Loops and Iteration

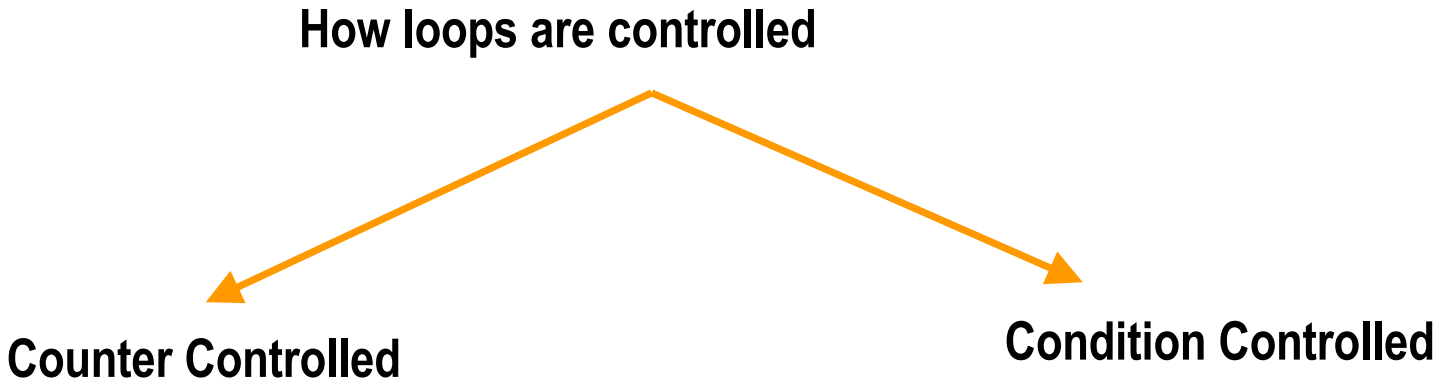
CS10003 PROGRAMMING AND DATA STRUCTURES

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Types of Repeated Execution

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

Each Execution of that Group of Instructions is called an **Iteration** of the loop



