CS100
Introduction to Programming

Lecture 4. Control Flow

Learning Objectives

- At the end of this lecture, you will be able to understand and use the following:
  - Relational and logical operators
  - if, if …else statements
  - if … else if … else statements
  - Nested if statements
  - switch statements
  - while loops
  - for loops
  - do-while loops
  - Break and continue statements
  - Nested loops

Relational Operators

Used for **comparison** between **two values**.

Return **Boolean** result: **true** or **false**.

Relational Operators:

operator	example	meaning
==	ch == 'a'	equal to
!=	f != 0.0	not equal to
<	num < 10	less than
<=	num <=10	less than or equal to
>	f > -5.0	greater than
>=	f >= 0.0	greater than or equal to

Logical Operators

- Work on one or more relational expressions to yield a logical value: **true** or **false**.
- Allow testing and combining the results of comparison expressions.

Logical Operators:

operator	example	meaning
!	!(num < 0)	not
&&	(num1 > num2) && (num2 >num3)	and
||	(ch == '\t') || (ch == ' ')	or

	A is true	A is false
!A	false	true

A && B	A is true	A is false
B is true	true	false
B is false	false	false

A || B	A is true	A is false
B is true	true	true
B is false	true	false

Precedence of operators

- List of operators of **decreasing precedence**:

!	not
* /	multiply and divide
+ -	add and subtract
< <= > >=	less, less or equal, greater, greater or equal
== !=	equal, not equal
&&	logical and
||	logical or

- **Example**: The expression `!(5 >= 3)||(7 > 3)` is true, where the **logical or operator ||** is executed in the end.

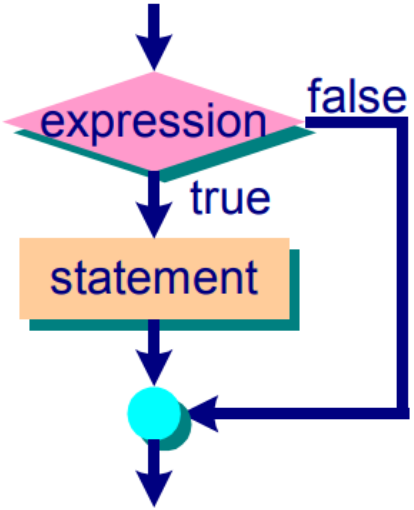
Boolean Result

- The result of evaluating an expression involving relational and/or logical operators is
  - either **true** or **false**
  - either **1** or **0**
  - When the result is **true**, it is **1**. Otherwise, it is **0**. That is, the C language uses 0 to represent a false condition.
- In general, **any integer expression whose value is non-zero is considered true**; otherwise it is **false**.
- Examples:

`3`	is true
`0`	is false
`1 || 0`	is true
`!(5 >= 3) || 0`	is false

The if Statement

```
if (expression)
    statement;
    /* simple or compound statement
    enclosed with brackets */
```




```
#include <stdio.h>
int main(void)
{
   int num;  /* value supplied by user. */
   printf("Give an integer from 1 to 10: ");
   scanf("%d", &num);
   if (num > 5)
      printf("Your number is larger than 5.\n");
   printf("%d is the number you entered.\n", num);
   return 0;
}
```

Output 1:

Give an integer from 1 to 10: ***3***

3 is the number you entered.

Output 2:

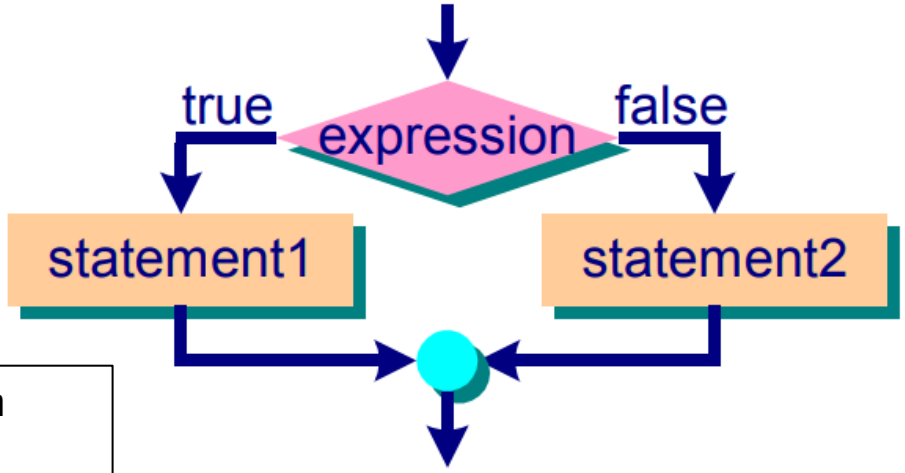
Give an integer from 1 to 10: ***7***

Your number is larger than 5.

7 is the number you entered.

