of the words array. Then it steps through the word, looking at non-whitespace characters, until it finds another whitespace character, or the \0 at the end of the line. If it finds the \0, it's done with the entire line; otherwise,

it changes the whitespace character to a \0, to terminate the word it's just found, and continues. (If it's found as many words as will fit in the words array, it returns prematurely.)

Each time it finds a word, the function increments the number of words (nwords) it has found. Since arrays in C start at [0], the number of words the function has found so far is also the index of the cell in the words array where the next word should be stored. The function actually assigns the next word and increments nwords in one expression:

```
words[nwords++] = p;
```

You should convince yourself that this arrangement works, and that (in this case) the preincrement form

```
words[++nwords] = p;     /* WRONG */
```

would *not* behave as desired.

When the function is done (when it finds the \0 terminating the input line, or when it runs out of cells in the words array) it returns the number of words it has found.

Here is a complete example of calling getwords:

```
char line[] = "this is a test";
int i;
nwords = getwords(line, words, 10);
for(i = 0; i < nwords; i++)
printf("%s\n", words[i]);
```

SELF-ASSESSMENT QUESTIONS – 3

4. An array of characters is called as ___________________.
5. You can represent an array of strings using pointers by using an array of ______________ to character.
6. A string must always be terminated with a __________________ character.

5. POINTERS AND TWO-DIMENSIONAL ARRAYS

Since a one-dimensional array can be represented in terms of pointer (the array name) and an offset (the subscript), it is reasonable to expect that a two-dimensional array can also be represented with an equivalent pointer notation. A two-dimensional array is actually a collection of one-dimensional arrays. Therefore we can define a two dimensional array as a pointer to a group of contiguous one-dimensional arrays. A two-dimensional array declaration can be written as:

*data-type (*ptr)[expression]*

where *data-type* is the type of array elements and *expression* is the positive-valued integer expression that indicates the number of columns in each row of the two-dimensional array.

Example 8.5: Suppose that x is a two-dimensional integer array having 10 rows and 20 columns. We can declare x as

```
int (*x)[20];
```

In this case, x is defined to be a pointer to a group of contiguous, one-dimensional, 20-element integer arrays. Thus x points to the first 20-element array, which is actually the first row(row 0) of the original two-dimensional array. Similarly, (x+1) points to the second 20-element array, which is the second row(row 1) of the original two-dimensional array and so on.

Arrays of pointers

A two-dimensional array can also be expressed in terms of an array of pointers rather than as a pointer to a group of contiguous arrays. Each element in the array is a pointer to a separate row in the two-dimensional array. In general terms, a two-dimensional array can be defined as a one-dimensional array of pointers by writing:

*data-type *ptr[expression]*

where data-type is the type of array elements and expression is the positive-valued integer expression that indicates the number of rows.

Example 8.6: Suppose that x is a two-dimensional array having 10 rows and 20 columns, we can define x as a one-dimensional array of pointers by writing

int *x[10];

Hence, x[0] points to the beginning of the first row, x[1] points to the beginning of the second row and so on.

An individual array element, such as x[2][4] can be accessed

by writing
*(x[2]+4)

In this expression, x[2] is a pointer to the first element in row 2, so that (x[2]+5) points to element 4(actually, the fifth element) within row 2. The element of this pointer, *(x[2]+4), therefore refers to x[2][4].

SELF-ASSESSMENT QUESTIONS – 4

5. We can define a two dimensional array as a pointer to a group of contiguous _______________ dimensional arrays.
6. A two-dimensional array can also be expressed in terms of an ____________________ of pointers rather than as a pointer to a group of contiguous arrays.

6. SUMMARY

A pointer is a variable that points at, or refers to, another variable. The general format of a simple pointer declaration is: datatype *variablename. We discover the value pointed to by a pointer using the "contents-of" operator, *. Pointers are very useful when you want to refer to some other variable by pointing at it. Pointers not only point to single variables but can also point at the cells of an array. Pointers are also closely associated with the arrays and therefore provide an alternate way to access individual array elements. Once we have a pointer pointing into an array, we can do some pointer arithmetic-add a constant to a variable or subtract a constant from a pointer, or you can subtract two pointers. There are similarities between pointers and one dimension arrays in some aspects although they are entirely different concepts and there are differences also in other aspects.

7. TERMINAL QUESTIONS

1. How do you declare a pointer to a floating point quantity and a double precision quantity? Illustrate it.
2. What is the significance of the following declaration? Explain with an example.

   int *p(int a)

3. What is the significance of the following declaration? Explain with an example.

   int (*p) (int a)

4. Illustrate with an example how you use pointer arithmetic.

8. ANSWERS

Self-Assessment Questions

1. indirection operator.
2. True
3. Incorrect
4. True
5. False
6. &a[0];
7. True
8. (*p)++.)

Terminal Questions

1. We declare a pointer to a floating point quantity and double precision quantity as follows:
   float *fptr; double *dptr;
   (Refer section 8. 2 and 8.3 for more details)
2. int *p(int a) defines the function that accepts an integer argument and returns a pointer to an integer. (Refer section 8. 2 and 8.3 for more details)
3. int (*p) (int a) indicates a pointer to a function that accepts an integer argument and returns an integer. (Refer section 8. 2 and 8.3 for more details)
4. You can apply addition, subtraction or comparison with pointers. (Refer section 8. 2 and 8.3 for more details)

9. EXERCISE

1. Write a program that uses the pointer arithmetic.
2. Write a program that can accept any 5 data and sort it in ascending order using pointers.
3. With the help of pointers, write a program that uses functions to swap the data.
4. What are the various operators that are used when implementing a pointer in a program? Explain with an example.