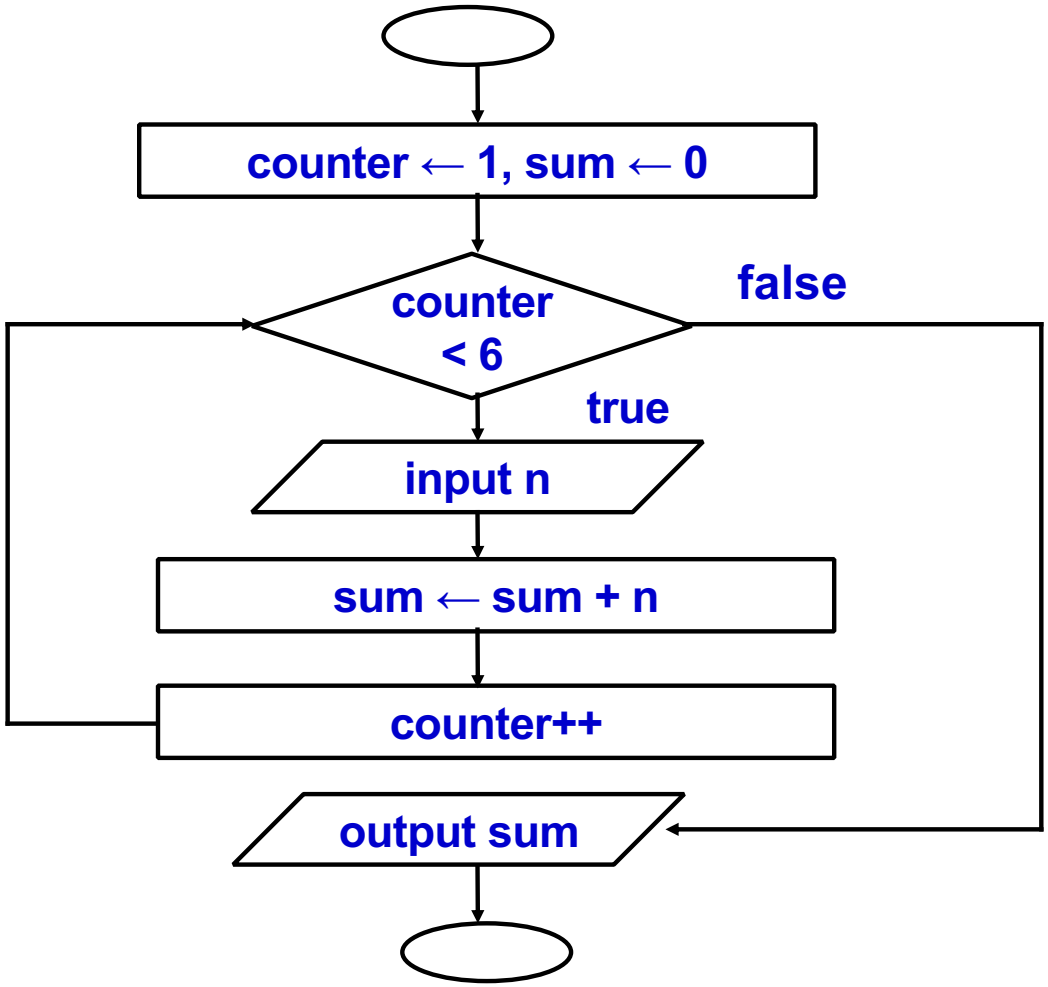
Counter Controlled Loop

Read 5 integers and display the value of their sum.

In this example, the loop 'counts up' to a maximum value (input).

We can also have loops that 'count down'.

