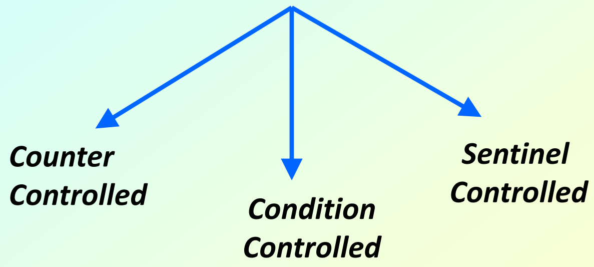
Control Structures that Allow Repetition

Types of Repeated Execution

- Loop: Group of instructions that are executed repeatedly while some condition remains true.

How loops are controlled?



- **Counter-controlled repetition**
  - Definite repetition – know how many times loop will execute.
  - Control variable used to count repetitions.
- **Condition-controlled repetition**
  - Loop executes as long as some specified condition is true.
- **Sentinel-controlled repetition**
  - Indefinite repetition.
  - Used when number of repetitions not known.
  - Sentinel value indicates “*end of data*”.

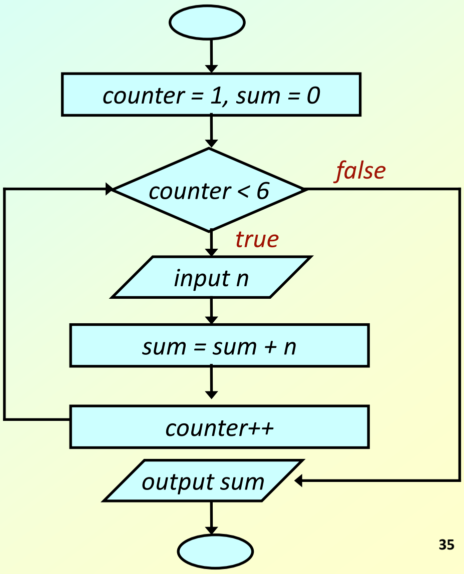
Counter-controlled Repetition

- **Counter-controlled repetition requires:**
  - *name* of a control variable (or loop counter).
  - *initial value* of the control variable.
  - *condition* that tests for the final value of the control variable (i.e., whether looping should continue).
  - *increment (or decrement)* by which the control variable is modified each time through the loop.

Counter Controlled Loop

Read 5 integers and display the value of their sum.

```
int counter=1, sum=0, n;

while (counter <6 ) {
   scanf (“%d”, &n);
   sum = sum + n;
   counter++;
}

printf (”\nSum is: %d”, sum);
```



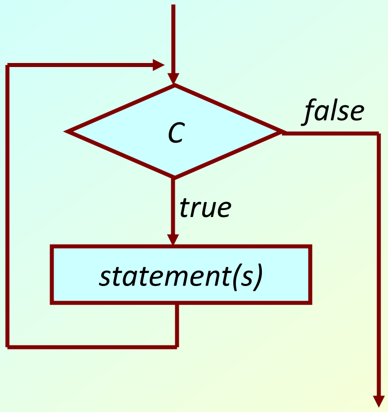
```
int counter, sum=0, n;

for (counter=1; counter<6; counter++)
{
   scanf (”%d”, &n);
   sum = sum + n;
}
printf (”\nSum is: %d”, sum);
```

while Statement

- The “while” statement is used to carry out looping operations, in which a group of statements is executed repeatedly, as long as some condition remains satisfied.

```
while  (condition)
          statement_to_repeat;
```

```
while  (condition)
{
          statement_1;
                    ...
          statement_N;
}
```



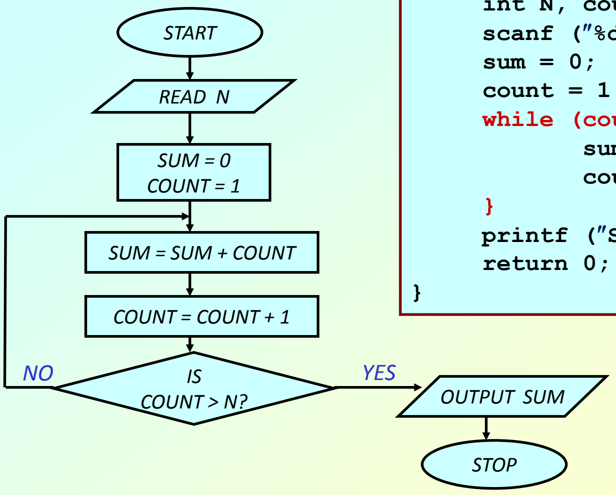
Single-entry / single-exit structure

while :: Examples

```
int  digit = 0;

while  (digit <= 9)
  printf ("%d \n", digit++);
```

```
int  weight=100;

while (weight > 65)
{
   printf ("Go, exercise,");
   printf ("then come back. \n");
   printf ("Enter your weight:");
   scanf ("%d", &weight);
}
```

Example: Sum of N Natural Numbers



```
int main () {
      int N, count, sum;
      scanf ("%d", &N);
      sum = 0;
      count = 1;
      while (count <= N)  {
              sum = sum + count;
              count = count + 1;
      }
      printf ("Sum=%d\n", sum);
      return 0;
}
```

Example: Maximum of inputs

```
printf ("Enter positive numbers, end with -1.0\n");
max = 0.0;
scanf("%f", &next);

while (next != -1.0)  {
       if (next > max)
             max = next;
       scanf("%f", &next);
}
printf ("The maximum number is %f\n", max) ;
```

