ICS 104 - Introduction to Programming in Python and C

Pointers and Modular Programming

Reading Assignment

- Chapter 6: Sections 1,2, 3 and 4.

Learning Outcomes

At the end of this chapter, you will be able to

- use pointers and indirect addressing in writing small C programs.
- read data from files and write data into files.
- return function results through a function’s arguments.
- recognize the differences between call-by-value and call-by-reference.
- distinguish between input, in-out, and output parameters.
- determine the scope of names in a C program.

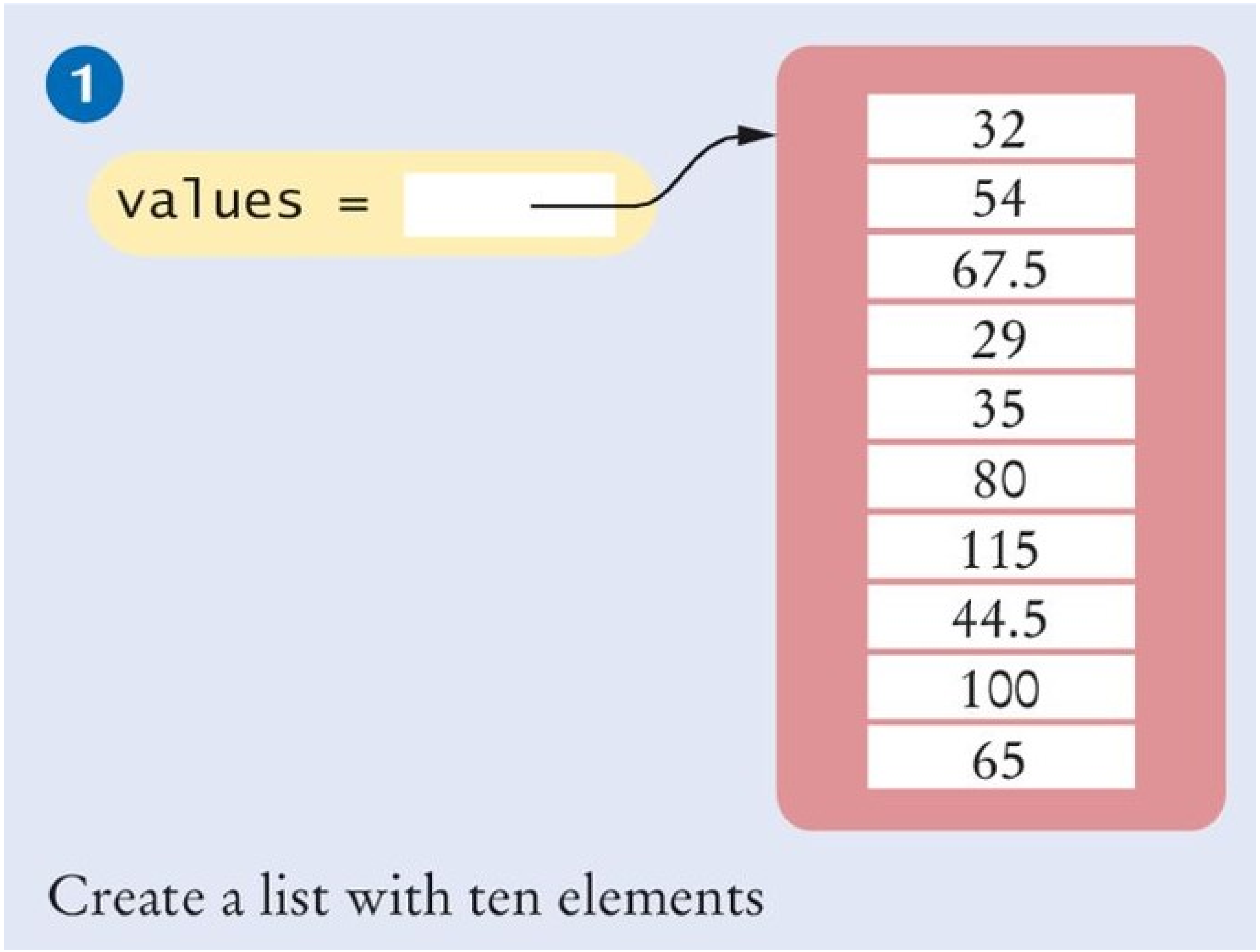
Pointers

- How do we interpret the following declaration:

```
double *p;
```

- p is considered as a **pointer variable** of type "pointer to double".
    - In current object-oriented languages notation, we say that p is a **reference** to a variable of type double.
- p stores the address in memory of a variable of type double.