While starting the loop, we know how many times the loop has to be executed

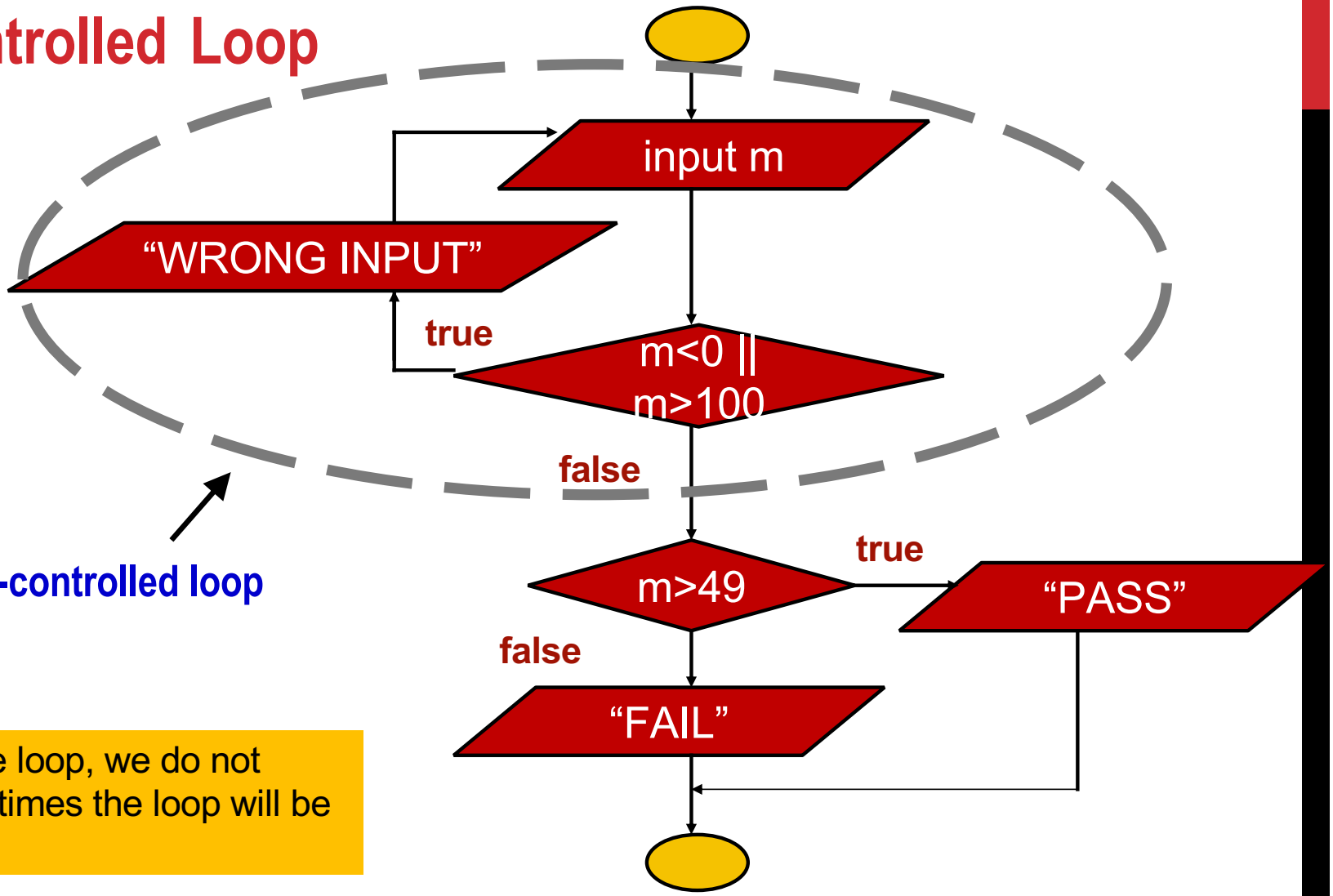


Condition-controlled Loop

Given an exam marks as input, display the appropriate message based on the rules below:

- If marks is greater than 49, display “PASS”, otherwise display “FAIL”
- However, if input is outside the 0-100 range, display “WRONG INPUT” and prompt the user to input again until a valid input is entered