Example of Sentinel-controlled loop

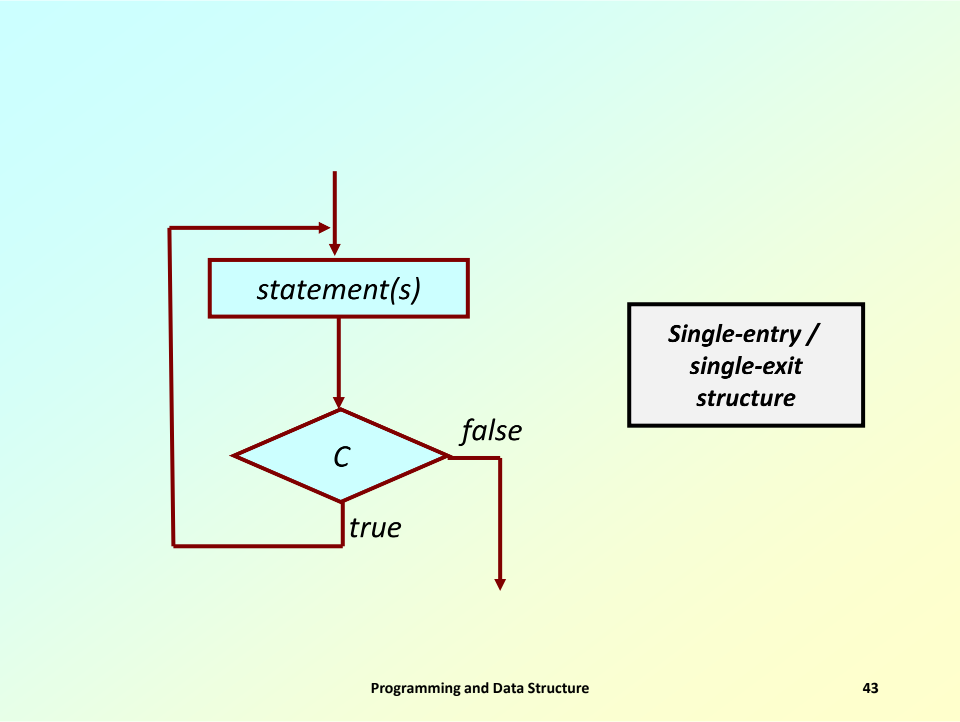
Inputs: 10 5 100 25 68 -1

do-while Statement

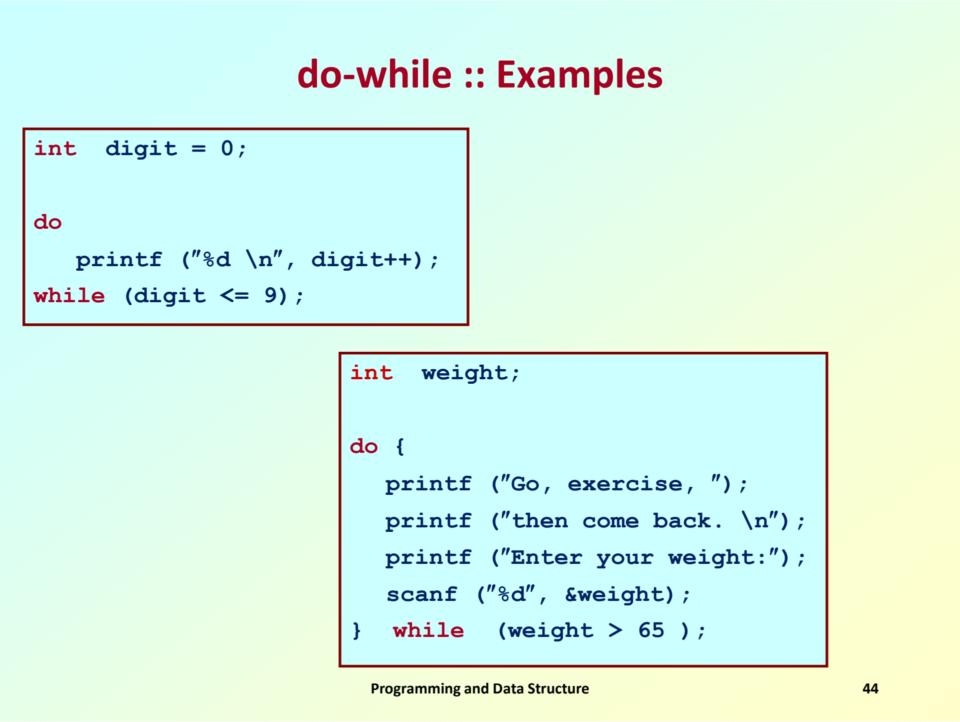
- Similar to "while", with the difference that the check for continuation is made at the *end* of each pass.
  - In "while", the check is made at the *beginning*.
- Loop body is executed *at least once*.

```
do
   statement_to_repeat;
while (condition );
```

```
do {
       statement-1;
       statement-2;

       statement-n;
     }   while (condition );
```



Single-entry / single-exit structure



do-while :: Examples

```
int  digit = 0;

do
   printf ("%d \n", digit++);
while (digit <= 9);
```

```
int  weight;

do {
   printf ("Go, exercise, ");
   printf ("then come back. \n");
   printf ("Enter your weight:");
   scanf  ("%d", &weight);
}  while  (weight > 65 );
```

for Statement

- The "for" statement is the most commonly used looping structure in C.
- General syntax:

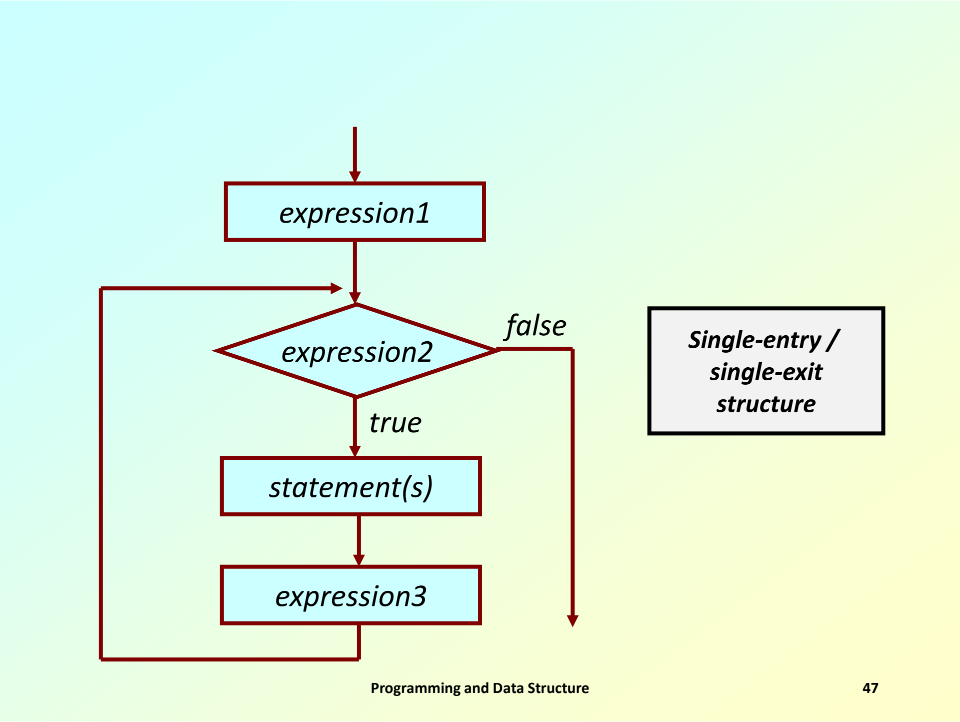
```
for (expression1; expression2; expression3)
  statement-to-repeat;
```

```
for (expression1; expression2; expression3)
{
  statement_1;
     :
  statement_N;
}
```

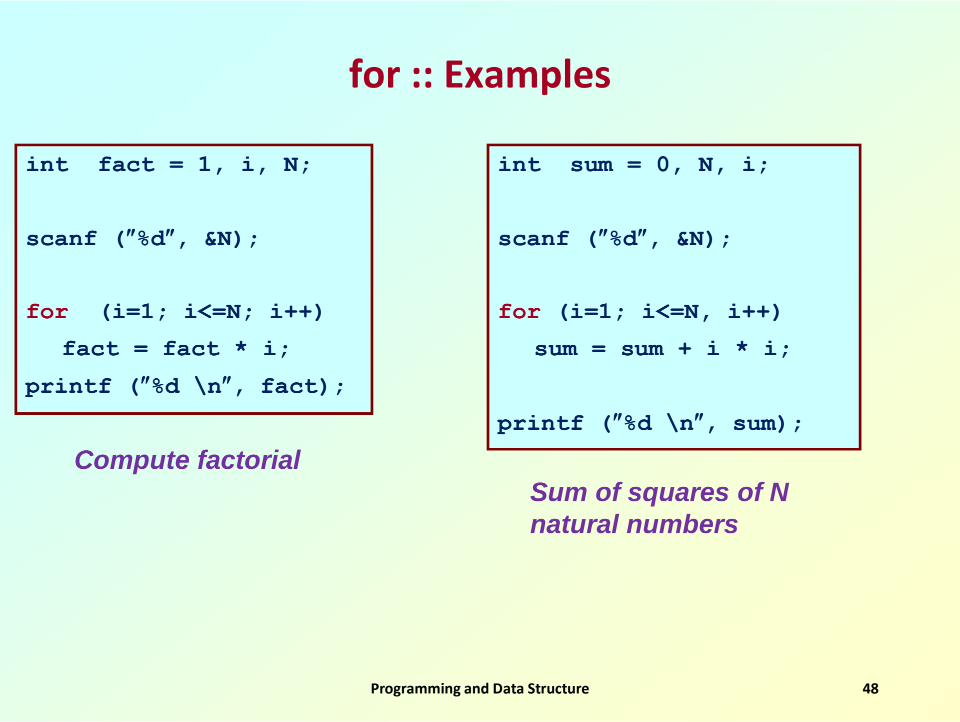
- How it works?
  - "expression1" is used to *initialize* some variable (called *index*) that controls the looping action.
  - "expression2" represents a *condition* that must be true for the loop to continue.
  - "expression3" is used to *alter* the value of the *index* initially assigned by "expression1".

```
int  digit;
for (digit=0; digit<=9;digit++)
  printf ("%d \n", digit);
```

```
int  digit;
for (digit=9;digit>=0;digit--)
   printf ("%d \n", digit);
```