The if-else Statement

```
if (expression)
    statement1;
else
    statement2;
```




```
/* This program computes the maximum
value of num1 and num2 */
#include <stdio.h>
int main(void)
{
   int num1, num2, max;
   printf("Please enter two integers:");
   scanf("%d %d", &num1, &num2);
   if (num1 > num2)
      max = num1;
   else
      max = num2;
   printf("The maximum of the two \
        is %d\n", max);
   return 0;
}
```

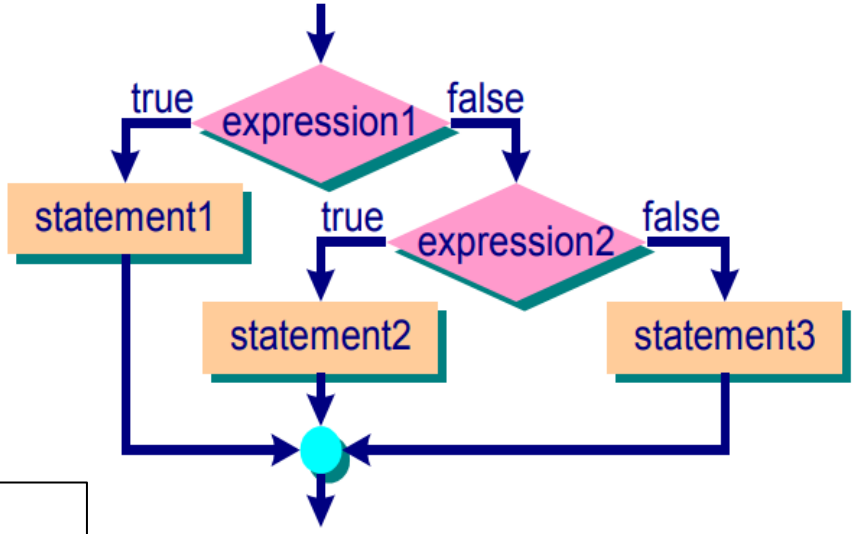
Output:

Please enter two integers: ***9 4***
The maximum of the two is 9

Please enter two integers: ***-2 0***
The maximum of the two is 0

The if…else if…else Statement

```
if (expression1)
    statement1;
else if (expression2)
    statement2;
else
    statement3;
```




```
#include <stdio.h>
int main(void)
{
   float temp;  // temperature reading.
   printf("Temperature reading:");
   scanf("%f", &temp);
   if (temp >= 100.00 && temp <= 120.0)
      printf("Temperature OK.\n");
   else if (temp < 100.0)
      printf("Temperature too low.\n");
   else
      printf("Temperature too high.\n");
   return 0;
}
```

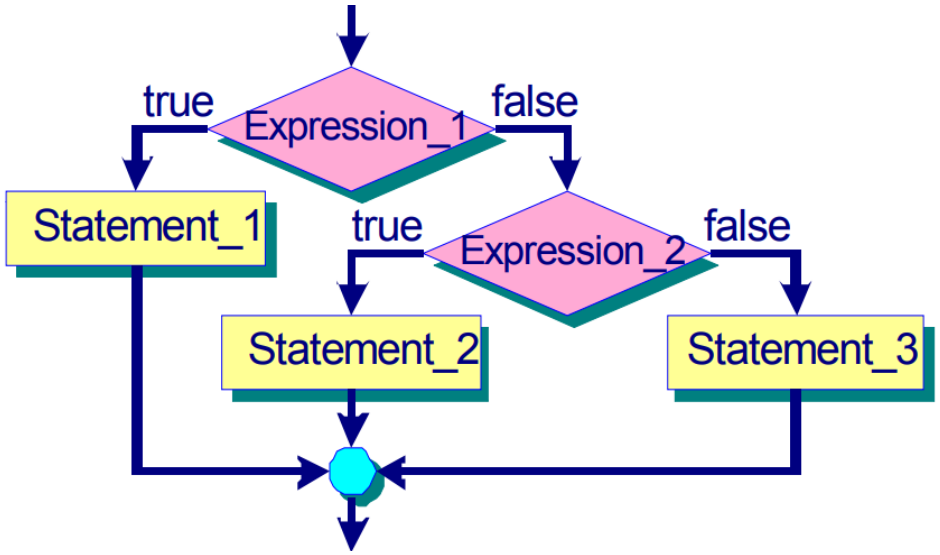
Output:

Temperature reading: ***105.0***
Temperature OK.