Condition-Controlled Loop



While starting the loop, we do not know how many times the loop will be executed

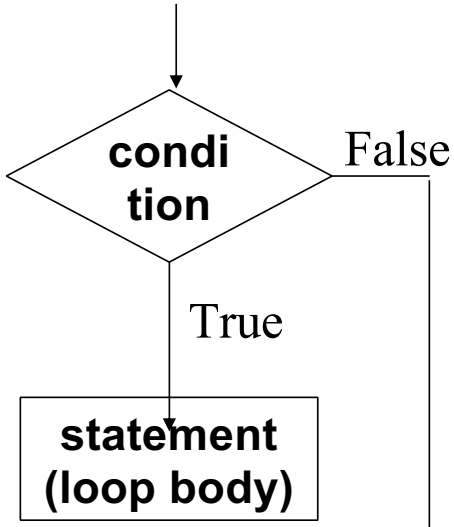
while Statement

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;
}
```

while-block
(loop body)



The condition to be tested is any expression enclosed in parentheses. The condition is evaluated, and if its value is true (non-zero), the loop-body is executed. Then the condition is evaluated again and the same sequence of operations repeats. The loop terminates when the condition evaluates to 0 or false.

Note: The while-loop will not be entered at all, if the loop-control condition evaluates to false (zero) even before the first iteration.

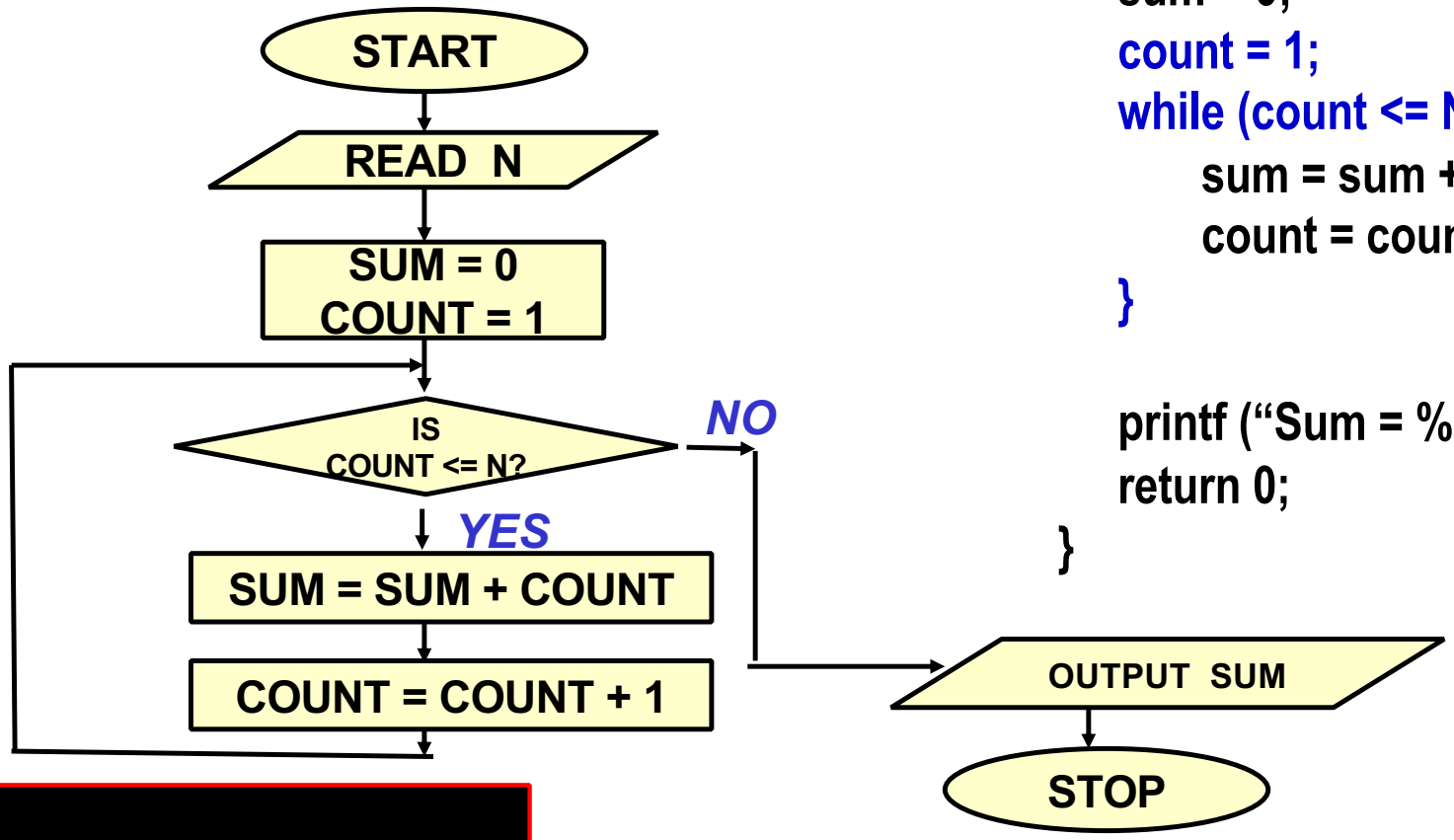
Example

```
int main()
{
        int i = 1, n;
        scanf("%d", &n);
        while (i <= n)  {
            printf ("Line no : %d\n",i);
            i = i + 1;
        }
}
```

Output

```
4
Line no : 1
Line no : 2
Line no : 3
Line no : 4
```

Sum of first 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;
}
```

Output

```
9
Sum of first 9 numbers = 45
```

Maximum of positive inputs

```
int main() {
    double max = 0.0, next;
    printf ("Enter positive numbers only, end with 0 or a negative number\n");
    scanf("%lf", &next);
    while (next > 0)  {
        if (next > max)  max = next;
        scanf("%f", &next);
    }
    printf ("The maximum number is %lf\n", max) ;
    return 0;
}
```

Output

```
Enter positive numbers only, end with 0 or a negative number
45
32
7
5
0
The maximum number is 45.000000
```

Find the sum of digits of a number

```
int main()
{
        int n, sum=0;
        scanf ("%d", &n);
        while (n != 0)  {
                sum = sum + (n % 10);
                n = n / 10;
        }
        printf ("The sum of digits is %d\n", sum);
   return 0;
}
```