Single-entry / single-exit structure



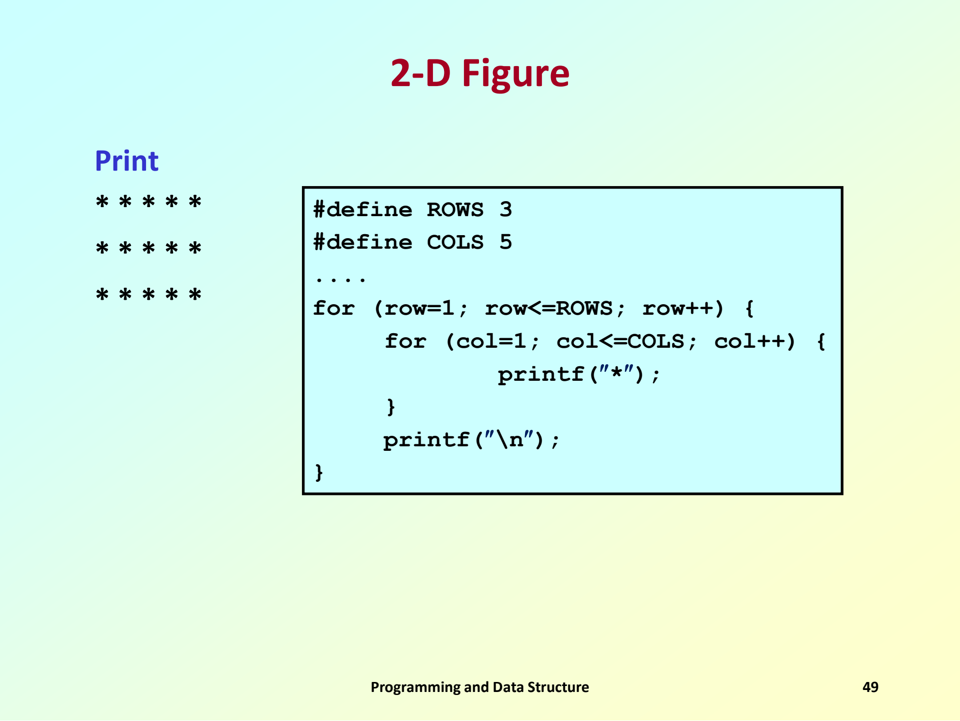
for :: Examples

```
int  fact = 1, i, N;

scanf ("%d", &N);

for  (i=1; i<=N; i++)
   fact = fact * i;
printf ("%d \n", fact);
```

Compute factorial

```
int  sum = 0, N, i;

scanf ("%d", &N);

for (i=1; i<=N, i++)
   sum = sum + i * i;

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

Sum of squares of N natural numbers

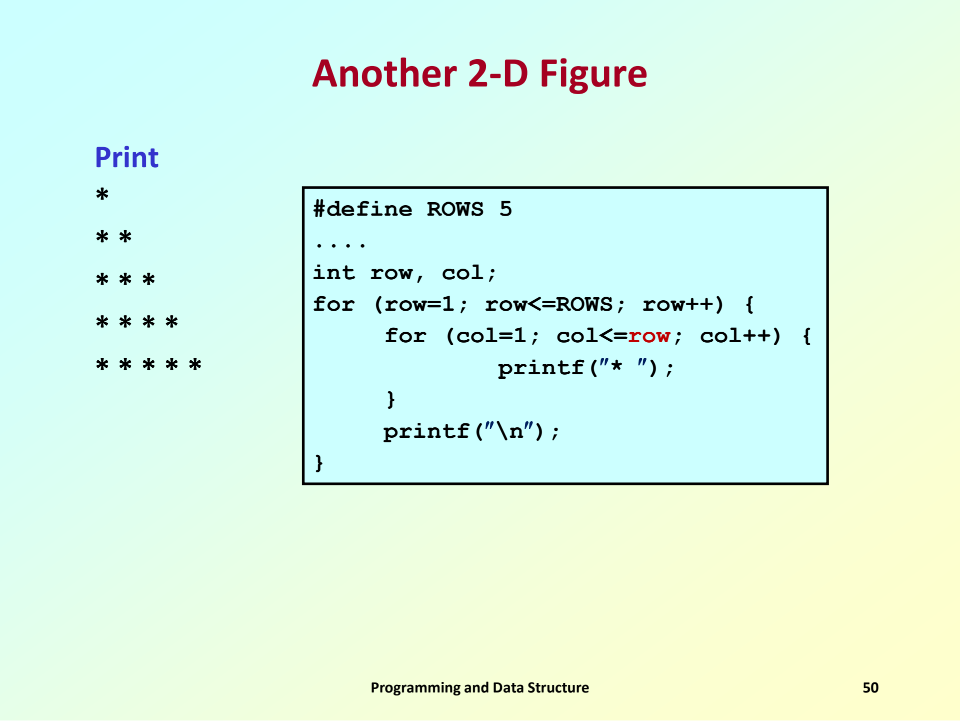


2-D Figure

Print

```
* * * * *
* * * * *
* * * * *
```

```
#define ROWS 3
#define COLS 5
....
for (row=1; row<=ROWS; row++) {
     for (col=1; col<=COLS; col++) {
              printf("*");
     }
     printf("\n");
}
```



Another 2-D Figure

Print

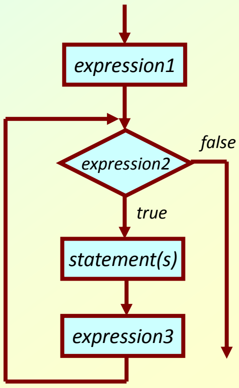
```
*
* *
* * *
* * * *
* * * * *
```

```
#define ROWS 5
....
int row, col;
for (row=1; row<=ROWS; row++) {
     for (col=1; col<=row; col++) {
              printf("* ");
     }
     printf("\n");
}
```

- The comma operator
  - We can give several statements separated by commas in place of “expression1”, “expression2”, and “expression3”.

```
for  (fact=1, i=1; i<=10; i++)
  fact = fact * i;
```

```
for (sum=0, i=1; i<=N, i++)
  sum = sum + i*i;
```



for :: Some Observations

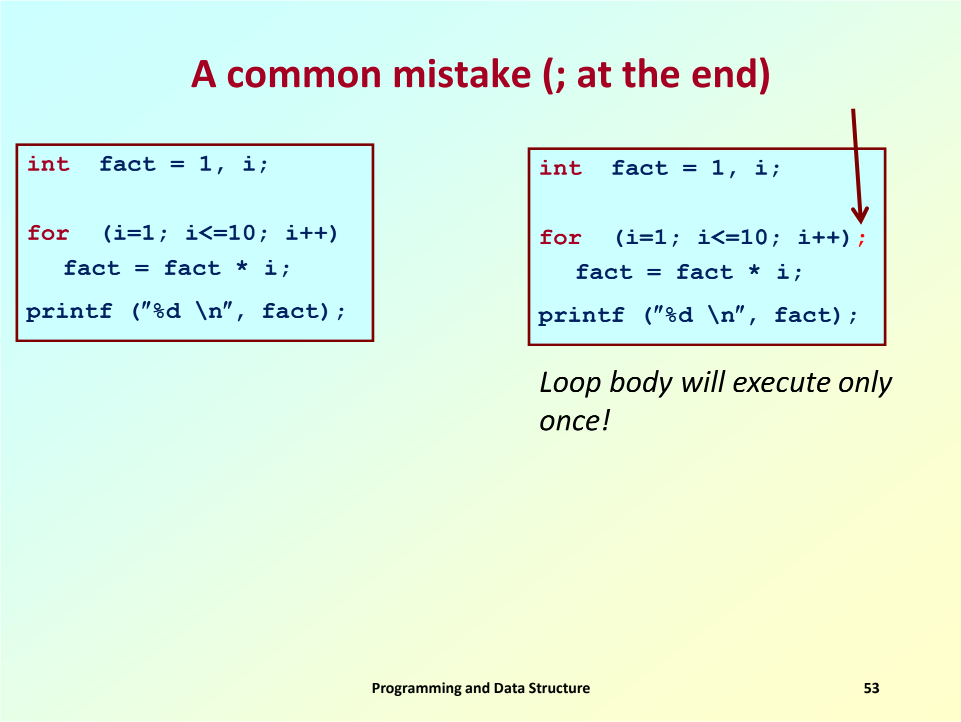
- Arithmetic expressions
  - Initialization, loop-continuation, and increment can contain arithmetic expressions.

