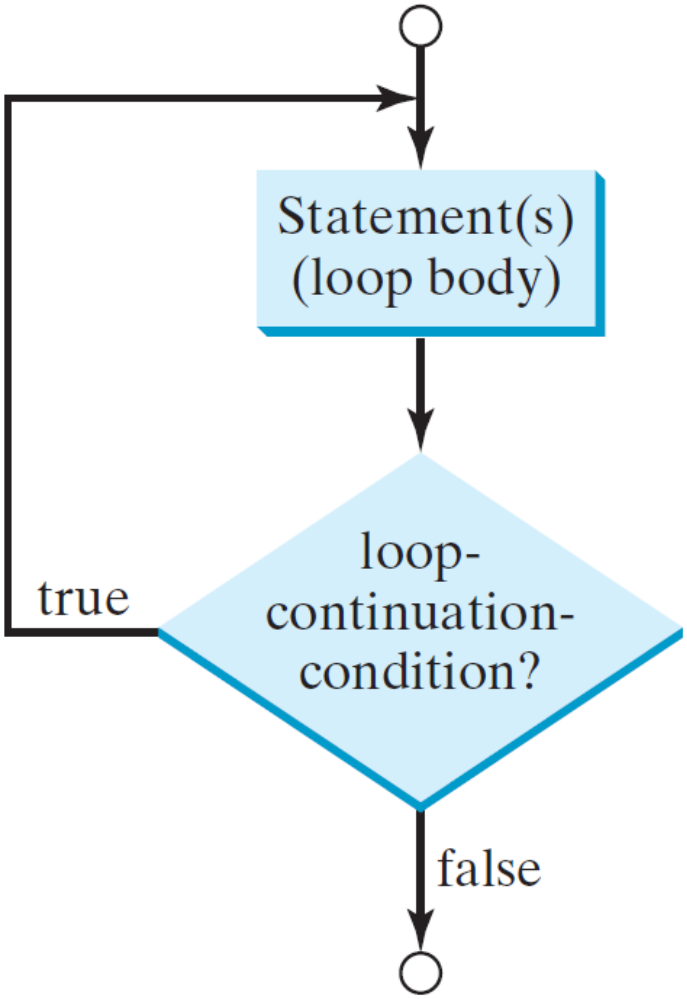
do-while Loops

A do-while loop is similar to a while loop except that it does execute the loop body first and then checks the loop continuation condition.

```
...
        do {
            // loop body
        } while (condition); // Do not miss the semicolon!
...
```

- Note that there must be a semicolon at the end of do-while loops.
- The do-while loops are also called posttest loops, in contrast to while loops, which are pretest loops.


Statement(s)
(loop body)
loop-
continuation-
condition?
true
false

Example (Revisted)

Write a program which sums over positive integers from consecutive inputs and then outputs the sum when the input is nonpositive.

```
...
        int total = 0, price = 0;
        Scanner input = new Scanner(System.in);

        do {
            total += price;
            System.out.println("Enter price?");
            price = input.nextInt();
        } while (price > 0);

        System.out.println("Total = " + total);
        input.close();
...
```

for Loops

A for loop generally uses a variable to control how many times the loop body is executed.

```
...
        for (init_action; condition; increment) {
            // loop body
        }
...
```