- Do you remember the following image?

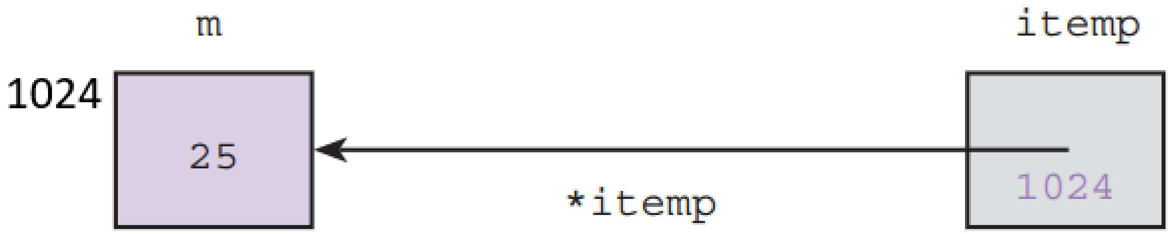


- The value of `values` is a reference (or an address) (or a pointer) to a list.

- Consider the following C code fragment:

```
int m = 25;
int *itemp;    /* pointer to integer */
itemp = &m;    /* Store address of m
                  in pointer itemp*/
```

- Assume that variable `m` is associated with memory cell 1024.

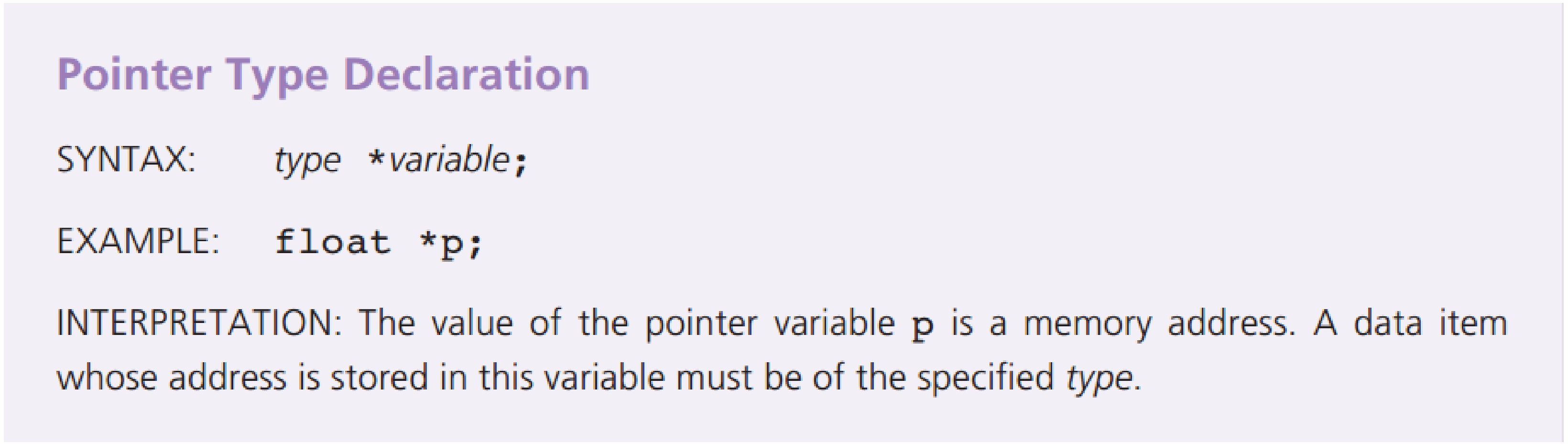


Indirect Reference

- When we try to access the contents (value) of a memory cell through a pointer variable that stores its address, then we are using an indirect reference to a variable.

```
*itemp = 35; /* changes the value of variable m (indirect reference) */
m = 40;      /* changes the value of variable m (direct reference) */
```

Pointer Declaration



Pointer Type Declaration

SYNTAX: *type* `*`*variable*`;`

EXAMPLE: `float *p;`

INTERPRETATION: The value of the pointer variable `p` is a memory address. A data item whose address is stored in this variable must be of the specified *type*.