```
for (k=x;  k <= 4*x*y;  k += y/x)
```

- "Increment" may be negative (decrement)

```
for  (digit=9; digit>=0; digit--)
```

- If loop continuation condition initially *false*:
  - Body of *for* structure not performed.
  - Control proceeds with statement after *for* structure.

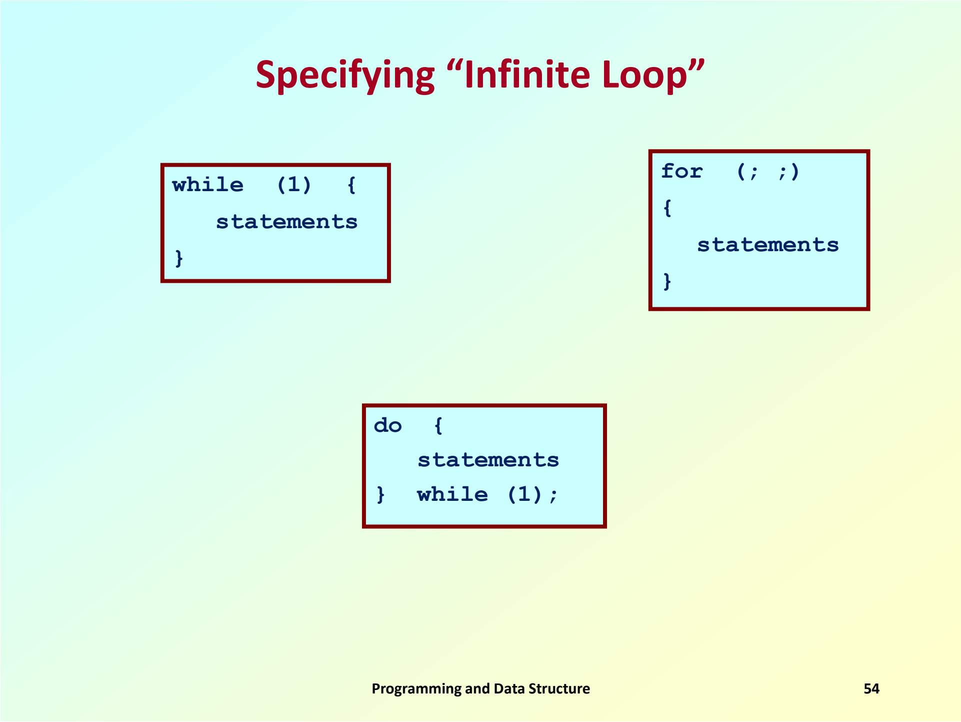


A common mistake (; at the end)

```
int  fact = 1, i;

for  (i=1; i<=10; i++)
   fact = fact * i;

printf (”%d \n”, fact);
```

```
int  fact = 1, i;

for  (i=1; i<=10; i++);
   fact = fact * i;

printf (”%d \n”, fact);
```

Loop body will execute only once!



Specifying “Infinite Loop”

```
while  (1)  {
   statements
}
```

```
for  (; ;)
{
   statements
}
```

```
do  {
   statements
}  while (1);
```

The “break” Statement Revisited

- Break out of the loop { }
  - can use with
    - while
    - do while
    - for
    - switch
  - does not work with
    - if
    - else
- Causes immediate exit from a *while*, *do/while*, *for* or *switch* structure.
- Program execution continues with the first statement after the structure.

An example with “*break*”

```
#include  <stdio.h>
main()
{
   int  fact, i;

   fact = 1;  i = 1;

   while  (i<10)     {      /* break when fact >100 */
        fact = fact * i;
        if ( fact > 100 )  {
               printf ("Factorial of %d above 100", i);
               break;      /* break out of the loop */
        }
        i++;
   }
}
```

The “continue” Statement

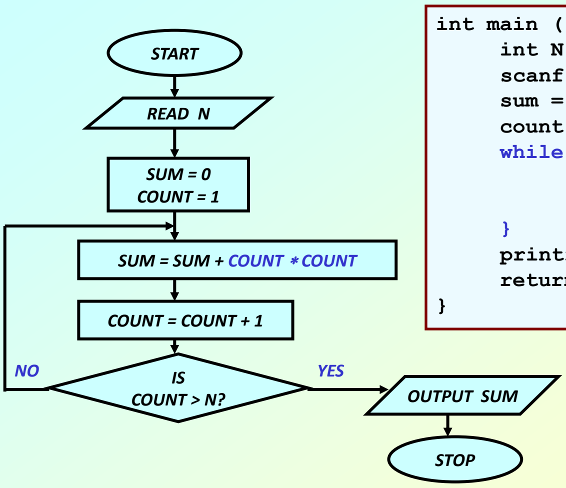
- Skips the remaining statements in the body of a ***while***, ***for*** or ***do/while*** structure.
  - Proceeds with the next iteration of the loop.
- while and do/while
  - Loop-continuation test is evaluated immediately after the continue statement is executed.
- for structure
  - ***expression3*** is evaluated, then ***expression2*** is evaluated.

An example with “*break*” and “*continue*”

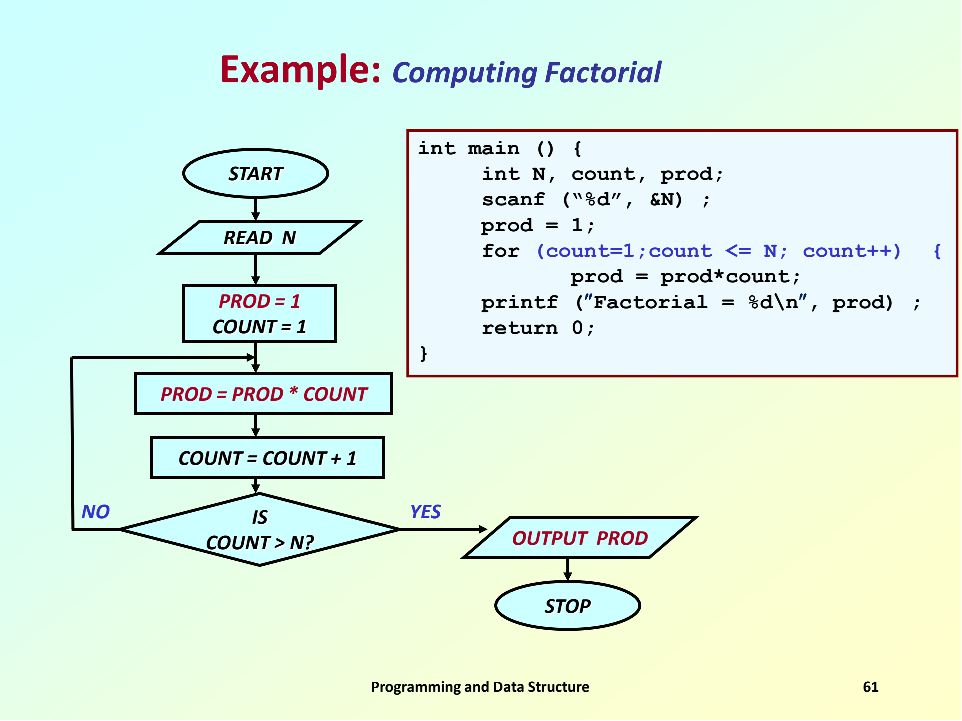
```
fact = 1; i = 1;     /* a program to calculate 10! */
while  (1)  {
   fact = fact * i;
   i ++;
   if (i<10)
        continue;     /* not done yet ! Go to loop and
                         perform next iteration*/
   break;
}
```

Some Examples

Example: *SUM = $1^2 + 2^2 + 3^2 + N^2$*

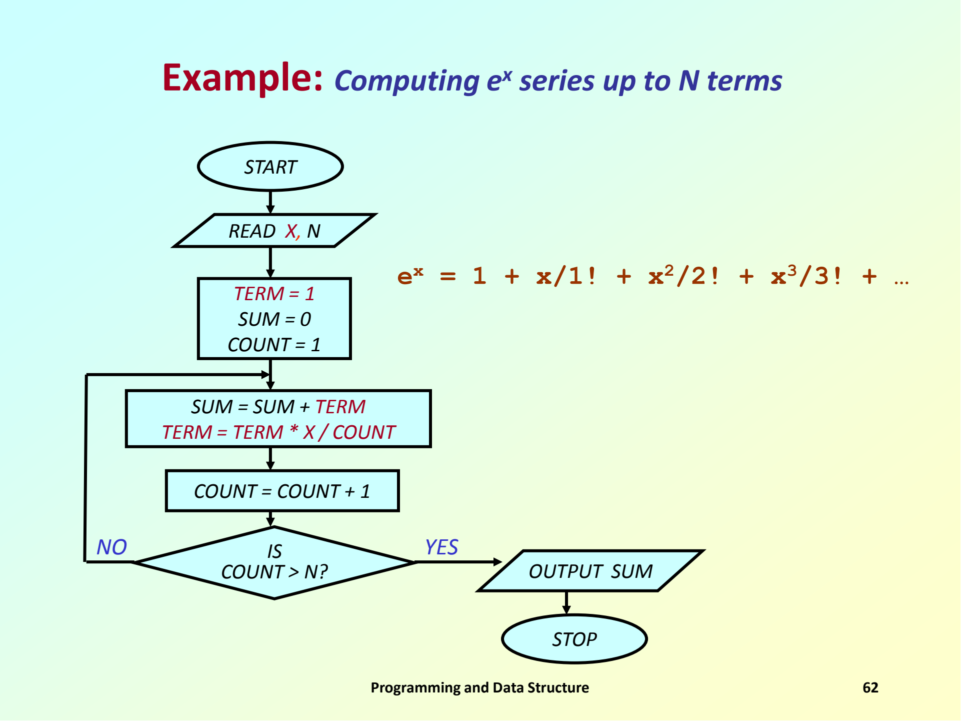