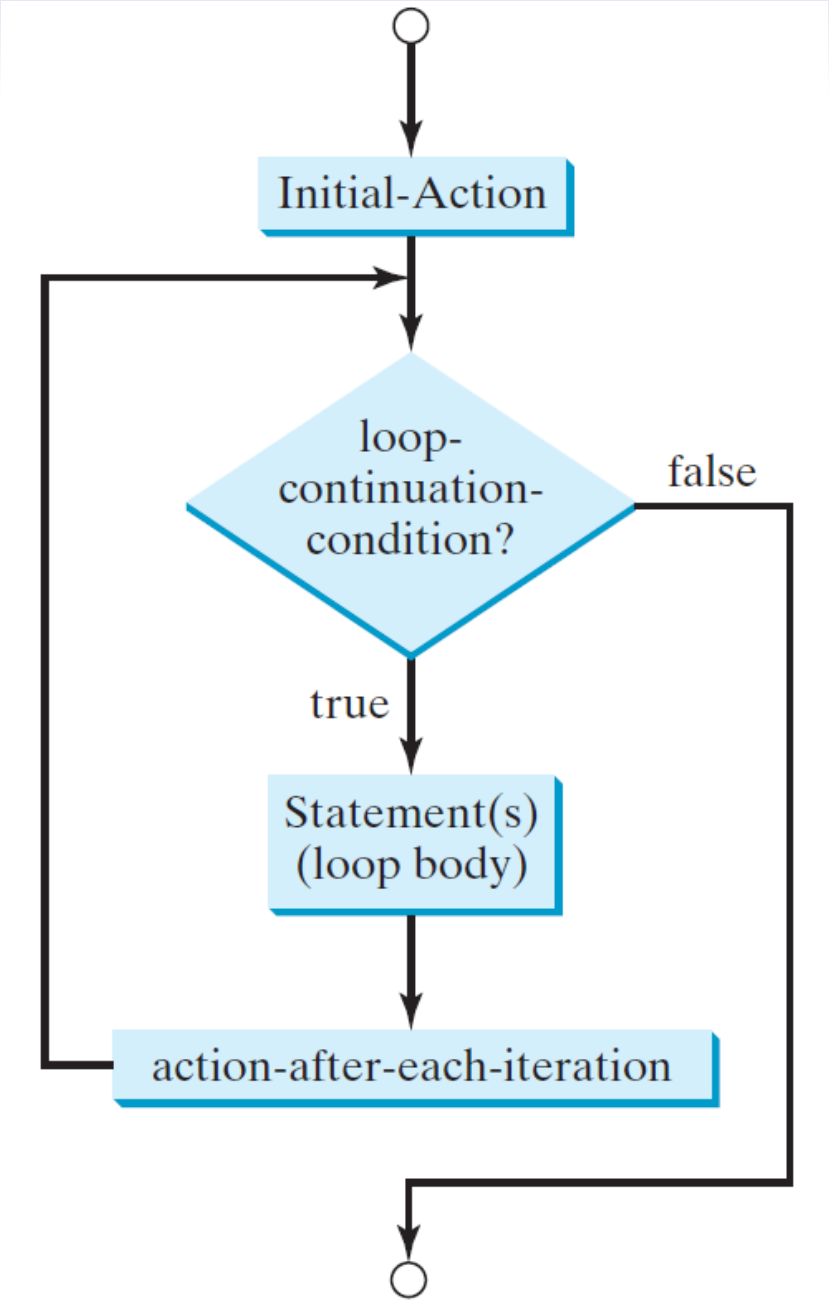
- *init-action*: declare and initialize a variable.
- *condition*: for loop continuation.
- *increment*: how the loop variable changes after each iteration.
- Note that these terms are separated by semicolons.

Example

Write a program which sums from 1 up to 100.

```
...
        int sum = 0;
        int i = 1;
        while (i <= 100) {
            sum = sum + i;
            ++i;
        }
...
```

```
...
        int sum = 0;
        for (int i = 1; i <= 100; ++i)
            sum = sum + i;
...
```


Initial-Action
loop-continuation-condition?
false
true
Statement(s) (loop body)
action-after-each-iteration

Exercise

Write a program which displays all even numbers between 1 and 100.

- You may use the modular operator (%).

```
...
        for (int i = 1; i <= 100; i++) {
            if (i % 2 == 0) System.out.println(i);
        }
...
```

- Also consider this alternative:

```
...
        for (int i = 2; i <= 100; i += 2) {
            System.out.println(i);
        }
...
```

- How about odd numbers?

