Functions

Function

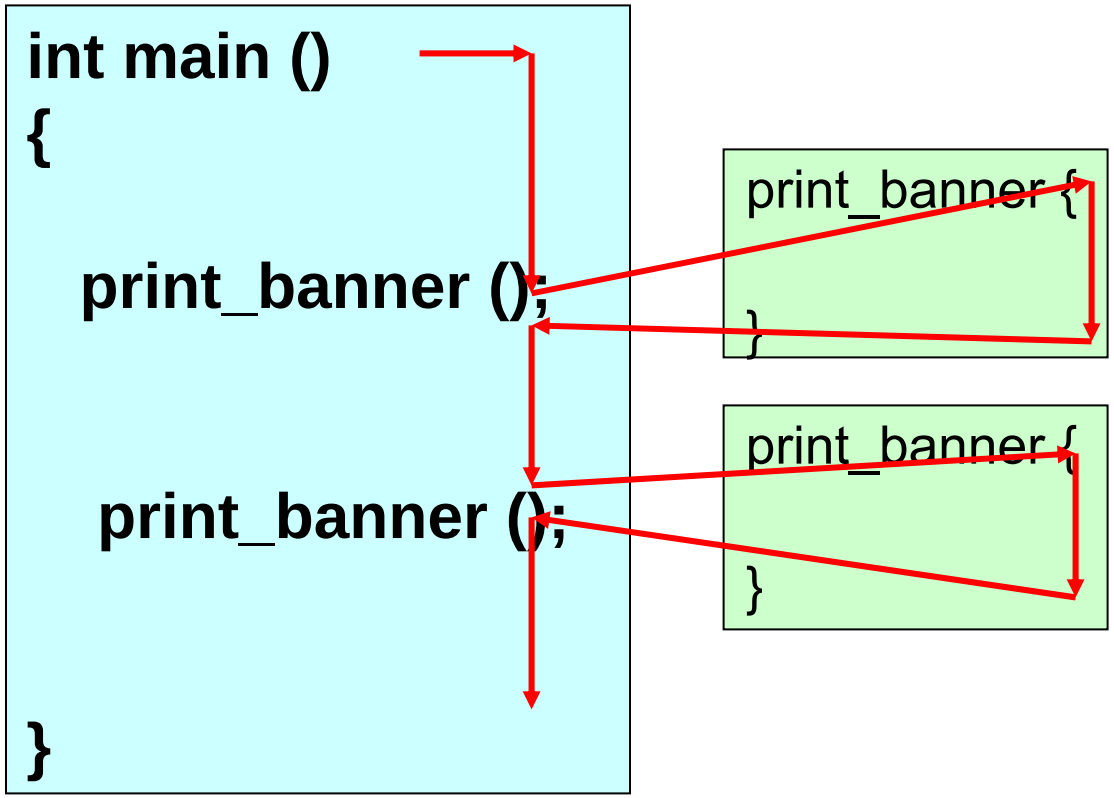
- A program segment that carries out some specific, well-defined task
- Example
  - A function to add two numbers
  - A function to find the largest of n numbers
- A function will carry out its intended task whenever it is called or invoked
  - Can be called multiple times

- Every C program consists of one or more functions
- One of these functions must be called main
- Execution of the program always begins by carrying out the instructions in main
- Functions call other functions as instructions

Function Control Flow

```
void print_banner ()
{
    printf("**********\n");
}
```

```
void main ()
{
    . . .
    print_banner ();
    . . .
    print_banner ();

}
```



- Calling function (caller) may pass information to the called function (callee) as parameters/arguments
  - For example, the numbers to add
- The callee may return a single value to the caller
  - Some functions may not return anything

Calling function (Caller)

Called function (Callee)

parameter

```
void main()
{ float cent, fahr;
  scanf("%f",&cent);
  fahr = cent2fahr(cent);
  printf("%fC = %fF\n",
    cent, fahr);
}
```

```
float cent2fahr(float data)
{
  float result;
  result = data*9/5 + 32;
  return result;
}
```