```
int main () {
      int N, count, sum;
      scanf ("%d", &N) ;
      sum = 0;
      count = 1;
      while (count <= N)   {
              sum = sum + count*count;
              count = count + 1;
      }
      printf ("Sum = %d\n", sum) ;
      return 0;
}
```



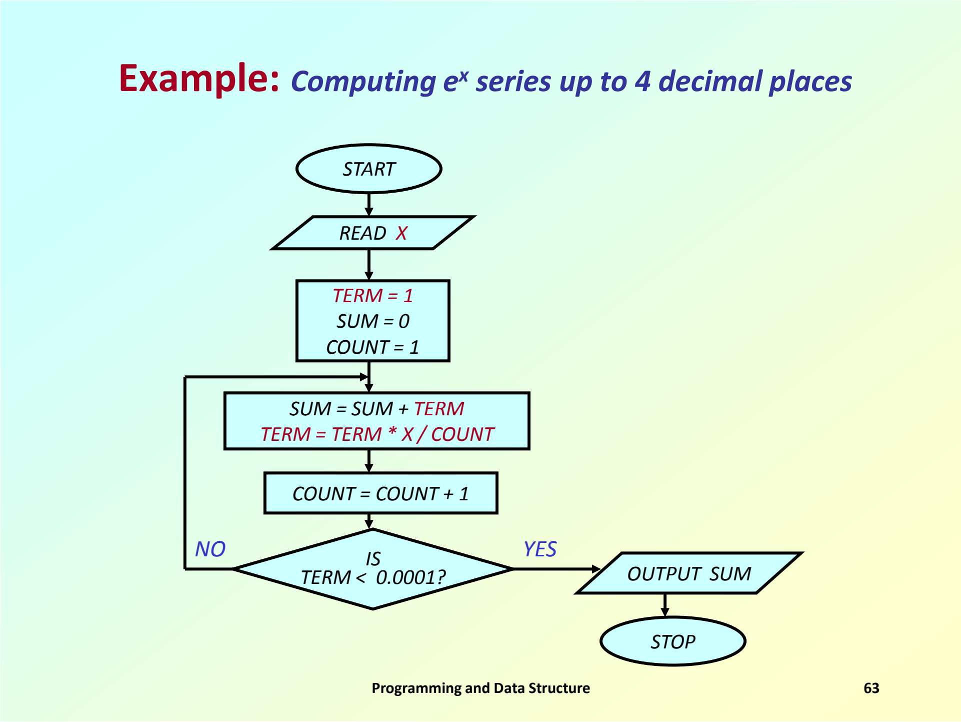
Example: *Computing Factorial*