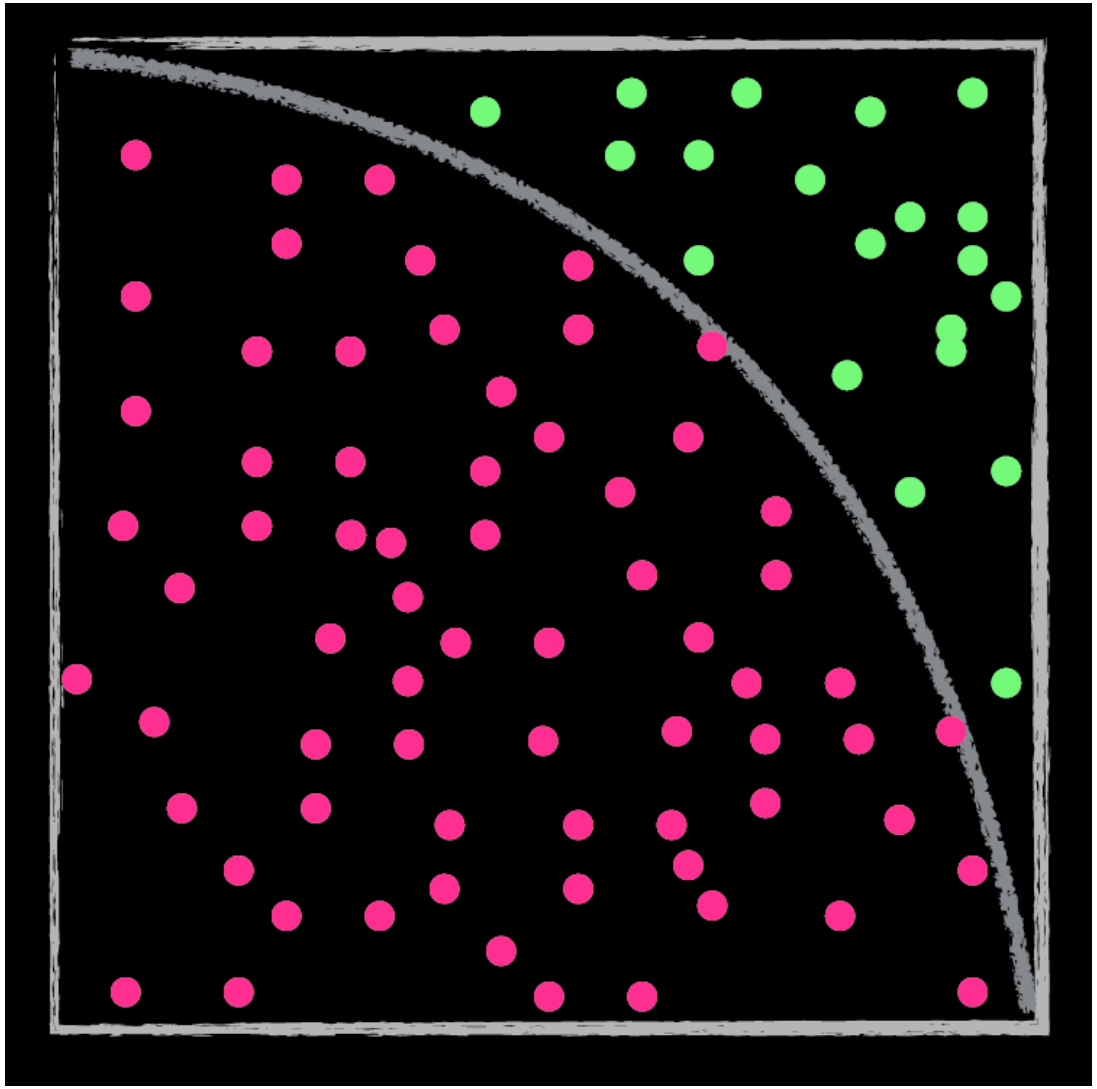
Numerical Example: Monte Carlo Simulation[1]

- Let m be the number of sample points falling in the region of the quarter circle shown in the next page, n be the total number of sample points.
  - Simply use **Math.random()** to generate a value between 0 and 1 (exclusive).
- Write a program which estimates π by

$$\hat{\pi} = 4 \times \frac{m}{n}.$$

- Cute and sweet!
- Note that $\hat{\pi} \to \pi$ as $n \to \infty$ by the law of large numbers (LLN).

[1] See `https://en.wikipedia.org/wiki/Monte_Carlo_method`. Also read `https://medium.com/@jonathan_hui/monte-carlo-tree-search-mcts-in-alphago-zero-8a403588276a`.