Parameter passed

Returning value

Calling/Invoking the cent2fahr function

How it runs

```
float cent2fahr(float data)
{
  float result;
  printf("data = %f\n", data);
  result = data*9/5 + 32;
  return result;
   printf("result = %f\n", result);
}
void main()
{ float cent, fahr;
  scanf("%f",&cent);
  printf("Input is %f\n", cent);
  fahr = cent2fahr(cent);
  printf("%fC = %fF\n", cent, fahr);
}
```

Output

```
$ ./a.out
32
Input is 32.000000
data = 32.000000
32.000000C = 89.599998F

$./a.out
-45.6
Input is -45.599998
data = -45.599998
-45.599998C = -50.079998F
$
```

Another Example

```
int  factorial (int m)
{
    int i, temp=1;
    for (i=1; i<=m; i++)
          temp = temp * i;
    return (temp);
}
```

```
void main()
{
    int  n;
    for  (n=1; n<=10; n++)
          printf ("%d! = %d \n",
                n, factorial (n) );
}
```

Output

1! = 1

2! = 2

3! = 6 …….. upto 10!

Why Functions?

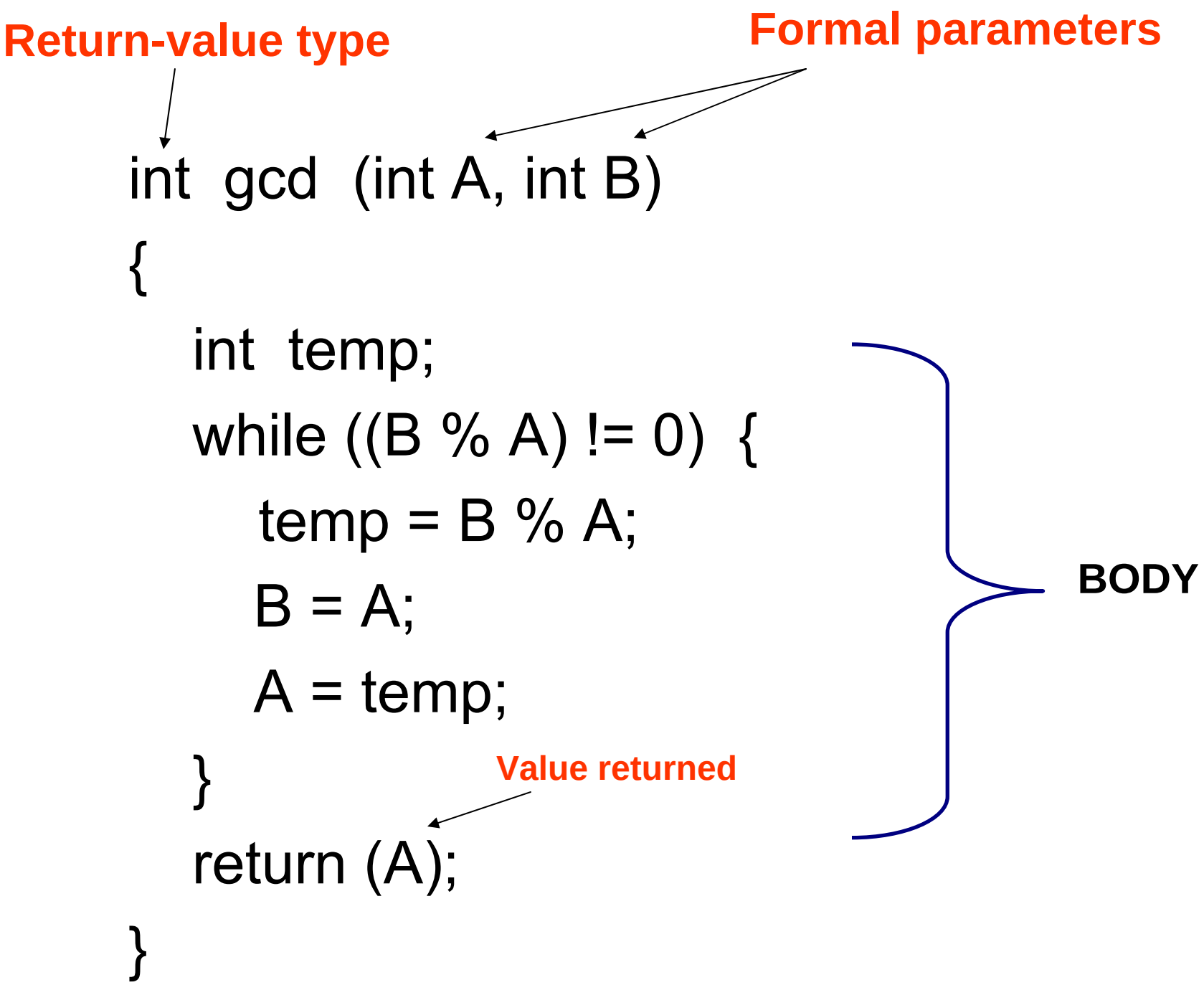
- Allows one to develop a program in a modular fashion
  - Divide-and-conquer approach
  - Construct a program from small pieces or components
- Use existing functions as building blocks for new programs
- Abstraction: hide internal details (library functions)