```
int main () {
     int N, count, prod;
     scanf ("%d", &N) ;
     prod = 1;
     for (count=1;count <= N; count++)   {
          prod = prod*count;
     printf ("Factorial = %d\n", prod) ;
     return 0;
}
```



Example: *Computing e^x series up to N terms*

$e^x = 1 + x/1! + x^2/2! + x^3/3! + \ldots$



Example: *Computing e^x series up to 4 decimal places*

START

READ X

TERM = 1
SUM = 0
COUNT = 1

SUM = SUM + TERM
TERM = TERM * X / COUNT

COUNT = COUNT + 1

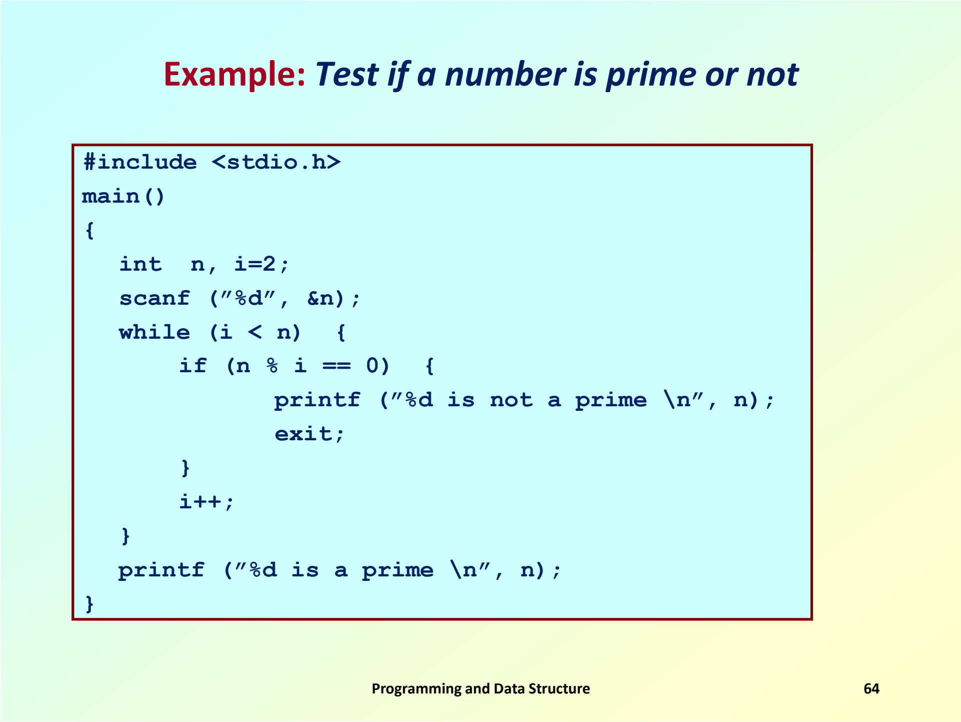
IS
TERM < 0.0001?

NO

YES

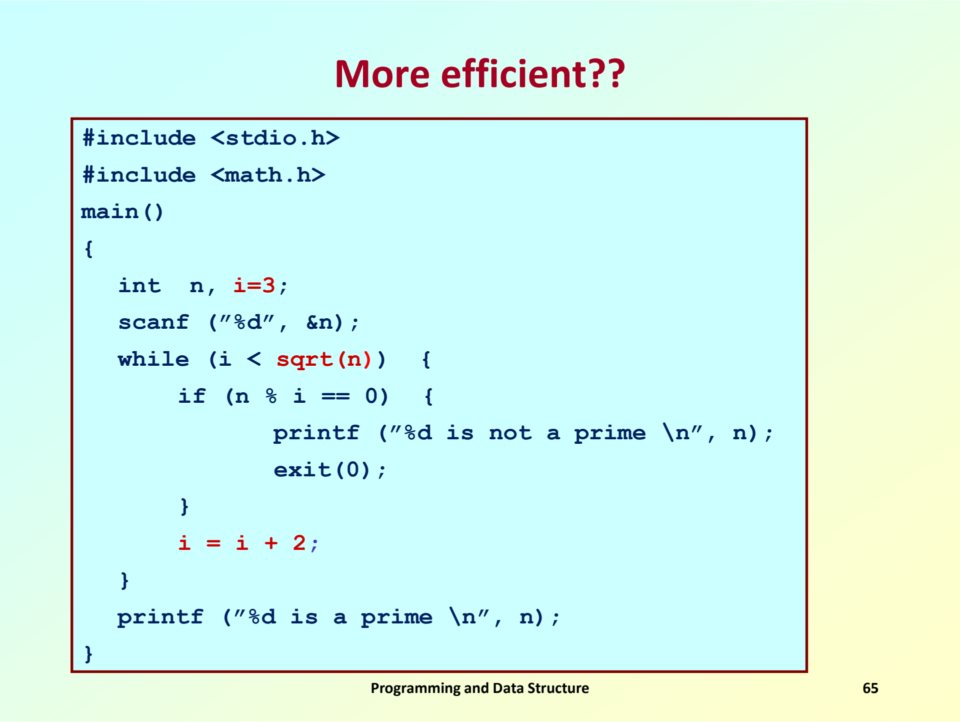
OUTPUT SUM

STOP



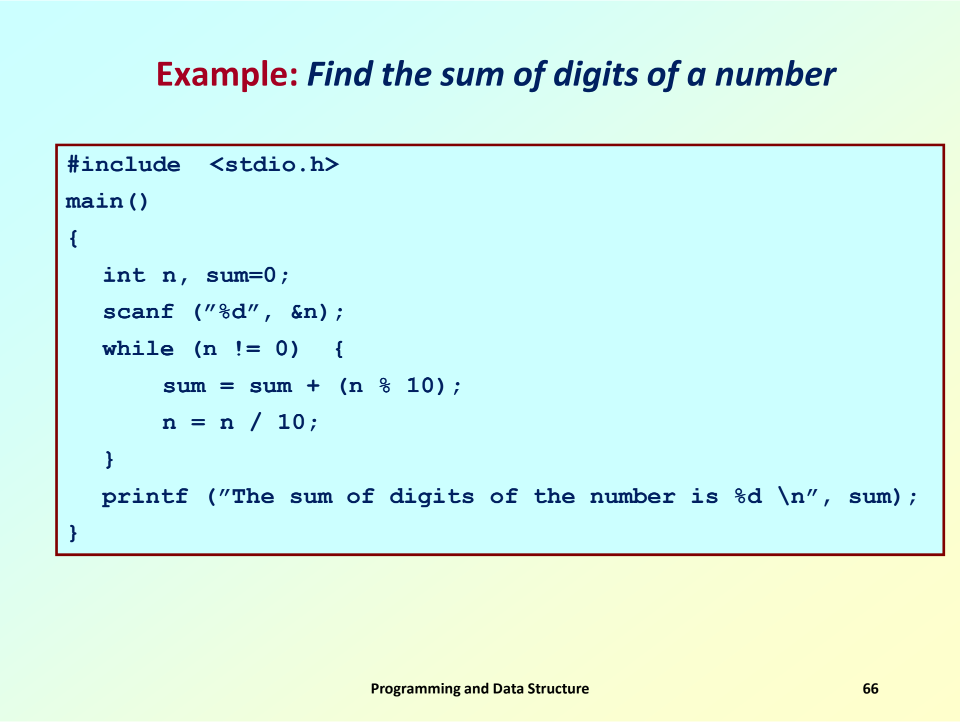
Example: *Test if a number is prime or not*

```
#include <stdio.h>
main()
{
   int  n, i=2;
   scanf ("%d", &n);
   while (i < n)  {
        if (n % i == 0)  {
                printf ("%d is not a prime \n", n);
                exit;
        }
        i++;
   }
   printf ("%d is a prime \n", n);
}
```



More efficient??

```
#include <stdio.h>
#include <math.h>
main()
{
   int  n, i=3;
   scanf (”%d”, &n);
   while (i < sqrt(n))  {
       if (n % i == 0)  {
              printf (”%d is not a prime \n”, n);
              exit(0);
       }
       i = i + 2;
   }
   printf (”%d is a prime \n”, n);
}
```



Example: *Find the sum of digits of a number*

```
#include  <stdio.h>
main()
{
   int n, sum=0;
   scanf (”%d”, &n);
   while (n != 0)  {
        sum = sum + (n % 10);
        n = n / 10;
   }
   printf (”The sum of digits of the number is %d \n”, sum);
}
```

Example: *Decimal to binary conversion*

```
#include  <stdio.h>
main()
{
   int  dec;
   scanf ("%d", &dec);
   do
   {
        printf ("%2d", (dec % 2));
        dec = dec / 2;
   }  while (dec != 0);
   printf ("\n");
}
```

Example: *Compute GCD of two numbers*

```
#include  <stdio.h>
main()
{
   int  A, B, temp;
   scanf ("%d %d", &A, &B);
   if  (A > B)
     {temp = A;  A = B;  B = temp;}
   while ((B % A) != 0)  {
        temp = B % A;
        B = A;
        A = temp;
   }
   printf ("The GCD is %d", A);
}
```