Student Activity

- Trace the execution of the following C program

```c
#include <stdio.h>
int main(void) {
  int m = 10, n = 5;
  int *mp, *np;

  mp = &m;
  np = &n;

  *mp = *mp + *np;
  *np = *mp - *np;

  printf("%d %d\n%d %d\n", m, *mp, n, *np);
  return (0);
}
```

Functions with Output Parameters

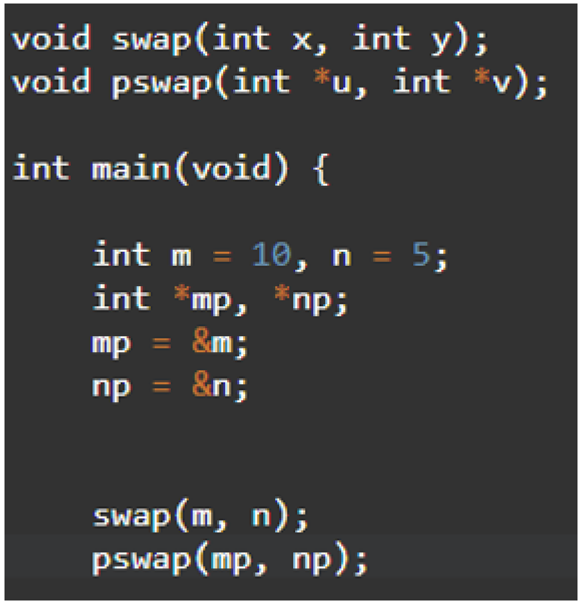
- Function arguments (arguments list) enable a function to manipulate different data each time it is called.
- So far, we know how to pass inputs to a function and how to use the return statement to send back one result value from a function.
- Using indirect references, we can use the argument to return results (in addition to the one returned by the function).

- When a function call executes, the computer allocates memory space **in the function data area** for each formal parameter.
- The value of each actual parameter (in the function call) is stored in the memory cell allocated to its corresponding formal parameter (in the function data area).
    - This type of function calls is called **call by value**.
- The question is: If the function formal parameters are, say, of type `int`, and if we change its value inside the function body, does that affect the actual parameter in the function call?

-
    - The answer is no. Why?
    - Because the call is **by value**. So, the value of the variable is copied to the address space of the function.
- Now, let us ask this question: If the function formal parameters are, say, of type `int *`, that is a pointer/reference to an integer and if we change its value inside the function body, does that affect the actual parameter in the function call?
    - The answer is yes. The reason is that we copied the address (reference) of the variable, not the value of the variable. Hence, inside the function body, when we use `*myVariable = ...`, we change the value of the variable in the main program.
    - This type of function calls is called **call by reference**.

Call by Value vs. Call by Reference

- Assume that function swap swaps the **integer values** in the body, and that the function pswap swaps the integer values **pointed to** by its arguments.



```
void swap(int x, int y);
void pswap(int *u, int *v);

int main(void) {

    int m = 10, n = 5;
    int *mp, *np;
    mp = &m;
    np = &n;


    swap(m, n);
    pswap(mp, np);
```

Address Space of main		
Var	Address	Value
m	001024	10
n	001028	5
...	...	...
mp	002052	001024
...	...	...
np	002140	001028

Address Space of swap		
Var	Address	Value
x	003000	10
y	003004	5

Address Space of pswap		
Var	Address	Value
u	004012	001024
V	004016	001028

Pointers to Files

- C allows a program to explicitly name a file for input or output.
- File pointers can be declared by:

```
FILE *inp;
FILE *outp;
```

- Just like Python, you need to first open the files for reading or writing:

```
inp  = fopen("infile.txt","r");
outp = fopen("outfile.txt","w");
```

- `fscanf`
  - The file equivalent of `scanf`. For example,

    ```
    fscanf(inp, "%1f", &item);
    ```

  - Like `scanf`, it returns the number of successfully read values (or a negative number if the end of file is reached)
- `fprintf`
  - The file equivalent of `printf`. For example,

    ```
    fprintf(outp, "%.2f\n", item);
    ```

- Closing a file when done:

```
fclose(inp);
fclose(outp);
```

Example of a program that reads and writes from files.