Defining a Function

- A function definition has two parts:
  - The first line, called header
  - The body of the function

```
return-value-type  function-name  ( parameter-list )
{
      declarations and statements
}
```

- The first line contains the return-value-type, the function name, and optionally a set of comma-separated arguments enclosed in parentheses
  - Each argument has an associated type declaration
  - The arguments are called formal arguments or formal parameters
- The body of the function is actually a block of statement that defines the action to be taken by the function


Return-value type
Formal parameters
int gcd (int A, int B)
{
int temp;
while ((B % A) != 0) {
temp = B % A;
B = A;
A = temp;
}
return (A);
}
BODY
Value returned

Return value

- A function can return a value
  - Using **return** statement
- Like all values in C, a function return value has a type
- The return value can be assigned to a variable in the caller

```
int x, y, z;
scanf("%d%d", &x, &y);
 z = gcd(x,y);
printf("GCD of %d and %d is %d\n", x, y, z);
```

Function Not Returning Any Value

- Example: A function which prints if a number is divisible by 7 or not

```
void  div7 (int n)
{
   if  ((n % 7) == 0)
        printf ("%d is divisible by 7", n);
   else
        printf ("%d is not divisible by 7", n);
   return;
}
```

Return type is void

Optional

return statement

- In a value-returning function (result type is not void), return does two distinct things
  - specify the value returned by the execution of the function
  - terminate that execution of the callee and transfer control back to the caller
- A function can only return one value
  - The value can be any expression matching the return type
  - but it might contain more than one return statement.
- In a void function
  - return is optional at the end of the function body.
  - return may also be used to terminate execution of the function explicitly.
  - No return value should appear following return.

```
void compute_and_print_itax ()
{
    float income;
    scanf ("%f", &income);
    if (income < 50000)  {
        printf ("Income tax = Nil\n");
        return;
    }
    if (income < 60000)  {
        printf ("Income tax = %f\n", 0.1*(income-50000));
        return;
    }
    if (income < 150000)          {
        printf ("Income tax = %f\n", 0.2*(income-60000)+1000);
        return ;
    }
    printf ("Income tax = %f\n", 0.3*(income-150000)+19000);
}
```

Terminate function execution before reaching the end

Calling a function

- Called by specifying the function name and parameters in an instruction in the calling function
- When a function is called from some other function, the corresponding arguments in the function call are called actual arguments or actual parameters
  - The function call must include a matching actual parameter for each formal parameter
  - Position of an actual parameters in the parameter list in the call must match the position of the corresponding formal parameter in the function definition
  - The formal and actual arguments must match in their data types