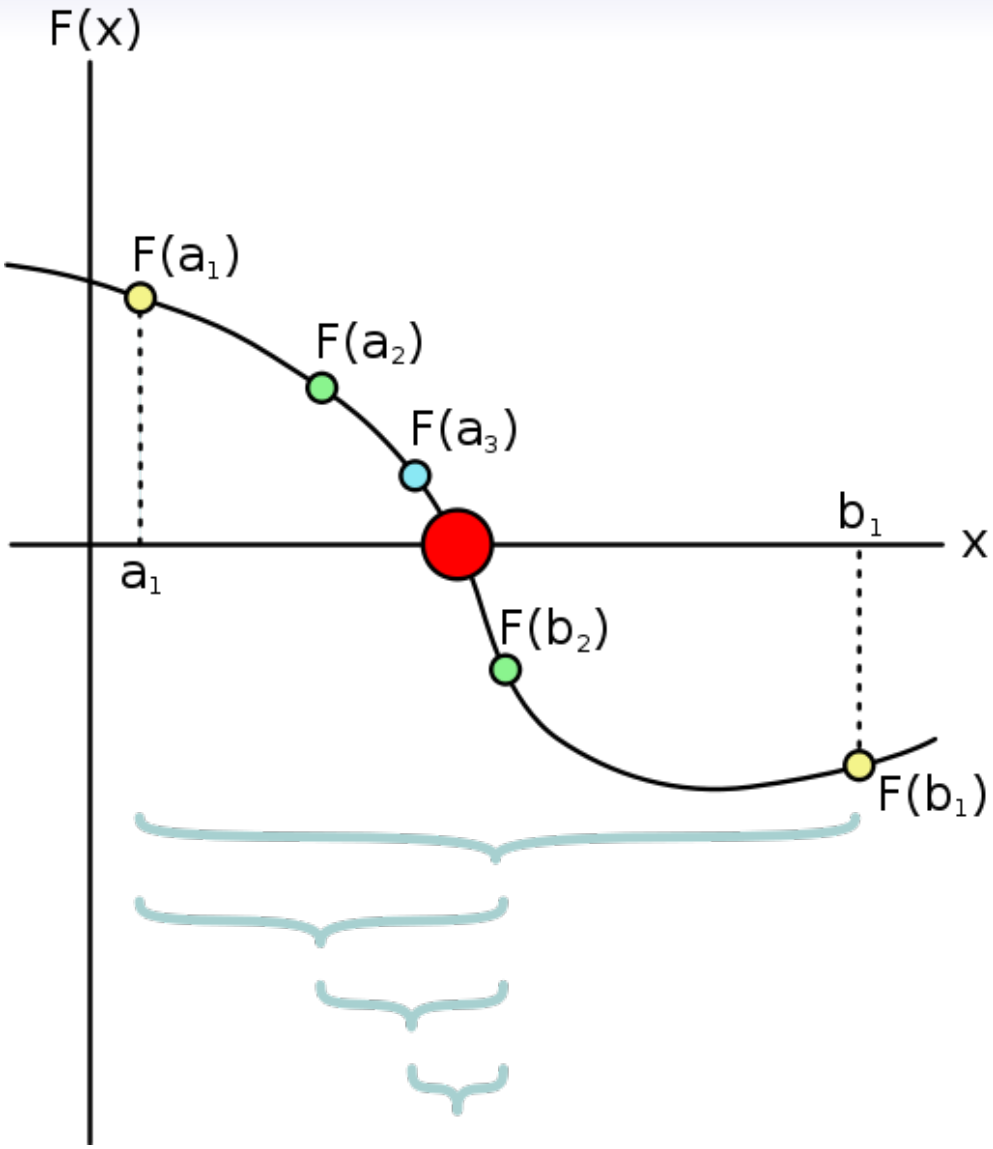


Numerical Example: Bisection Method for Root-Finding[3]

- Assume that $f(x) = x^3 - x - 2$.
- Consider to find a root between $[a, b] = [1, 2]$ as initial guess.[2]
- Write a program to calculate the approximate root $\hat{r}$ by using the bisection method.
- Note that we set an error tolerance, say $\epsilon = 1e - 9$, to strike a balance between efficiency and accuracy.

[2] For most of numerical algorithms, say Newton's method, an initial guess is a must. Even more, the solution is severely sensitive to the initial guess for some cases.

[3] See `https://en.wikipedia.org/wiki/Bisection_method`.



https://en.wikipedia.org/wiki/Bisection_method#/media/File:Bisection_method.svg

Jump Statements

The keyword break and continue are often used in repetition structures to provide additional controls.

- break: the loop is terminated right after a break statement is executed.
- continue: the loop skips this iteration right after a continue statement is executed.
- In practice, jump statements in loops should be conditioned.

Example: Primality Test

Write a program which determines if the input integer is a prime number.

- Let $x > 1$ be any natural number.
- Then x is said to be a prime number if x has no positive divisors other than 1 and itself.
- It is then straightforward to check if it is prime by dividing x by all natural numbers smaller than x.
- For speedup, you can divide x by only numbers smaller than $\sqrt{x}$. (Why?)

```
...
        Scanner input = new Scanner(System.in);
        System.out.println("Enter x > 2?");
        int x = input.nextInt();
        boolean isPrime = true;
        input.close();

        double upperBd = Math.sqrt(x);
        for (int y = 2; y <= upperBd; y++) {
            if (x % y == 0) {
                isPrime = false;
                break;
            }
        }

        if (isPrime) {
            System.out.println("Prime");
        } else {
            System.out.println("Composite");
        }
...
```

Exercise (Revisited)

- Redo the cashier problem by using an infinite loop with a break statement.

```
...
        while (true) {
            System.out.println("Enter price?");
            price = input.nextInt();
            if (price <= 0) break;
            total += price;
        }
        System.out.println("Total = " + total);
...
```

Another Example: Compounding

Write a program which determines the holding years for an investment doubling its value.