- Note that you need to run C on your machine in order to read from files and write into files.

In [3]:
```
%%writefile indata.txt
344 55 6.3556 9.4
 43.123 47.596
```

```
Writing indata.txt
```

In [ ]:

```c
#include <stdio.h>

int
main(void)
{
      FILE *inp;          /* pointer to input file */
      FILE *outp;         /* pointer to ouput file */
      double item;
      int input_status;   /* status value returned by fscanf */

      /* Prepare files for input or output */
      inp = fopen("indata.txt", "r");
      outp = fopen("outdata.txt", "w");

      /* Input each item, format it, and write it */
      input_status = fscanf(inp, "%lf", &item);
      while (input_status == 1) {
          fprintf(outp, "%.2f\n", item);
          input_status = fscanf(inp, "%lf", &item);
      }

      /* Close the files */
      fclose(inp);
      fclose(outp);

      return (0);
}
```

Example Function with Input and Output Parameters

- Consider the following function:

```
/*
* Separates a number into three parts: a sign (+, -, or blank),
* a whole number magnitude, and a fractional part.
*/

void
separate(double num, /* input - value to be split */
         char *signp, /* output - sign of num */
         int *wholep, /* output - whole number magnitude of num */
         double *fracp) /* output - fractional part of num */
{
 double magnitude; /* local variable - magnitude of num */

 /* Determines sign of num */
 if (num < 0)
    *signp = '-';
 else if (num == 0)
    *signp = ' ';
 else
    *signp = '+';

 /* Finds magnitude of num (its absolute value) and
 separates it into whole and fractional parts */
 magnitude = fabs(num);
 *wholep = floor(magnitude);
 *fracp = magnitude - *wholep;
}
```

```
In [ ]: #include <stdio.h>
        #include <math.h>
        void separate(double num, char *signp, int *wholep, double *fracp);

        int
        main(void)
        {
              double value; /* input - number to analyze                          */
              char sn;      /* output - sign of value                             */
              int whl;      /* output - whole number magnitude of value           */
              double fr;    /* output - fractional part of value                  */

              /* Gets data                                                         */
              printf("Enter a value to analyze> ");
              scanf("%lf", &value);

              /* Separates data value into three parts                             */
              separate(value, &sn, &whl, &fr);

              /* Prints results                                                    */
              printf("Parts of %.4f\n sign: %c\n", value, sn);
              printf(" whole number magnitude: %d\n", whl);
              printf(" fractional part: %.4f\n", fr);

              return (0);
        }

        /*
         * Separates a number into three parts: a sign (+, -, or blank),
         * a whole number magnitude, and a fractional part.
         * Pre: num is defined; signp, wholep, and fracp contain addresses of memory
         *      cells where results are to be stored
         * Post: function results are stored in cells pointed to by signp, wholep, and
         *       fracp
         */
        void
```

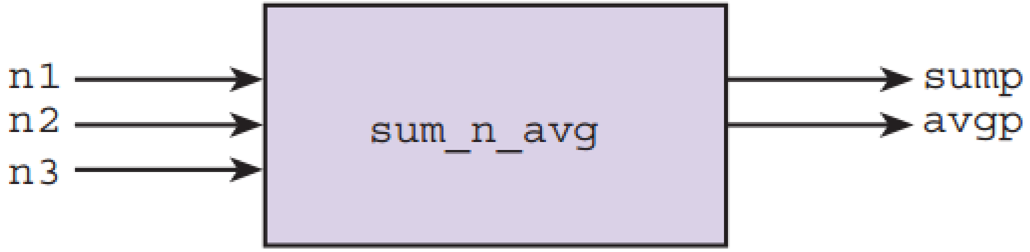
```
separate(double num,     /* input - value to be split                            */
         char   *signp,  /* output - sign of num                                 */
         int    *wholep, /* output - whole number magnitude of num               */
         double *fracp)  /* output - fractional part of num                      */
{
      double magnitude; /* local variable - magnitude of num                     */
      /* Determines sign of num */
      if (num < 0)
            *signp = '-';
      else if (num == 0)
            *signp = ' ';
      else
            *signp = '+';

      /* Finds magnitude of num (its absolute value) and separates it into
         whole and fractional parts                                                */
      magnitude = fabs(num);
      *wholep = floor(magnitude);
      *fracp = magnitude - *wholep;
}
```