Example

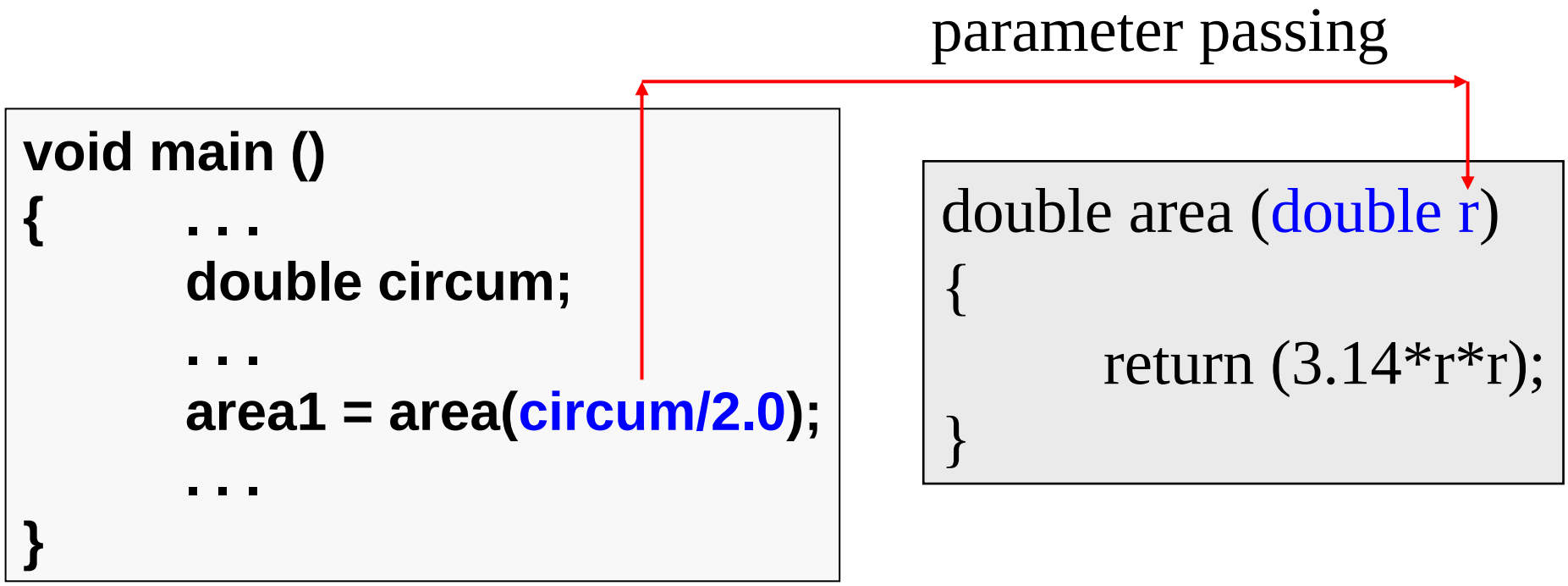
Formal parameters

```
double operate (double x, double y, char op)
{
        switch (op) {
            case '+' : return x+y+0.5 ;
            case '~'  : if (x>y)
                            return x-y + 0.5;
                        return y-x+0.5;
            case 'x' : return x*y + 0.5;
            default : return –1;
        }
}
```

```
void main ()
{
    double x, y, z;
    char op;
    . . .
   z = operate (x, y, op);
        . . .
}
```

Actual parameters

- When the function is executed, the value of the actual parameter is copied to the formal parameter



Another Example

```
/* Compute the GCD of four numbers */
void main()
{
   int  n1, n2, n3, n4, result;
   scanf ("%d %d %d %d", &n1, &n2, &n3, &n4);
   result  =  gcd ( gcd (n1, n2), gcd (n3, n4) );
   printf ("The GCD of %d, %d, %d and %d is %d \n",
   n1, n2, n3, n4, result);
}
```

Another Example

```
void main()
{
  int numb, flag, j=3;
  scanf("%d",&numb);
   while (j <=numb)
   {
       flag = prime(j);
       if (flag==0)
          printf("%d is prime\n",j);
       j++;
   }
 }
```

```
int prime(int x)
{
   int i, test;
   i=2, test =0;
   while ((i <= sqrt(x)) && (test
    ==0))
   {  if (x%i==0) test = 1;
       i++;
     }
    return test;
}
```

Tracking the flow of control

```
void main()
{
  int numb, flag, j=3;
  scanf("%d",&numb);
  printf("numb = %d \n",numb);
  while (j <= numb)
  {  printf("Main, j = %d\n",j);
     flag = prime(j);
     printf("Main, flag = %d\n",flag);
     if (flag == 0)
        printf("%d is prime\n",j);
     j++;
  }
 }
```

```
int prime(int x)
{
   int i, test;
   i = 2;  test = 0;
   printf("In function, x = %d \n",x);
   while ((i <= sqrt(x)) && (test == 0))
   {  if (x%i == 0) test = 1;
      i++;
   }
   printf("Returning, test = %d \n",test);
   return test;
}
```