- Let *balance* be the current amount, *goal* be the goal of this investment, and r be the annual interest rate.
- Recall that the compounding formula is given by

$$balance = balance \times (1 + r/100).$$

- Then this investment should take at least n years so that the balance of the investment can double its value.

```
...
        int r = 18; // 18%
        int balance = 100;
        int goal = 200;

        int years = 0;
        while (balance < goal) {
            balance *= (1 + r / 100.0);
            years++;
        }

        System.out.println("Balance = " + balance);
        System.out.println("Years = " + years);
...
```

```
...
        int years = 0; // should be declared here; scope issue
        for (; balance < goal; years++) {
            balance *= (1 + r / 100.0);
        }
...
```

```
...
        int years = 1; // check this initial value
        for (; true; years++) {
            balance *= (1 + r / 100.0);
            if (balance > goal) break;
        }
...
```

- A for loop can be an infinite loop by setting true or simply leaving empty in the condition.
- An infinite for loop with an if-break statement is equivalent to a normal while loop.

Equivalence: while and for Loops (Concluded)

In general, a for loop may be used if the number of repetitions is known in advance. If not, a while loop is preferred.

Nested Loops

A loop can be nested inside another loop.

- Nested loops consist of an outer loop and one or more inner loops.
- Each time the outer loop is repeated, the inner loops are reentered, and started anew.

Example

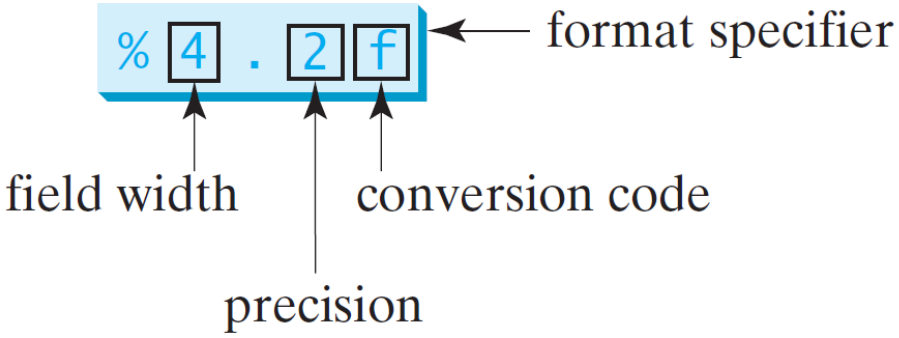
Write a program which displays the multiplication table.

```
1  2  3  4  5  6  7  8  9
2  4  6  8 10 12 14 16 18
3  6  9 12 15 18 21 24 27
4  8 12 16 20 24 28 32 36
5 10 15 20 25 30 35 40 45
6 12 18 24 30 36 42 48 54
7 14 21 28 35 42 49 56 63
8 16 24 32 40 48 56 64 72
9 18 27 36 45 54 63 72 81
```

Formatting Console Output

You can use *System.out.printf*() to display formatted output on the console.

```
...
        double pi = 3.1415926;
        System.out.printf("pi = %4.2f", pi); // output 3.14
...
```



Format Specifier	*Output*	*Example*
%b	a Boolean value	true or false
%c	a character	'a'
%d	a decimal integer	200
%f	a floating-point number	45.460000
%e	a number in standard scientific notation	4.556000e+01
%s	a string	"Java is cool"

- By default, a floating-point value is displayed with 6 digits after the decimal point.

Multiple Items to Print

```
int count = 5;
double amount = 45.56;
System.out.printf("count is %d and amount is %f", count, amount);
```

items

```
display              count is 5 and amount is 45.560000
```

- Items must match the format specifiers in order, in number, and in exact type.
- By default, the output is right justified.
- If an item requires more spaces than the specified width, the width is automatically increased.
- You may try the plus sign (+), the minus sign (-), and 0 in the middle of format specifiers.
  - Say %+8.2f, %−8.2f, and %08.2f.

```java
...
    public static void main(String[] args) {

        for (int i = 1; i <= 9; ++i) {

            // In row i, output each j
            for (int j = 1; j <= 9; ++j) {
                System.out.printf("%3d", i * j);
            }
            System.out.println();

        }

    }
...
```

- For each i, the inner loop goes from $j = 1$ to $j = 9$.
- As an analog, i acts like the hour hand of the clock, while j acts like the minute hand.

Exercise: Coupled Loops

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

(a) (b) (c) (d)

```java
public class PrintStarsDemo {
    public static void main(String[] args) {
        // case (a)
        for (int i = 1; i <= 5; i++) {
            for (int j = 1; j <= i; j++) {
                System.out.printf("*");
            }
            System.out.println();
        }

        // case (b), (c), (d)
        // your work here
    }
}
```