Output

```
573254
The sum of digits is 26
```

Note how to separate out the digits of an integer number

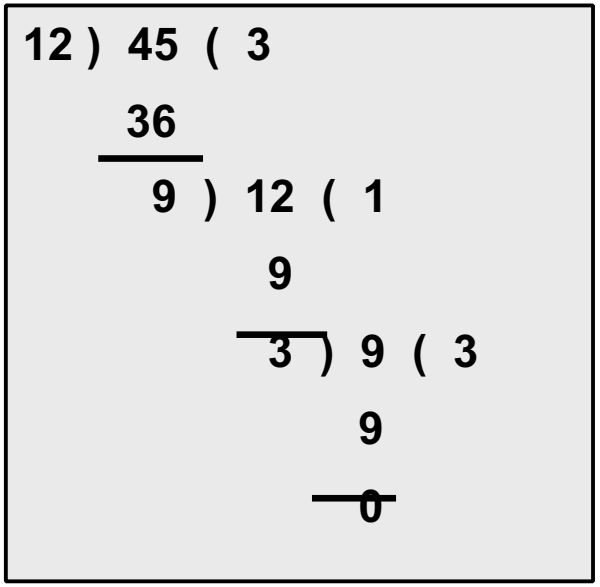
Double your money

Suppose your Rs 10000 is earning interest at 1% per month. How many months until you double your money?

```
int main() {
   double my_money = 10000.0;
   int n=0;
   while (my_money < 20000.0) {
      my_money = my_money * 1.01;
      n++;
   }
  printf (“My money will double in %d months.”, n);
  return 0;
}
```

Compute GCD of two numbers

```
int 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);
  return 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

Which expressions decide how long a while loop will run?

```
int main()
{
        int i = 1, n;
        scanf("%d", &n);
        while (i <= n)  {
            printf ("Line no : %d\n",i);
            i = i + 1;
        }
}
```

Initialization of the loop control variable

Test condition

Updation of loop control variable in each iteration

Next, we will see another way of writing the same loop, where these 3 parts will be written together

Looping: for Statement

Most commonly used looping structure in C

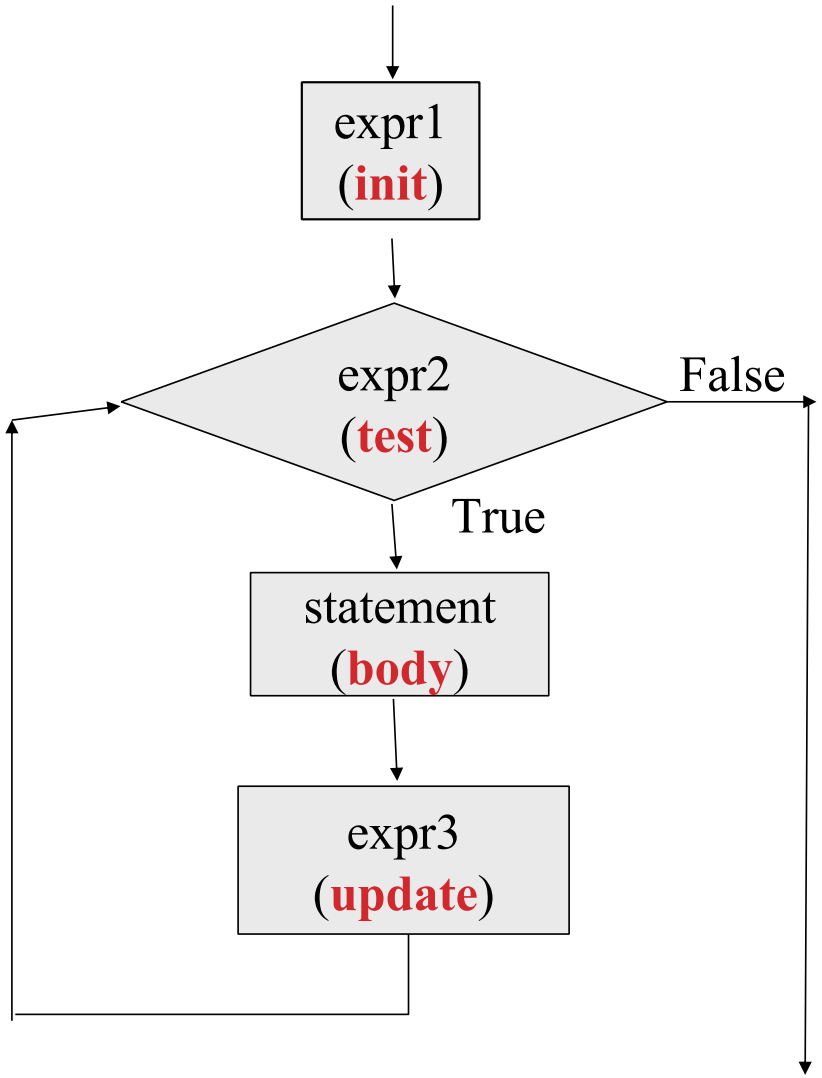
```
for ( expr1; expr2; expr3)
    statement;