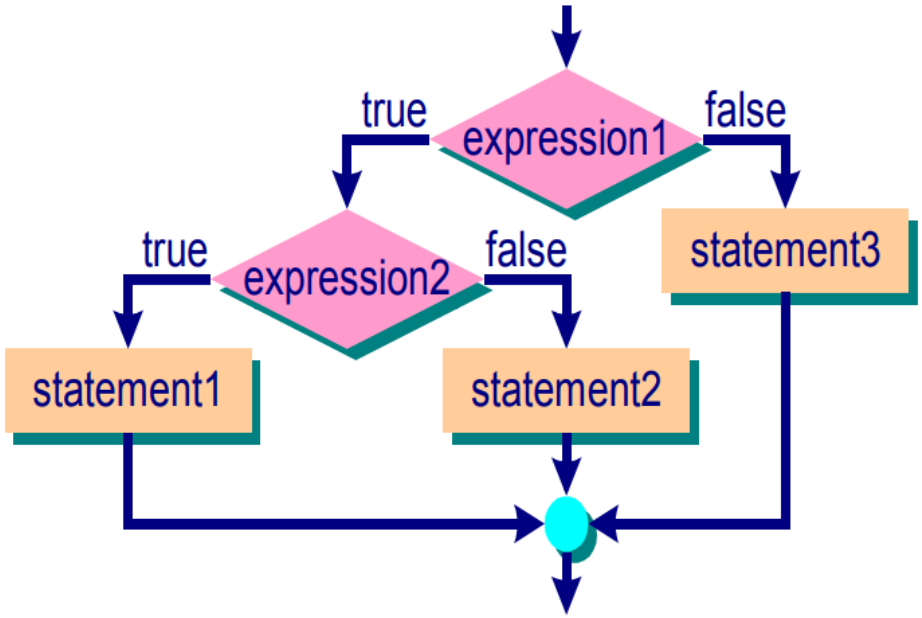
Temperature reading: ***130.0***
Temperature too high.

Nested-if

```
if (expression 1)
      statement1;
else
      if (expression2)
            statement2;
      else
            statement3;
```



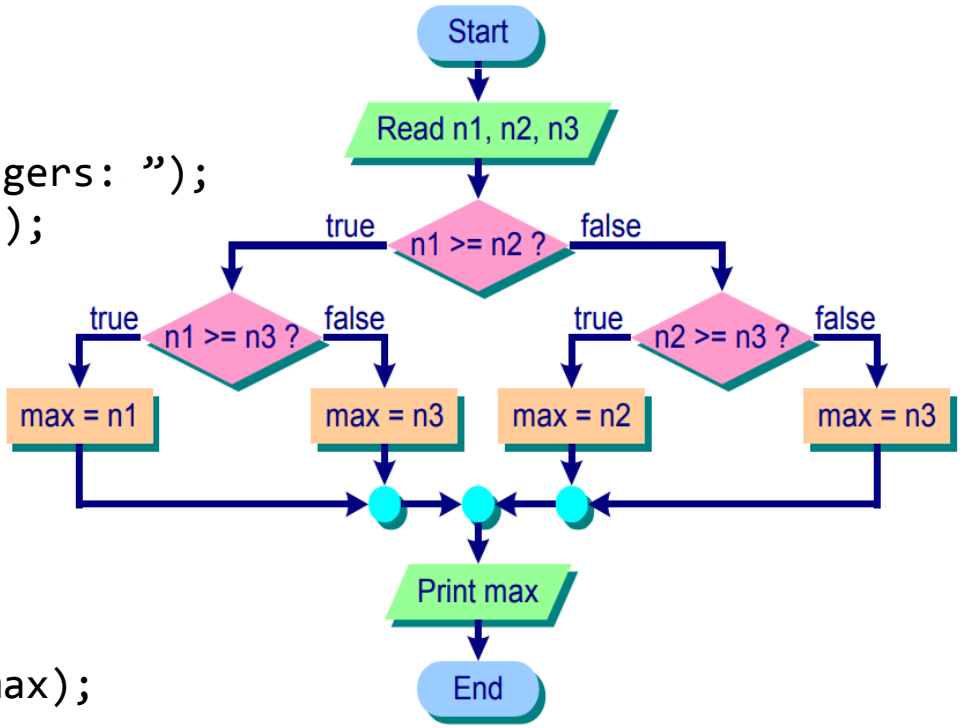

```
if (expression 1)
      if (expression2)
            statement1;
      else
            statement2;
else
      statement3;
```



Nested-if Example

```
/* This program computes the maximum value of
three numbers */
#include <stdio.h>
int main(void)
{
   int n1, n2, n3, max;
   printf("Please enter three integers: ");
   scanf("%d %d %d", &n1, &n2, &n3);
   if (n1 >= n2)
      if (n1 >= n3)
         max = n1;
      else max = n3;
   else if (n2 >= n3)
      max = n2;
   else max = n3;

   printf("The maximum is %d\n", max);
   return 0;
}
```



Output:

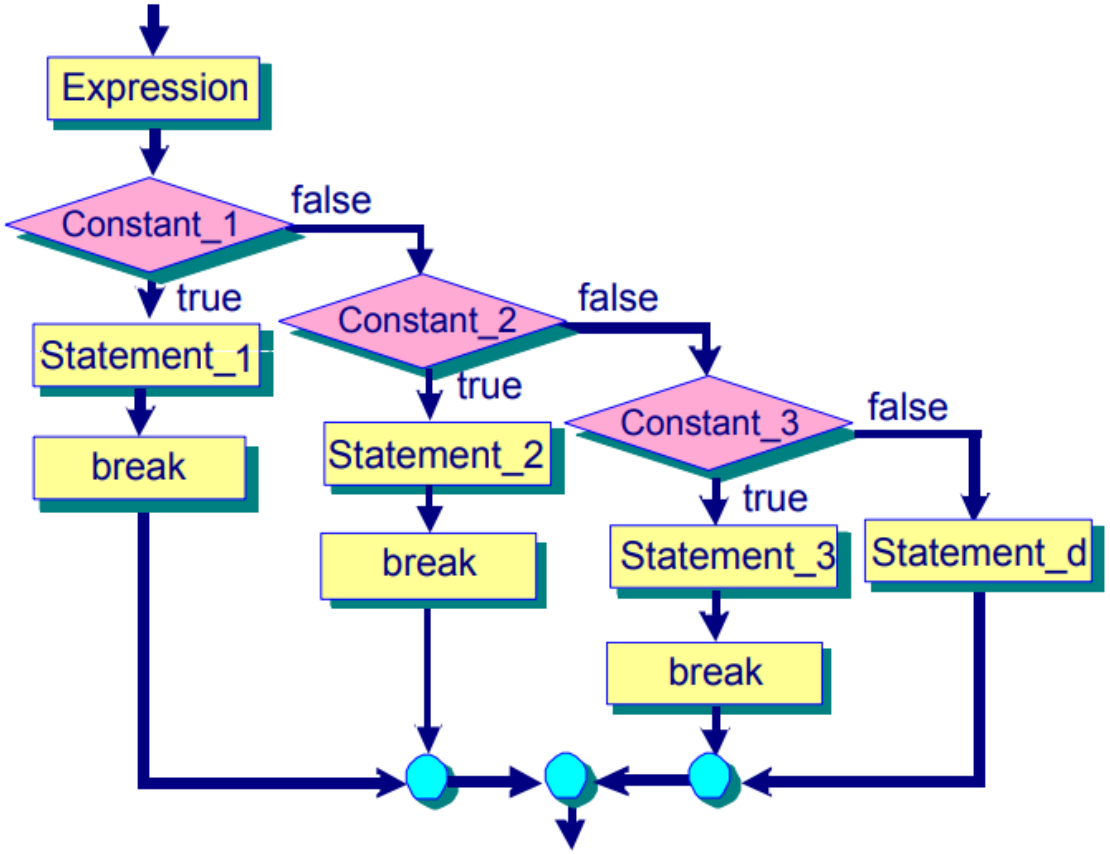
Please enter three integers: ***1 2 3***

The maximum of the three is 3

The switch Statement

The **switch** is for multi-way selection. The syntax is:

```
switch (Expression) {
      case Constant_1:
            Statement_1;
            break;
      case Constant_2:
            Statement_2;
            break;
      case Constant_3;
            Statement_3;
            break;
      default:
            Statement_d;
}
```



The switch Statement

- ***switch***, ***case***, ***break*** and ***default*** are reserved words.
- The result of ***Expression*** in ( ) must be an **integral type**.
- *Constant_1*, *Constant_2*, … are called **labels**. Each must be an integer constant, a character constant or an integer constant expression, e.g. 3, 'A', 4+'b', 5+7, etc.
- Each of the labels *Constant_1*, *Constant_2*, … must deliver a **unique integer value**. Duplicates are not allowed.
- We may also have **multiple labels** for a statement, for example, to allow both the lower and upper case selection.
- If we do not use **break** after some statements in the switch statement, execution will continue with the statements for the subsequent labels until a break statement or the end of the switch statement. This is called the **fall through** situation.

switch: Example

```
#include <stdio.h>
main(void) {
   char choice;
   int num1, num2, result;
   printf("Enter your choice (A, S or M)=> ");
   scanf("%c", &choice);
   printf("Enter two numbers:");
   scanf("%d %d", &num1, &num2);
   switch (choice) {
      case 'a':
      case 'A': result = num1 + num2;
         printf("num1 + num2 = %d\n", result);
         break;
      case 's':
      case 'S': result = num1 - num2;
         printf("num1 - num2 = %d\n", result);
         break;
      case 'm':
      case 'M': result = num1 * num2;
         printf("num1 * num2 = %d\n", result);
         break;
      default: printf("Not a proper choice.\n");
   }
   return 0;
}
```

Output:

Enter your choice (A, S or M) => ***S***

Enter two numbers: ***9 5***

9 – 5 = 4

A switch Example: Converting Score to Grade

Weighted Average Score S	Grade
90 <= S	A
80 <= S < 90	B
70 <= S < 80	C
60 <= S < 70	D
50 <= S < 60	E
S < 50	F

```
switch ((int)averageScore/10) {
  case 10: case 9:
    grade = 'A'; break;
  case 8:
    grade = 'B'; break;
  case 7:
    grade = 'C'; break;
  case 6:
    grade = 'D'; break;
  case 5:
    grade = 'E'; break;
  default: grade = 'F';
}
```