The output

```
5
numb = 5
Main, j = 3
In function, x = 3
Returning, test = 0
Main, flag = 0
3 is prime
Main, j = 4
In function, x = 4
Returning, test = 1
Main, flag = 1
Main, j = 5
In function, x = 5
Returning, test = 0
Main, flag = 0
5 is prime
```

Points to note

- The identifiers used as formal parameters are “local”.
  - Not recognized outside the function
  - Names of formal and actual arguments may differ
- A value-returning function is called by including it in an expression
  - A function with return type T (≠ void) can be used anywhere an expression of type T can be used

- Returning control back to the caller
  - If nothing returned
    - return;
    - or, until reaches the last right brace ending the function body
  - If something returned
    - return expression;

Function Prototypes

- Usually, a function is defined before it is called
  - main() is the last function in the program written
  - Easy for the compiler to identify function definitions in a single scan through the file

- However, many programmers prefer a top-down approach, where the functions are written after main()
  - Must be some way to tell the compiler
  - Function prototypes are used for this purpose
    - Only needed if function definition comes after use

- Function prototypes are usually written at the beginning of a program, ahead of any functions (including main())
- Prototypes can specify parameter names or just types (more common)
- Examples:

```
int  gcd (int , int );
void div7 (int number);
```

  - Note the semicolon at the end of the line.
  - The parameter name, if specifed, can be anything; but it is a good practice to use the same names as in the function definition

Some more points

- A function cannot be defined within another function
  - All function definitions must be disjoint
- Nested function calls are allowed
  - A calls B, B calls C, C calls D, etc.
  - The function called last will be the first to return
- A function can also call itself, either directly or in a cycle
  - A calls B, B calls C, C calls back A.
  - Called recursive call or recursion

Example: main calls ncr, ncr calls fact

```
int ncr (int n, int r);
int fact (int n);

void main()
{
    int i, m, n, sum=0;
    scanf ("%d %d", &m, &n);
    for (i=1; i<=m; i+=2)
        sum = sum + ncr (n, i);
    printf ("Result: %d \n",
    sum);
}
```

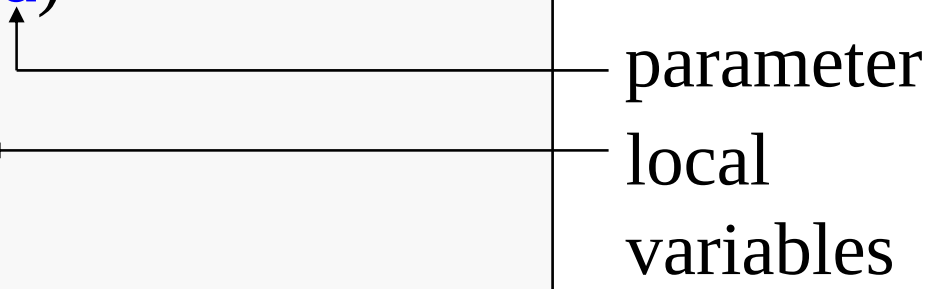
```
int  ncr (int n, int r)
{
    return (fact(n) / fact(r) /
    fact(n-r));
}

int  fact (int n)
{
    int  i, temp=1;
    for (i=1; i<=n; i++)
        temp *= i;
    return (temp);
}
```

Local variables

- A function can define its own local variables
- The locals have meaning only within the function
  - Each execution of the function uses a new set of locals
  - Local variables cease to exist when the function returns
- Parameters are also local

Local variables

```
/* Find the area of a circle with diameter d */
double circle_area (double d)
{
        double radius, area;
        radius = d/2.0;
        area = 3.14*radius*radius;
        return (area);
}
```



Revisiting nCr

```
int fact(int x)
{ int i,fact=1;
  for(i=2; i<=x; ++i) fact=fact*i;
  return fact;
}
```

```
void main()
{
    int n, r;
    scanf("%d%d",&n,&r);
    printf("n=%d, r=%d,
    nCr=%d\n",n, r, ncr(n,r));
}
```

```
int ncr(int x,int y)
{
    int p,q,r;
    p=fact(x);
    q=fact (y);
    r = fact(x-y);
   return p/(q*r);
}
```

The variable x in function fact and x in function ncr are different.