for ( expr1; expr2; expr3)
{
    Block of statements;
}
```

expr1 (init) : initialize parameters

expr2 (test): test condition, loop continues if expression is non-0

expr3 (update): used to alter the value of the parameters after each iteration

statement (body): body of loop



Equivalence of for and while

```
for ( expr1; expr2; expr3)
        statement;
```

Same as

```
expr1;
while (expr2)  {
      statement
      expr3;
}
```

Sum of first N natural numbers

```
int main () {
    int N, count, sum;
    scanf ("%d", &N) ;

    sum = 0;
    count = 1;
    while (count <= N)  {
        sum = sum + count;
        count++;
    }

    printf ("Sum = %d\n", sum) ;
    return 0;
}
```

```
int main () {
    int N, count, sum;
    scanf ("%d", &N) ;

    sum = 0;
    for (count=1; count <= N; count++)
        sum = sum + count;

    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;
}
```

Output

```
7
Factorial = 5040
```

Example: *Computing e^x series up to N terms* (1 + x + (x^2 / 2!) + (x^3 / 3!) + …)

```
int main () {
    float x, term, sum;
    int n, count;
    scanf ("%f", &x);
    scanf ("%d", &n);
    term = 1.0; sum = 0;
    for (count = 1; count <= n; ++count)  {
        sum += term;
        term *= x/count;
     }
    printf ("The series sum is %f\n", sum);
    return 0;
}
```

Instead of computing each term from scratch, we are using one term (that we have already calculated) to compute the next term.

This makes the program more efficient, reduces the number of operations

Output

```
2.3
10
The series sum is 9.972747
```

Some observations on for

Initialization, loop-continuation test, and update can contain arithmetic expressions

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

Update may be negative (decrement)

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

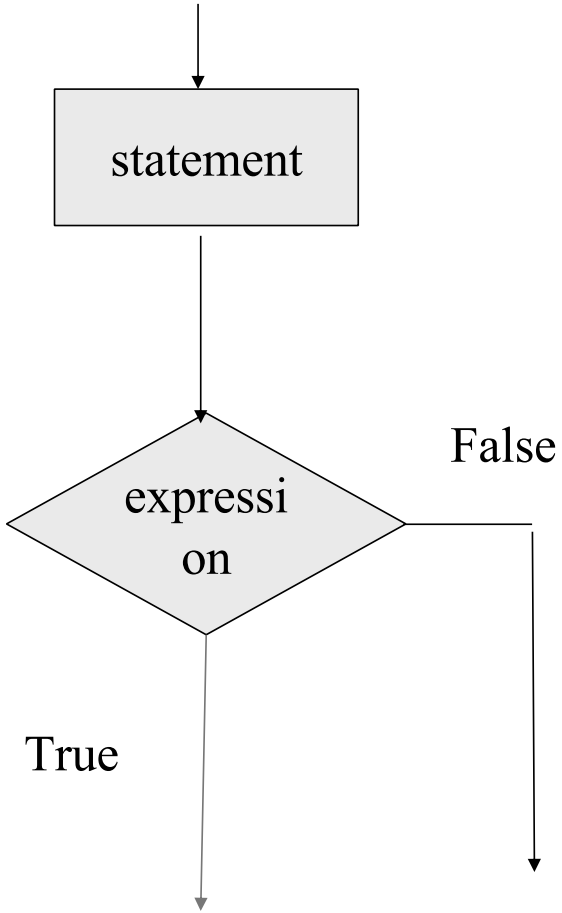
If loop continuation test is initially 0 (false)

- Body of for structure not performed
  - No statement executed
- Program proceeds with statement after for structure
- This is exactly the same as in the case of while loop

Looping: do-while statement