```
12 ) 45 ( 3
     36
     ──
      9 ) 12 ( 1
           9
          ──
           3 ) 9 ( 3
               9
              ──
               0
```

Initial: A=12, B=45
Iteration 1: temp=9, B=12,A=9
Iteration 2: temp=3, B=9, A=3
B % A = 0 ➔ GCD is 3

Shortcuts in Assignments

- Additional assignment operators:

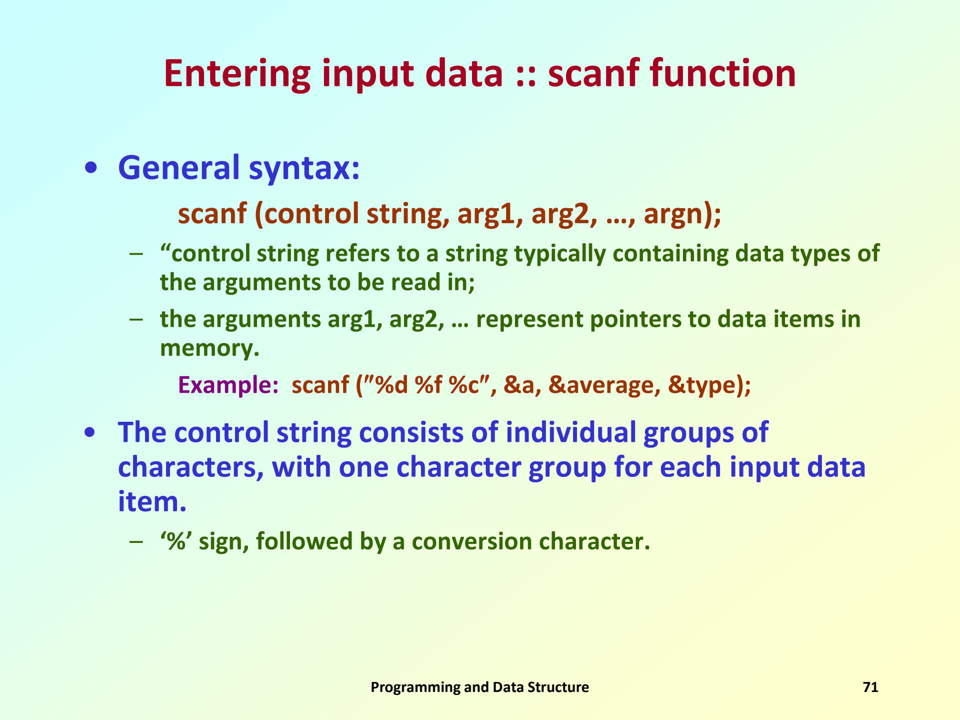
  + =, − =, * =, / =, % =

a += b is equivalent to a = a + b

a *= (b+10) is equivalent to a = a * (b + 10)

and so on.

More about scanf and printf



Entering input data :: scanf function

- General syntax:

  scanf (control string, arg1, arg2, …, argn);

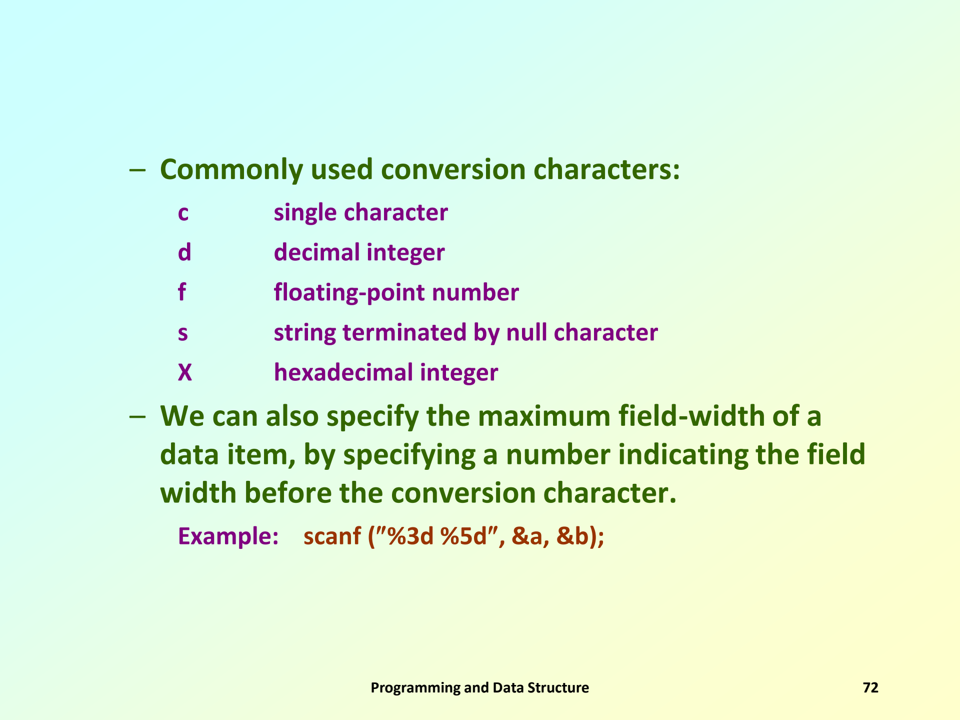
  – “control string refers to a string typically containing data types of the arguments to be read in;

  – the arguments arg1, arg2, … represent pointers to data items in memory.

  Example: scanf (”%d %f %c”, &a, &average, &type);

- The control string consists of individual groups of characters, with one character group for each input data item.

  – ‘%’ sign, followed by a conversion character.

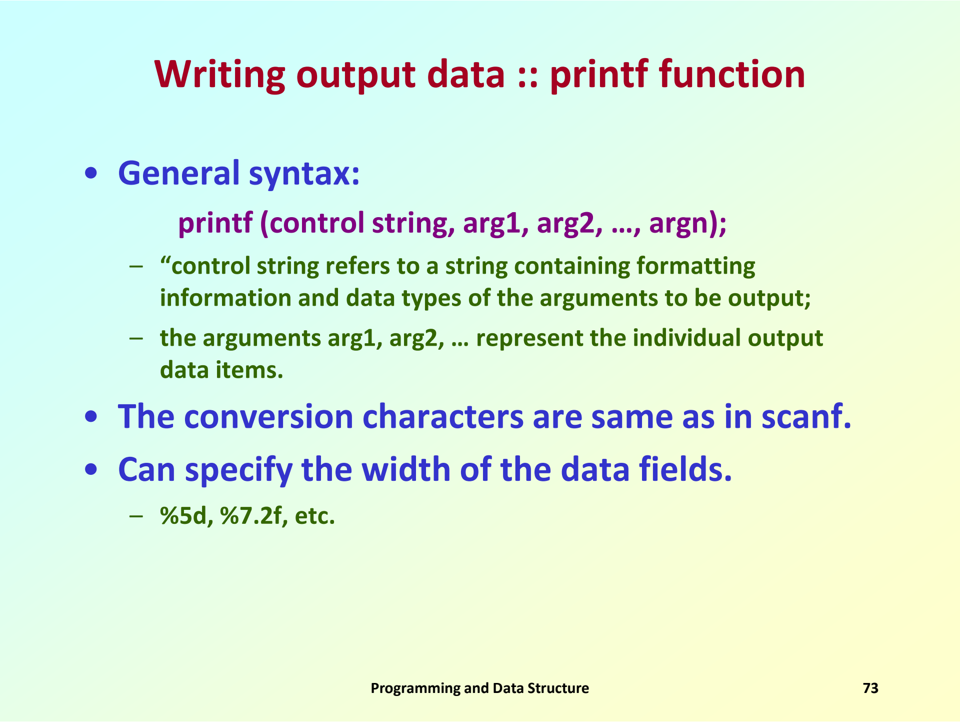


– Commonly used conversion characters:

c	single character
d	decimal integer
f	floating-point number
s	string terminated by null character
X	hexadecimal integer

– We can also specify the maximum field-width of a data item, by specifying a number indicating the field width before the conversion character.

Example: scanf (”%3d %5d”, &a, &b);

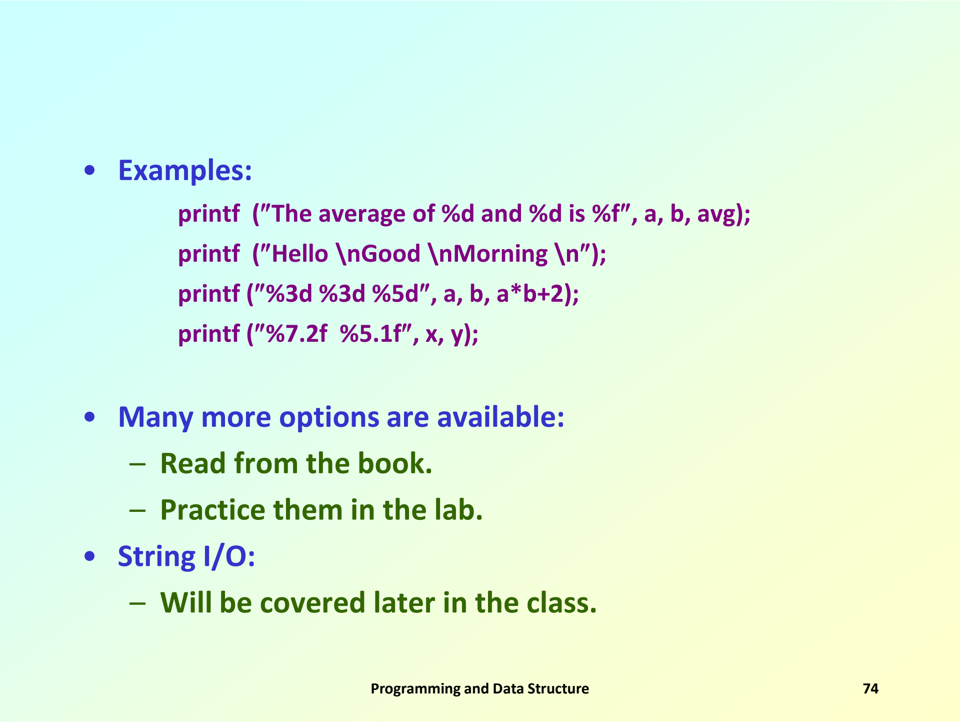


Writing output data :: printf function

- General syntax:

  printf (control string, arg1, arg2, …, argn);

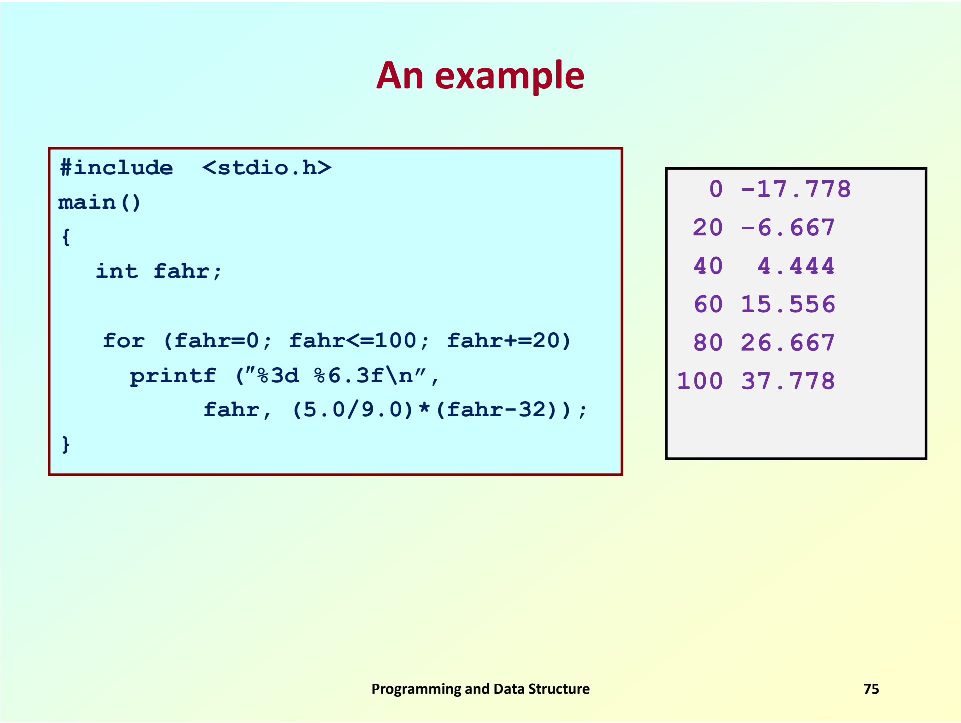
  - “control string refers to a string containing formatting information and data types of the arguments to be output;
  - the arguments arg1, arg2, … represent the individual output data items.
- The conversion characters are same as in scanf.
- Can specify the width of the data fields.
  - %5d, %7.2f, etc.



- Examples:

```
printf  (″The average of %d and %d is %f″, a, b, avg);
printf  (″Hello \nGood \nMorning \n″);
printf (″%3d %3d %5d″, a, b, a*b+2);
printf (″%7.2f  %5.1f″, x, y);
```

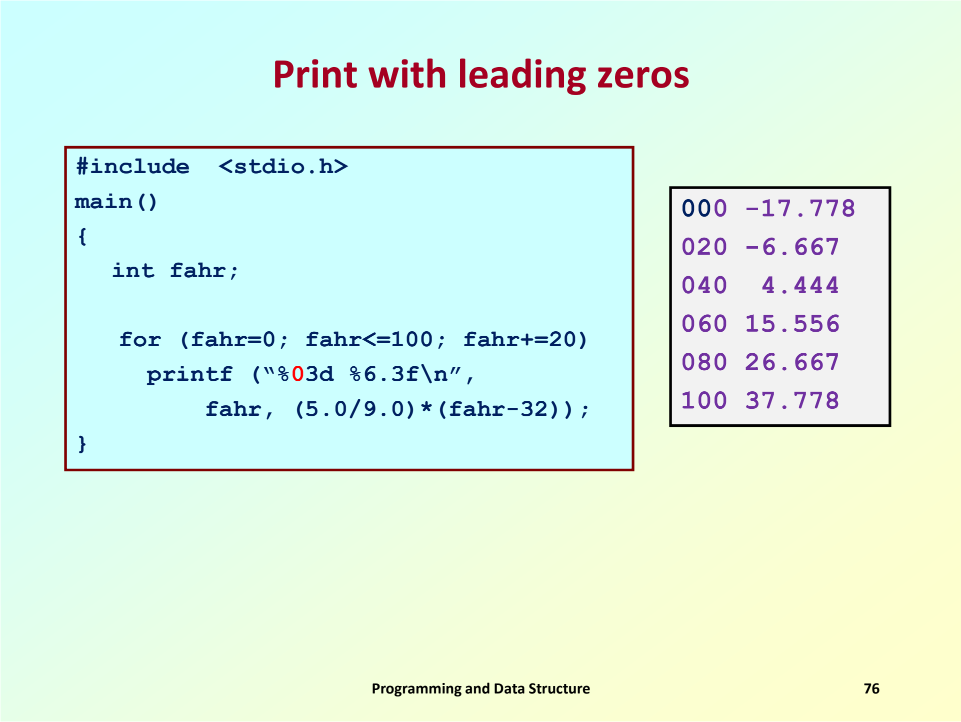
- Many more options are available:
  - Read from the book.
  - Practice them in the lab.
- String I/O:
  - Will be covered later in the class.



An example

```
#include  <stdio.h>
main()
{
   int fahr;

   for (fahr=0; fahr<=100; fahr+=20)
     printf ("%3d %6.3f\n”,
           fahr, (5.0/9.0)*(fahr-32));
}
```

```
  0 -17.778
 20 -6.667
 40  4.444
 60 15.556
 80 26.667
100 37.778
```



Print with leading zeros

```
#include  <stdio.h>
main()
{
   int fahr;

   for (fahr=0; fahr<=100; fahr+=20)
     printf (“%03d %6.3f\n”,
           fahr, (5.0/9.0)*(fahr-32));
}
```

```
000 -17.778
020 -6.667
040  4.444
060 15.556
080 26.667
100 37.778
```