The Conditional Operator

- The conditional operator is used in the following way:

Expression_1 ? Expression_2 : Expression_3

The value of this expression depends on whether **Expression_1** is true or false.

if Expression_1 is true

=> value of the expression is that of Expression_2

else

=> value of the expression is that of Expression_3

- **Example**:

```
max = (x > y) ? x : y;
```

<==>

```
if (x > y)
    max = x;
else
    max = y;
```

Conditional Operator: Example

```
/* An example to show a conditional expression */
#include <stdio.h>
int main(void)
{
   int selection; /* User input selection */
   printf("Enter a 1 or a 0 => ");
   scanf("%d", &selection);

   selection ? printf("A one.\n") : printf("A zero.\n");
   return 0;
}
```

Output:

Enter a 1 or a 0 => ***1***

A one.

Enter a1 or a0 => ***0***

A zero.

Repetition: Loops

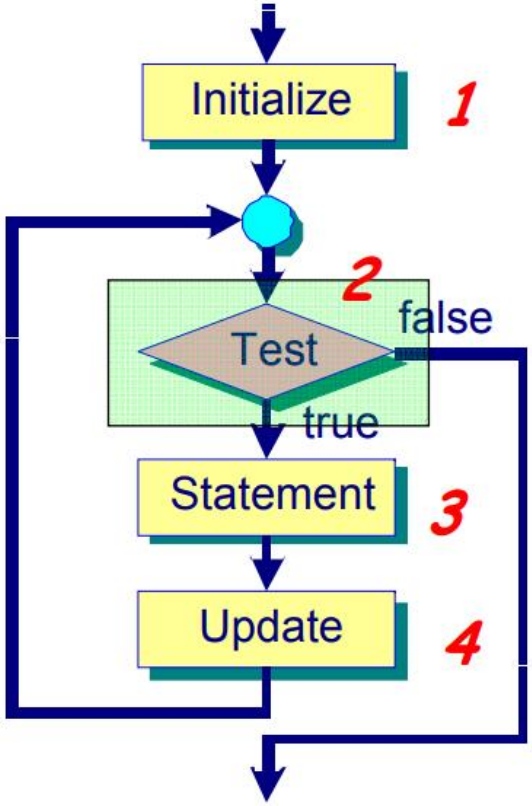
Some sections of statements are executed repeatedly. These repetitions are referred to as **loops**. There are two types of loops:

- **Counter-controlled loops**: The loop body is repeated for a number of times, and *the number of repetitions is known* before the loop starts execution.
- **Sentinel-controlled loops**: *The number of repetitions is not known* before the loop starts execution. Usually, a **sentinel value** (such as −1, different from regular data) is used to determine whether to execute the loop body.

Looping

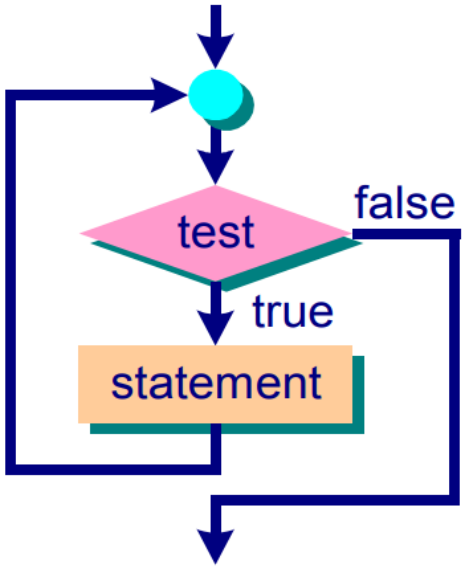
To construct loops, we need:

1. **Initialization** – initialize the ***loop control variable***.
2. **Test condition** – evaluate the test condition (involve ***loop control variable***).
3. **Loop body** – if test is true, the loop body is executed.
4. **Update** – typically, ***loop control variable*** is modified through the execution of the loop body. It can then go through the **test** condition again.



The while Loop

```
while (test)
        statement
```




```
/* sum up a list of integers. The list of
integers is terminated by -1. */
#include <stdio.h>
int main(void)
{
   int sum, item;
   printf("Enter the list of integers:\n");
   scanf("%d", &item);
   while (item != -1) {
      /* Sentinel-controlled */
      sum += item;
      scanf("%d", &item);
   }
   printf("The sum if %d\n", sum);
   return 0;
}
```

Output:

Enter the list of integers:

1 8 11 24 36 48 67 –1

The sum is 195

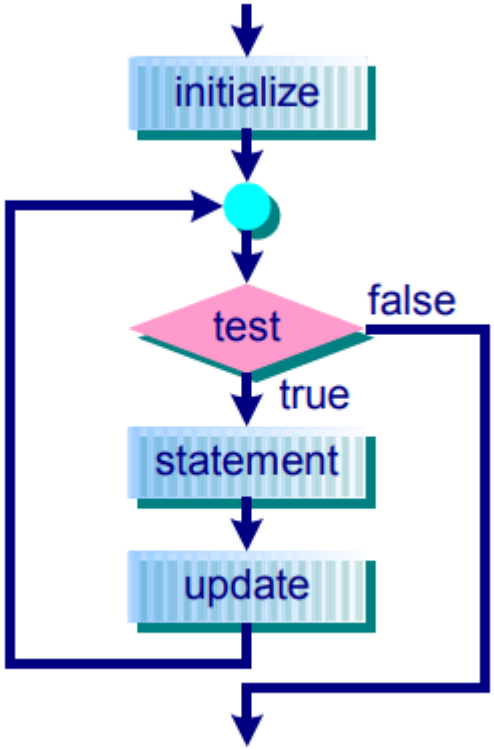
Enter the list of integers:

–1

The sum is 0

The for Loop

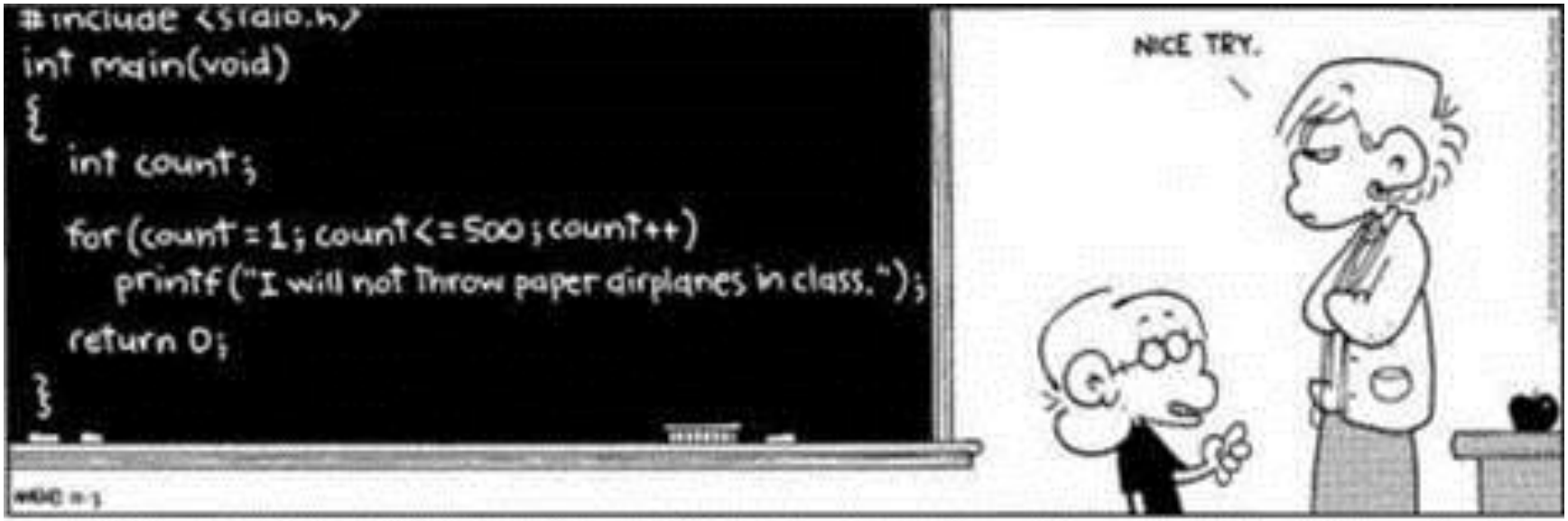
for (initialize; test; update)
statement;



- Normally, *test* is a relational expression to control iterations.
- *update* is frequently used to update some loop control variable before repeating the loop.
- Any or all of the 3 expressions may be omitted. In case test is missing, it becomes an *infinite loop*, i.e. all statements inside the loop will be executed again and again. For example:

```
for (;;) {    /* an infinite loop */
    statement1;
    …
}
```

for Loop: Example 0



for Loop: Example 1

```
/* Display the distance a body falls in
feet/sec for the first n seconds; n is input
by user. */
#include <stdio.h>
#define ACCELERATION 32.0
main()
{
    int timeLimit, t;
    /* Distance by a falling body */
    int distance;

    printf("Enter the time limit(seconds): ");
    scanf("%d", &timeLimit);
    for (t = 1; t <= timeLimit; t++) {
        distance = 0.5 * ACCELERATION * t * t;
        printf("Dist after %d seconds is %d\
            feet.\n", t, distance);
    }
    return 0;
}
```

Output:

Enter the time limit(seconds): ***5***

Dist after 1 seconds is 16 feet.

Dist after 2 seconds is 64 feet.

Dist after 3 seconds is 144 feet.

Dist after 4 seconds is 256 feet.

Dist after 5 seconds is 400 feet.