```
do
   statement;
while (expression);


do {
   Block of statements;
} while (expression);
```

```
main () {
    int digit=0;
    do
        printf("%d\n",digit++);
     while (digit <= 9) ;
}
```



Example

Problem: Prompt user to input “month” value, keep prompting until a correct value of month is given as input

```
do {
        printf (“Please input month {1-12}”);
         scanf (“%d”, &month);
} while ((month < 1) || (month > 12));
```

Echo characters typed on screen until end of line

```
int main () {
    char echo ;
    do {
        scanf ("%c", &echo);
        printf ("%c", echo);
     }  while (echo != '\n') ;
     return 0;
}
```

Output

```
This is a test line
This is a test line
```

Specifying “Infinite Loop”

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

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

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

The break Statement

Break out of the loop { }

- can use with
  - while
  - do while
  - for
  - switch
- does not work with
  - if
  - if-else

Causes immediate exit from a *while*, *do/while*, *for* or *switch* structure.

Program execution continues with the first statement after the structure.

Example: *Find smallest n such that n! exceeds 100*

```
#include  <stdio.h>
int main() {
        int  fact, i;
        fact = 1;  i = 1;
        while  (1)   {          /* run loop –break when fact >100*/
                fact = fact * i;
                if ( fact > 100 )  {
                        printf ("Factorial of %d  above 100", i);
                        break;          /* break out of the while loop */
                }
                i ++ ;
        }
return 0;
}
```

Test if a number is prime or not

```
int main() {
        int  n, i=2;
        scanf (“%d”, &n);
   limit = sqrt(n);
        for (i = 2; i <= limit; i++)  {
                if (n % i == 0)  {
                        printf (“%d is not a prime \n”, n);
                        break;
                }
        }
        if (i > limit) printf (“%d is a prime \n”, n);
   return 0;
}
```

Another way to test if a number is prime

```
int main() {
        int  n, i = 2, flag = 0;
   double limit;
        scanf ("%d", &n);
   limit = sqrt(n);
        while (i <= limit)  {
                if (n % i == 0)  {
                        printf ("%d is not a prime \n", n);
                        flag = 1; break;
                }
                i = i + 1;
        }
        if (flag == 0) printf ("%d is a prime \n", n);
   return 0;
}
```

The continue Statement

Skips the remaining statements in the body of a *while*, *for* or *do/while* structure in the ongoing iteration.

- **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.**

Example with break and continue:

Add positive numbers until a 0 is typed, but ignore any negative numbers typed

```
int main() {
    int sum = 0, next;
            while (1)  {
                    scanf("%d", &next);
                    if (next < 0)  continue;
                    else if (next == 0) break;
                    sum = sum + next;
            }
    printf ("Sum = %d\n", sum) ;
    return 0;
}
```

Output

```
10
-20
30
40
-5
10
0
Sum = 90
```

Some Loop Pitfalls

```
while (sum <= NUM) ;
    sum = sum+2;
```

```
for (i=0; i<=NUM; ++i);
    sum = sum+i;
```

```
for (i=1; i!=10; i=i+2)
    sum = sum+i;
```

Nested Loops: Printing a 2-D Figure

How would you print the following diagram?

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