Meanings of * Symbol

- We have studied 3 meanings of the * symbol:
    1. Binary Multiplication Operator.
    2. Defining the data type "pointer to" in declaring variables
        - e.g. `char *signp`
    3. Accessing a variable, indirectly, through its address
        - e.g. `*signp = '-'`

Student Activity

- Write a prototype for a function `sum_n_avg` that has three type `double` input parameters and two output parameters. The function computes the sum and the average of its three input arguments and relays its results through two output parameters



- The following code fragment is from a function preparing to call `sum_n_avg`. Complete the function call statement.

```
{
double one, two, three, sum_of_3, avg_of_3;
printf("Enter three numbers> ");
scanf("%lf%lf%lf", &one, &two, &three);
sum_n_avg(???);
}
```

Multiple Calls to a Function with Input/Output Parameters

- We can define a function, in which some input arguments can also act as output results.
- Consider developing a function `order` that orders the `double` values in its arguments, such that the first argument will always hold the smaller number and the second argument will always hold the larger number.
- First of all, what shall the type of the arguments of function `order` be?

- The type of arguments shall be a pointer to double.

```c
/*
* Arranges arguments in ascending order.
* Pre:  smp and lgp are addresses of defined type double variables
* Post: variable pointed to by smp contains the smaller of the type
*       double values; variable pointed to by lgp contains the larger
*/
void
order(double *smp, double *lgp)    /* input/output */
{
      double temp; /* temporary variable to hold one number during swap      */
      /* Compares values pointed to by smp and lgp and switches if necessary */
       if (*smp > *lgp) {
              temp = *smp;
              *smp = *lgp;
              *lgp = temp;
      }
}
```

- Now, consider the problem of sorting three input numbers, `num1`, `num2` and `num3` from lowest to highest.
    - That is, we would like `num1` to hold the smallest value, `num2` to hold the second smallest value, and `num3` to hold the largest value. How can achieve that using the `order` function?

-
  ```
  order(num1, num2) -> num1 <= num2
  order(num1, num3) -> num1 <= num3
  order(num2, num3) -> num2 <= num3
  ```