Enter the time limit(seconds): ***0***

for Loop: Example 2

```
/* Display the distance a body falls every
5 seconds for the first n seconds; n is input
by user. */
#include <stdio.h>
#define ACCELERATION 32.0

main()
{
    int timeLimit, t;
    /* Distance by a falling body */
    int distance;

    printf("Enter the time limit(seconds): ");
    scanf("%d", &timeLimit);
    for (t = 5; t <= timeLimit; t += 5) {
        distance = 0.5 * ACCELERATION * t * t;
        printf("Dist after %d seconds is %d\
            feet.\n", t, distance);
    }
    return 0;
}
```

Output:

Enter the time limit(seconds): ***15***

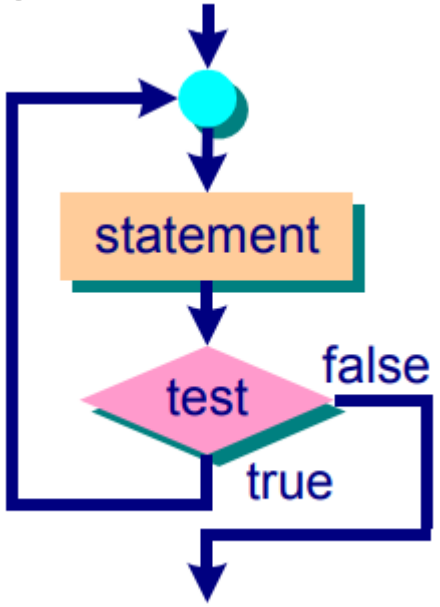
Dist after 5 seconds is 400 feet.

Dist after 10 seconds is 1600 feet.

Dist after 15 seconds is 3600 feet.

The do-while Loop

```
do {
    statement;
} while (test);
```




```
/* Menu-Based User Selection */
#include <stdio.h>
int main()
{
    int input; /* User input number. */
    do {
        printf("Input a number >= 1 and <=5: ");
        scanf("%d", &input);
        if (input > 5 || input < 1)
            print("%d is out of range.\n", input);
    } while (input > 5 || input < 1);
    printf("Input = %d\n", input);
    return 0;
}
```

Output:

Input a number >= 1 and <=5: ***6***

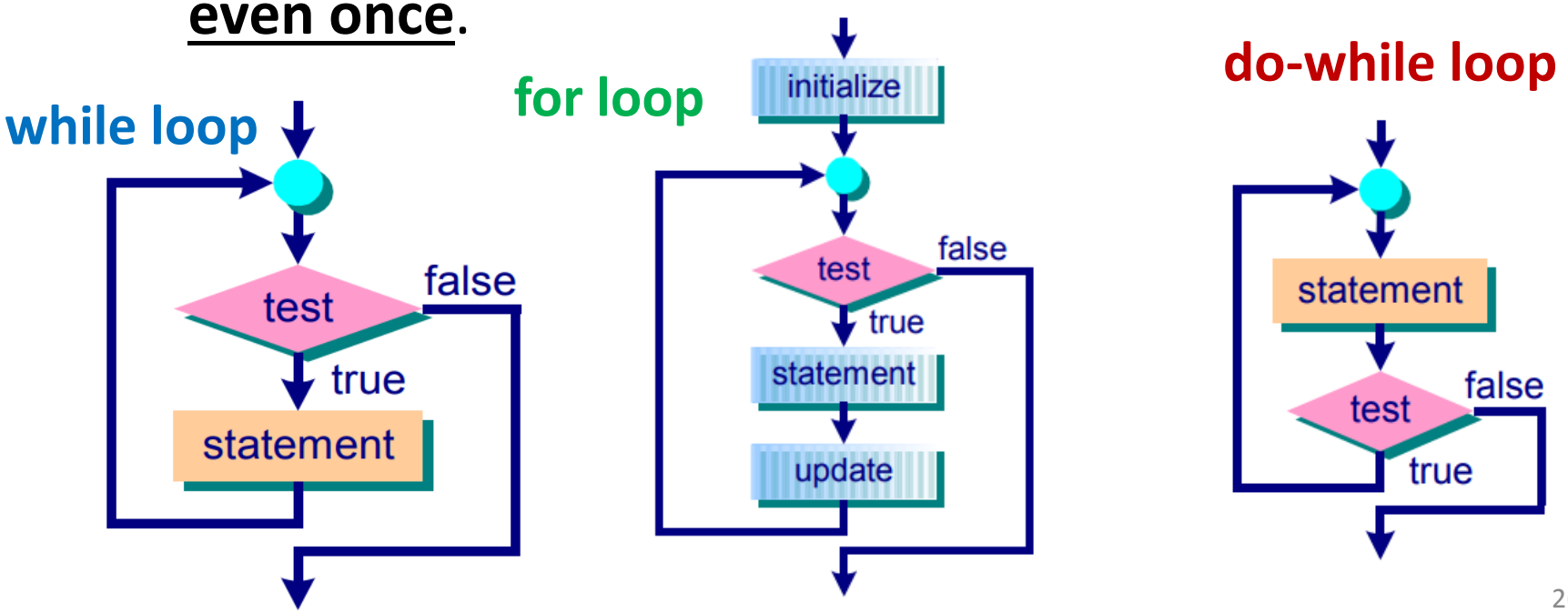
6 is out of range.