The values computed from the arguments at the point of call are copied on to the corresponding parameters of the called function before it starts execution.

Scope of a variable

- Part of the program from which the value of the variable can be used (seen)
- Scope of a variable - Within the block in which the variable is defined
  - Block = group of statements enclosed within { }
- Local variable – scope is usually the function in which it is defined
  - So two local variables of two functions can have the same name, but they are different variables
- Global variables – declared outside all functions (even main)
  - scope is entire program by default, but can be hidden in a block if local variable of same name defined

Variable Scope

```
#include  <stdio.h>
int A = 1;
void main()
{
   myProc();
   printf ( "A = %d\n", A);
}

void myProc()
{    int A = 2;
     if ( A==2 )
     {
       int A = 3;
       printf ( "A = %d\n", A);
     }
     printf ( "A = %d\n", A);
}
```

Global variable

Hides the global A

Output:

A = 3

A = 2

A = 1

Parameter Passing: by Value and by Reference

- Used when invoking functions
- Call by value
  - Passes the value of the argument to the function
  - Execution of the function does not change the actual parameters
    - All changes to a parameter done inside the function are done on a copy of the actual parameter
    - The copy is removed when the function returns to the caller
    - The value of the actual parameter in the caller is not affected
  - Avoids accidental changes

- Call by reference
  - Passes the address to the original argument.
  - Execution of the function may affect the original
  - Not directly supported in C except for arrays

Parameter passing & return: 1

```
void main()
{
   int  a=10, b;
   printf  (“Initially a = %d\n”, a);
   b = change (a);
   printf  (“a = %d, b = %d\n”, a, b);
}
int  change  (int x)
{
  printf  (“Before x = %d\n”,x);
   x = x / 2;
  printf  (“After x = %d\n”, x);
   return (x);
}
```

Output

```
Initially a = 10
Before x = 10
After x = 5
a = 10, b = 5
```

Parameter passing & return: 2

```
void main()
{
    int  x=10, b;
    printf  (“M: Initially x = %d\n”, x);
    b = change (x);
    printf  (“M: x = %d, b = %d\n”, x, b);
}
int  change  (int x)
{
   printf  (“F: Before x = %d\n”,x);
    x = x / 2;
   printf  (“F: After x = %d\n”, x);
    return (x);
}
```

Output

```
M: Initially x = 10
F: Before x = 10
F: After x = 5
M: x = 10, b = 5
```

Parameter passing & return: 3

```
void main()
{
    int  x=10, b;
    printf  (“M: Initially x = %d\n”, x);
    x = change (x);
    printf  (“M: x = %d, b = %d\n”, x, x);
}
int  change  (int x)
{
   printf  (“F: Before x = %d\n”,x);
    x = x / 2;
   printf  (“F: After x = %d\n”, x);
    return (x);
}
```

Output

```
M: Initially x = 10
F: Before x = 10
F: After x = 5
M: x = 5, b = 5
```

Parameter passing & return: 4

```
void main()
{
   int  x=10, y=5;
   printf  ("M1:  x = %d, y = %d\n", x, y);
   interchange (x, y);
   printf  ("M2:  x = %d, y = %d\n", x, y);
}

void interchange  (int x, int y)
{ int temp;
  printf  ("F1:  x = %d, y = %d\n", x, y);
  temp= x; x = y; y = temp;
  printf  ("F2:  x = %d, y = %d\n", x, y);
}
```

Output

```
M1:  x = 10, y = 5
F1:  x = 10, y = 5
F2:  x = 5, y = 10
M2:  x = 10, y = 5
```

How do we write an interchange function? (will see later)

Passing Arrays to Function

- Array element can be passed to functions as ordinary arguments
  - IsFactor (x[i], x[0])
  - sin (x[5])