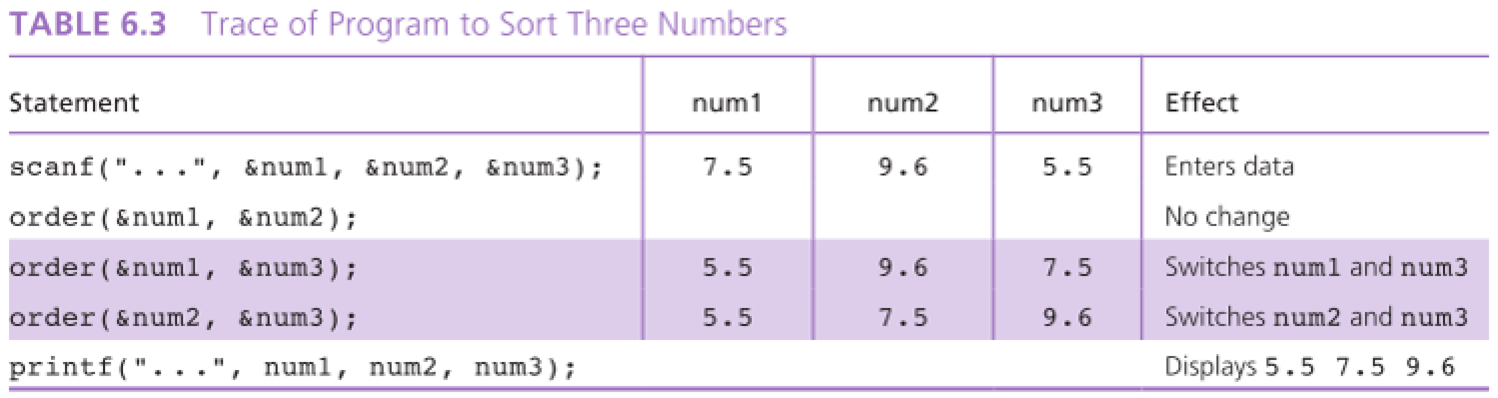


TABLE 6.3 Trace of Program to Sort Three Numbers

Statement	num1	num2	num3	Effect
`scanf("...", &num1, &num2, &num3);`	7.5	9.6	5.5	Enters data
`order(&num1, &num2);`				No change
`order(&num1, &num3);`	5.5	9.6	7.5	Switches `num1` and `num3`
`order(&num2, &num3);`	5.5	7.5	9.6	Switches `num2` and `num3`
`printf("...", num1, num2, num3);`				Displays `5.5 7.5 9.6`

In [ ]:
```c
#include <stdio.h>

void order(double *smp, double *lgp);

int
main(void)
{
        double num1, num2, num3; /* three numbers to put in order       */

        /* Gets test data                                               */
        printf("Enter three numbers separated by blanks> ");
        scanf("%lf%lf%lf", &num1, &num2, &num3);

        /* Orders the three numbers                                     */
        order(&num1, &num2);
        order(&num1, &num3);
        order(&num2, &num3);

        /* Displays results                                             */
        printf("The numbers in ascending order are: %.2f %.2f %.2f\n",
               num1, num2, num3);

        return (0);
}

/*
 * Arranges arguments in ascending order.
 * Pre:  smp and lgp are addresses of defined type double variables
 * Post: variable pointed to by smp contains the smaller of the type
 *       double values; variable pointed to by lgp contains the larger
 */
void
order(double *smp, double *lgp)    /* input/output */
{
        double temp; /* temporary variable to hold one number during swap      */
        /* Compares values pointed to by smp and lgp and switches if necessary */
```

```
          if (*smp > *lgp) {
                  temp = *smp;
                  *smp = *lgp;
                  *lgp = temp;
          }
}
```