```
repeat 3 times
    print a row of 5 *'s
```

```
repeat 5 times
    print *
```

Nested Loops (full program on next slide)

```
#define ROWS 3
#define COLS 5
...
row=1;
while (row <= ROWS) {
    /* print a row of 5 *'s */
     …
    printf("\n");
    row++;
}
```

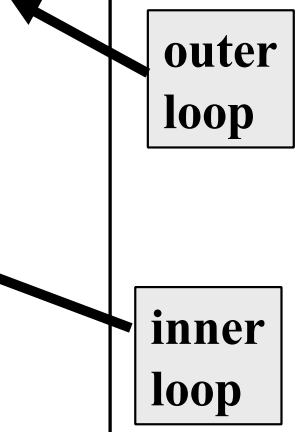
```
while (col <= COLS) {
        printf ("* ");
        col++;
}
```

Nested Loops

For every iteration of the outer loop, the inner loop runs its entire length (all iterations)

```
const int ROWS = 3;
const int COLS = 5;
...
row = 1;
while (row <= ROWS) {
    /* print a row of 5 *'s */
     ...
    ++row;
}
```

```
row = 1;
while (row <= ROWS) {
    /* print a row of 5 *'s */
    col = 1;
    while (col <= COLS) {
        printf ("* ");
        col++;
    }
    printf("\n");
    ++row;
}
```



2-D Figure: with for loop

Print

* * * * *

* * * * *

* * * * *

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

Another 2-D Figure

Print

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

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

Yet Another One

Print

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

```
const int ROWS = 5;
....
int row, col;
for (row=0; row<ROWS; ++row)  {
      for (col=1; col<=row; ++col)
            printf("  ");
      for (col=1; col<=ROWS-row; ++col)
            printf("* ");
      printf ("\n");
}
```

Each row contains a certain number of blank spaces (may be zero), followed by a certain number of *

Two inner loops within the outer loop:
First inner loop prints the blanks
Second inner loop prints the *

break and continue with nested loops

For nested loops, break and continue are matched with the nearest loops (for, while, do-while)

Example:

```
while (i < n) {
    for (k=1; k < m; ++k) {
      if  (k % i == 0) break;
    }
    i = i + 1;
  }
```

Breaks here

Example

```
int main()
{
    int low, high, desired, i, flag = 0;
    scanf("%d %d %d", &low, &high, &desired);
    i = low;
    while (i < high) {
      for (j = i+1; j <= high; ++j) {
            if  (j % i == desired) {
                flag = 1;
                  break;
             } // end if
      } // end for
      if (flag == 1) break;
      i = i + 1;
    } // end while

    return 0;
}
```

Breaks here

Breaks here

The comma operator

- Separates expressions
- Syntax

  expr-1, expr-2, …,expr-n

  where expr-1, expr-2,…are all expressions

- Is itself an expression, which evaluates to the value of the last expression in the sequence
- Useful in for loops, by using side effects of the expressions

Example

- We can give several expressions separated by commas in place of expr1 and expr3 in a for loop to do multiple assignments for example

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

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

Practice Problems

Practice Problems (do each with both for and while loops separately)

1. Read in an integer N. Then print the sum of the squares of the first N natural numbers
2. Read in an integer N. Then read in N numbers and print their maximum and second maximum (do not use arrays even if you know it)
3. Read in an integer N. Then read in N numbers and print the number of integers between 0 and 10 (including both), between 11 and 20, and > 20. (do not use arrays even if you know it)
4. Repeat 3, but this time print the average of the numbers in each range.
5. Read in a positive integer N. If the user enters a negative integer or 0, print a message asking the user to enter the integer again. When the user enters a positive integer N finally, find the sum of the logarithmic series ($\log_e(1+x)$) upto the first N terms
6. Read in an integer N. Then read in integers, and find the sum of the first N positive integers read. Ignore any negative integers or 0 read (so you may actually read in more than N integers, just find the sum with only the positive integers and stop when N such positive integers are read)
7. Read in characters until the '\n' character is typed. Count and print the number of lowercase letters, the number of uppercase letters, and the number of digits entered.