Input a number >= 1 and <= 5: ***5***

Input = 5

The do-while Loop

- Different from the ***while*** and ***for*** statements:
  - The condition ***test*** is performed **after** executing the statement every time.
  - This means the loop will be executed **at least once**.
  - Note: the *while* or *for* loop might **not** be executed **even once**.



The break Statement

- To alter flow of control inside loop (and inside the switch statement). Execution of **break** causes immediate termination of the inner most enclosing loop or switch statement.

```
/* use break to exit a loop */
#include <stdio.h>
int main(void)
{
   float length, width;
   printf("Enter rectangle length:\n");
   while (scanf("%f", &length) == 1) {
      printf("Enter its width:\n");
      if (scanf("%f", &width) != 1)
         break;
      printf("The area = %6.3f\n\n",
         length * width);
      printf("Enter rectangle length:\n");
   }
   return 0;
}
```

Output:

Enter rectangle length:

2

Enter its width:

10

The area = 20.000

Enter rectangle length:

4

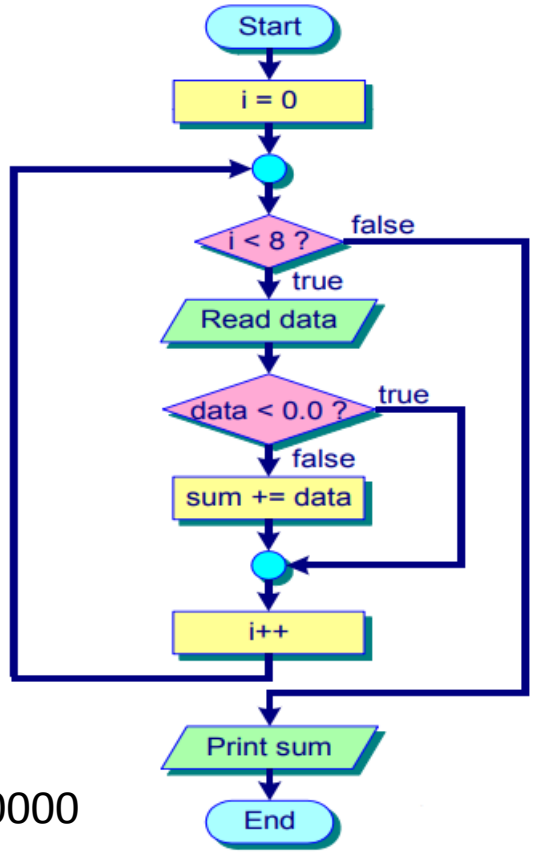
Enter its width:

a

The continue Statement

- The control immediately passed to the (update and) test condition of the nearest enclosing loop. All subsequent statements after the continue statement are not executed for this particular iteration.

```
/* summing up positive numbers
from a list of 8 numbers */
#include <stdio.h>
int main(void)
{
   int i;
   float data, sum = 0.0;
   /* read 8 numbers */
   for (i=0; i < 8; i++) {
      scanf("%f", &data);
      if (data < 0.0)
         continue;
      sum += data;
   }
   printf("The sum is %f\n", sum);
   return 0;
}
```



Output:

3 7 -1 4 -5 8 3 1

The sum is 26.000000

Nested Loops

- A loop may appear inside another loop. This is called a nested loop. We can nest as many levels of loops as the hardware allows. And we can nest different types of loops.

```
/* count the number of different strings of a, b, c
*/
#include <stdio.h>
int main(void)
{
   char i, j;   /* for loop counters */
   int num = 0; /* overall loop counter */
   for (i = 'a'; i <= 'c'; i++) {
      for (j = 'a'; j <= 'c'; j++) {
         num++;
         printf("%c%c ", i, j);
      }
      printf("\n");
   }
   printf("%d different strings of letters.\n", num);
   return 0;
}
```

Output:

aa ab ac
ba bb bc
ca cb cc
9 different strings of letters.

Nested Loops: Example

```
#include <stdio.h>
int main(void)
{
   int a, b, height, lines;

   printf("Enter the height of pattern: ");
   scanf("%d", &height);
   for (lines=1; lines <= height; lines++) {
      for (a=1; a <= (height – lines); a++)
         putchar(' '); // print blank space
      for (b=1; b <= (2*lines – 1); b++)
         putchar('*'); // print asterisk
      putchar('\n');
   }
   return 0;
}
```

Output:

Enter the height of pattern: ***5***

Recap

- The following concepts are covered in this lecture:
  - Relational and logical operators
  - if, if … else …, if … else if … else statements
  - Nested if statements
  - switch statements
  - while, for and do-while loops
  - break and continue statements
  - Nested loops