Summary of Different Types of Functions in C

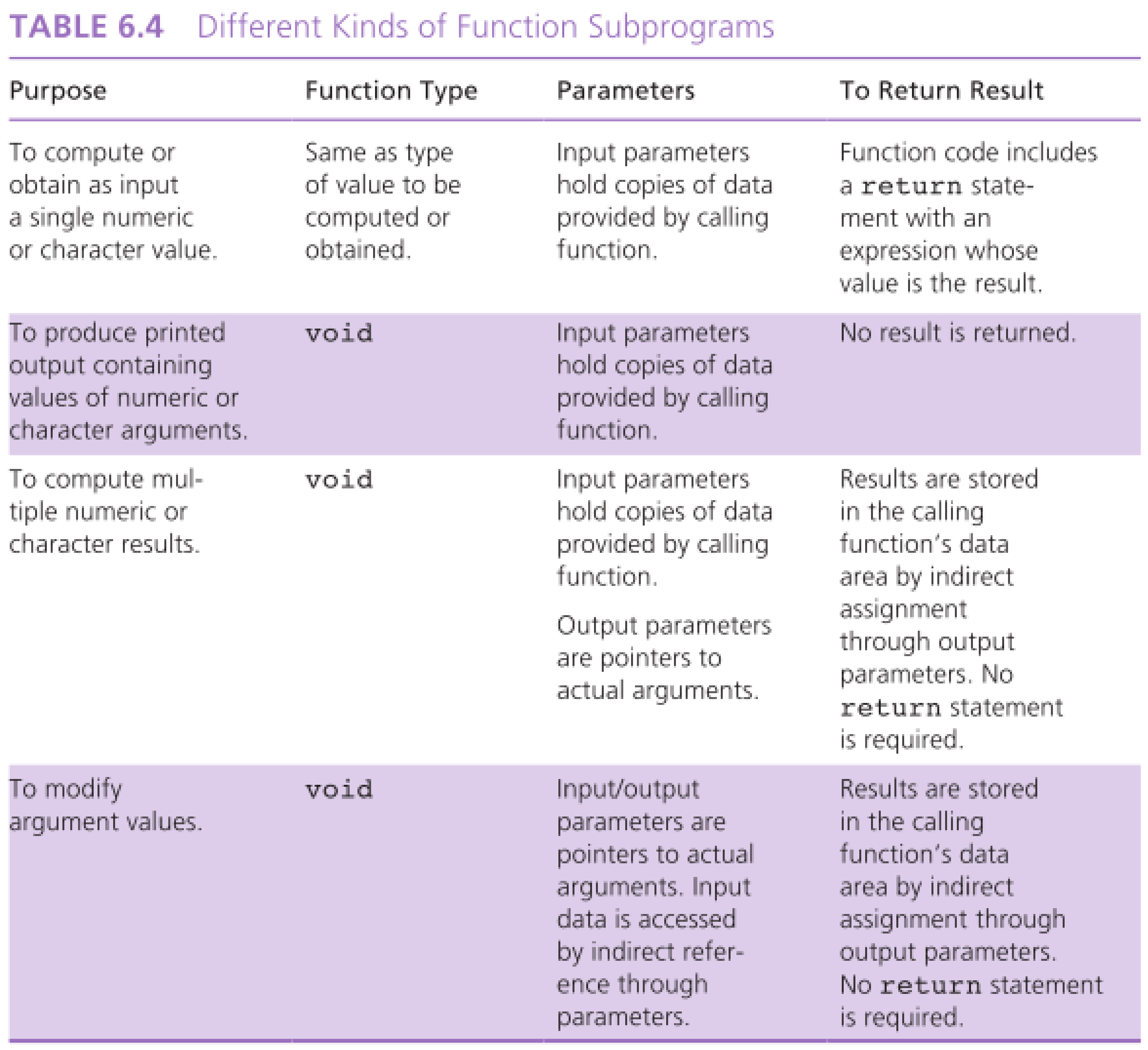


TABLE 6.4 Different Kinds of Function Subprograms

Purpose	Function Type	Parameters	To Return Result
To compute or obtain as input a single numeric or character value.	Same as type of value to be computed or obtained.	Input parameters hold copies of data provided by calling function.	Function code includes a **`return`** statement with an expression whose value is the result.
To produce printed output containing values of numeric or character arguments.	`void`	Input parameters hold copies of data provided by calling function.	No result is returned.
To compute multiple numeric or character results.	`void`	Input parameters hold copies of data provided by calling function. Output parameters are pointers to actual arguments.	Results are stored in the calling function's data area by indirect assignment through output parameters. No **`return`** statement is required.
To modify argument values.	`void`	Input/output parameters are pointers to actual arguments. Input data is accessed by indirect reference through parameters.	Results are stored in the calling function's data area by indirect assignment through output parameters. No **`return`** statement is required.

Scope of Names

- The **scope of a name** refers to the region of a program where a particular meaning of a name is visible or can be referenced.
- The scope of:
    - constant macros begins at their definition and continues to the end of the source file.
    - a function subprogram begins with its prototype and continues to the end of the source file.
    - formal parameters and local variables extends from their declaration to the closing brace of the function in which they were declared.
- A local variable or a formal parameter may block the definition of a function (e.g.) if it has the same name.

Example

- Consider the following C Code:

In [ ]:
```
#define MAX 950
#define LIMIT 200

void one(int anarg, double second); /* prototype 1 */

int fun_two(int one, char anarg);   /* prototype 2 */

int
main(void)
{
         int localvar;
        . . .
} /* end main */


void
one(int anarg, double second)       /* header 1     */
{
        int onelocal;               /* local 1      */
        . . .
} /* end one */


int
fun_two(int one, char anarg)        /* header 2     */
{
        int localvar;               /* local 2      */
        . . .
} /* end fun_two */
```

Name	Visible in main	Visible in one	Visible in fun_two
MAX	yes	yes	yes
LIMIT			
main			
localvar (in **main**)			
one (the function)			