Passing Entire Array to a Function

- An array name can be used as an argument to a function
  - Permits the entire array to be passed to the function
  - The way it is passed differs from that for ordinary variables
- Rules:
  - The array name must appear by itself as argument, without brackets or subscripts
  - The corresponding formal argument is written in the same manner
    - Declared by writing the array name with a pair of empty brackets

Whole Array as Parameters

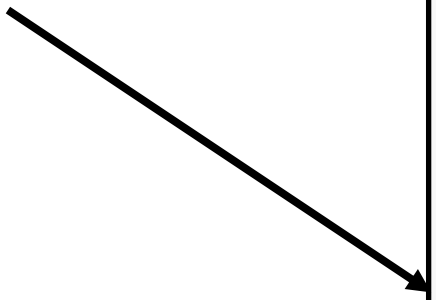
```
const int ASIZE = 5;
float average (int B[ ])
{
    int i, total=0;
    for (i=0; i<ASIZE; i++)
          total = total + B[i];
    return ((float) total / (float) ASIZE);
}

void main ( )  {
    int x[ASIZE] ; float x_avg;
     x = {10, 20, 30, 40, 50};
    x_avg = average (x) ;
}
```

Only Array Name/address passed. [ ] mentioned to indicate that is an array.

Called only with actual array name

Contd.

We don't need to write the array size. It works with arrays of any size.



```
void main()
{
    int  n;
    float   list[100], avg;
    :
    avg  =  average (n, list);
    :
}

float  average  (int a, float x[])
{
    :
    sum = sum + x[i];
}
```

Arrays used as Output Parameters

```
void VectorSum (int a[ ], int b[ ], int vsum[ ], int length) {
    int i;
    for (i=0; i<length; i=i+1)
          vsum[i] = a[i] + b[i] ;
}
void PrintVector (int a[ ], int length)  {
    int i;
    for (i=0; i<length; i++) printf ("%d ", a[i]);
}

void main ()  {
    int x[3] = {1,2,3}, y[3] = {4,5,6}, z[3];
    VectorSum (x, y, z, 3) ;
    PrintVector (z, 3) ;
}
```

vector-sum.c

The Actual Mechanism

- When an array is passed to a function, the values of the array elements are not passed to the function
  - The array name is interpreted as the address of the first array element
  - The formal argument therefore becomes a pointer to the first array element
  - When an array element is accessed inside the function, the address is calculated using the formula stated before
  - Changes made inside the function are thus also reflected in the calling program

Contd.

- Passing parameters in this way is called

  call-by-reference
- Normally parameters are passed in C using

  call-by-value
- Basically what it means?
  - If a function changes the values of array elements, then these changes will be made to the original array that is passed to the function
  - This does not apply when an individual element is passed on as argument

Library Functions

Library Functions

- Set of functions already written for you, and bundled in a “library”
- Example: printf, scanf, getchar,
- C library provides a large number of functions for many things
- We look at functions for mathematical use

Math Library Functions

- Math library functions
  - perform common mathematical calculations
  - Must include a special header file

```
#include <math.h>
```

- Example
  - printf ("%f", sqrt(900.0));
    - Calls function sqrt, which returns the square root of its argument
- Return values of math functions can be float/double/long double
- Arguments may be constants, variables, or expressions

Math Library Functions

double acos(double x) – Compute arc cosine of x.

double asin(double x) – Compute arc sine of x.

double atan(double x) – Compute arc tangent of x.

double atan2(double y, double x) – Compute arc tangent of y/x.

double cos(double x) – Compute cosine of angle in radians.

double cosh(double x) – Compute the hyperbolic cosine of x.

double sin(double x) – Compute sine of angle in radians.

double sinh(double x) – Compute the hyperbolic sine of x.

double tan(double x) – Compute tangent of angle in radians.

double tanh(double x) – Compute the hyperbolic tangent of x.

Math Library Functions

double ceil(double x) – Get smallest integral value that exceeds x.

double floor(double x) – Get largest integral value less than x.

double exp(double x) – Compute exponential of x.

double fabs (double x) – Compute absolute value of x.

double log(double x) – Compute log to the base e of x.

double log10 (double x) – Compute log to the base 10 of x.

double pow (double x, double y) – Compute x raised to the power y.

double sqrt(double x) – Compute the square root of x.