Methods Provided by Scanner Objects[1]

Method	*Description*
`nextByte()`	reads an integer of the `byte` type.
`nextShort()`	reads an integer of the `short` type.
`nextInt()`	reads an integer of the `int` type.
`nextLong()`	reads an integer of the `long` type.
`nextFloat()`	reads a number of the `float` type.
`nextDouble()`	reads a number of the `double` type.
`next()`	reads a string that ends before a whitespace character.
`nextLine()`	reads a line of text (i.e., a string ending with the *Enter* key pressed).

[1] See Table 2-1 in YDL, p. 38.

Example: Mean and Standard Deviation

Write a program which calculates the mean and the standard deviation of 3 numbers.

- The mean of 3 numbers is given by $\overline{x} = \left(\sum_{i=1}^{3} x_i\right)/3$.
- Also, the resulting standard deviation is given by

$$S = \sqrt{\frac{\sum_{i=1}^{3}(x_i - \overline{x})^2}{3}}.$$

- You may use these two methods:
  - Math.pow(double x , double y) for x^y
  - Math.sqrt(double x) for $\sqrt{x}$
- See more methods within Math class.

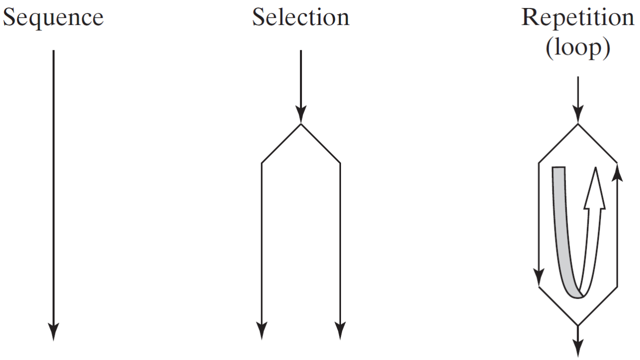
```java
...
        Scanner input = new Scanner(System.in);
        System.out.println("a = ?");
        double a = input.nextDouble();
        System.out.println("b = ?");
        double b = input.nextDouble();
        System.out.println("c = ?");
        double c = input.nextDouble();

        double mean = (a + b + c) / 3;
        double std = Math.sqrt((Math.pow(a - mean, 2) +
                                Math.pow(b - mean, 2) +
                                Math.pow(c - mean, 2)) / 3);

        System.out.println("mean = " + mean);
        System.out.println("std = " + std);
...
```

```java
class Lecture3 {

                    "Selections"

}

// Keywords
if, else, else if, switch, case, default
```

Flow Controls

The basic algorithm (and program) is constituted by the following operations:

- Sequential statements: execute instructions in order.
- Selection: first check if the predetermined condition is satisfied, then execute the corresponding instruction.
- Repetition: repeat the execution of some instructions until the criterion fails.



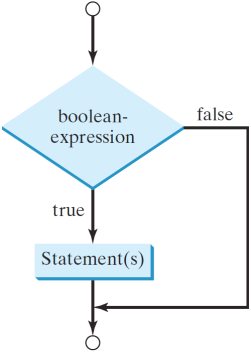
- Note that they are involved with each other generally.
- For example, recall how to find the maximum in the input list?

Selections

- One-way if statements
- Two-way if-else statements
- Nested if statements
- Multiway if-else if-else statements
- switch-case statements
- Conditional operators

One-Way if Statements

A one-way if statement executes an action if and only if the condition is true.



```java
...
        if (condition) {
            // selection body
        }
...
```

- The keyword if is followed by the parenthesized condition.
- The condition should be a boolean expression or a boolean value.
- It the condition is true, then the statements in the selection body will be executed once.
- If not, then the program won't enter the selection body and skip the whole selection body.
- Note that the braces can be omitted if the block contains only single statement.

Example

Write a program which receives a nonnegative number as input for the radius of a circle, and determines the area of the circle.

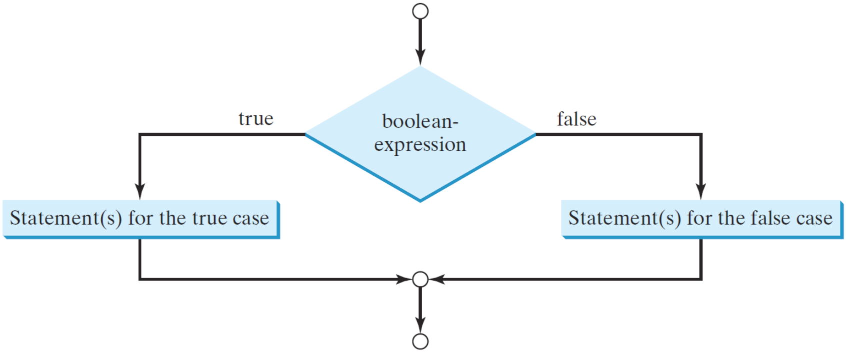
```
...
        double area;
        if (r > 0) {
            area = r * r * 3.14;
            System.out.println(area);
        }
...
```

- However, the world is not well-defined.

Two-Way if-else Statements

A two-way if-else statement decides which statements to execute based on whether the condition is true or false.

```
...
        if (condition) {
            // body for the true case
        } else {
            // body for the false case
        }
...
```


true
boolean-
expression
false
Statement(s) for the true case
Statement(s) for the false case

Example

Write a program which receives a number as input for the radius of a circle. If the number is nonnegative, then determine the area of the circle; otherwise, output "Not a circle."

```
...
        double area;
        if (r > 0) {
            area = r * r * 3.14;
            System.out.println(area);
        } else {
            System.out.println("Not a circle.");
        }
        input.close();
    }
...
```

Nested if Statements

- For example,

```
...
        if (score >= 90)
            System.out.println("A");
        else {
            if (score >= 80)
                System.out.println("B");
            else {
                if (score >= 70)
                    System.out.println("C");
                else {
                    if (score >= 60)
                        System.out.println("D");
                    else
                        System.out.println("F");
                }
            }
        }
...
```

Multi-Way if-else

- Let's redo the previous problem.

```
...
        if (score >= 90)
            System.out.println("A");
        else if (score >= 80)
            System.out.println("B");
        else if (score >= 70)
            System.out.println("C");
        else if (score >= 60)
            System.out.println("D");
        else
            System.out.println("F");
...
```

- An if-elseif-else statement is a preferred format for multiple alternatives, in order to avoid deep indentation and make the program easy to read.

- The order of conditions may be relevant. (Why?)

```
...
        if (score >= 90 && score <= 100)
        else if (score >= 80 && score < 90)
        ...
        else
...
```

- The performance may degrade due to the order of conditions. (Why?)

Common Errors

```
...
        double area;
        if (r > 0);
            area = r * r * 3.14;
            System.out.println(area);
...
```

Example

Generating random numbers

Write a program which generates 2 random integers and asks the user to answer the math expression.

- For example, the program shows $2 + 5 =?$
- If the user answers 7, then the program reports "Correct." and terminates.
- Otherwise, the program reports "Wrong answer. The correct answer is 7." for this case.
- You may use **Math.random**() for a random value between 0.0 and 1.0, excluding themselves.[2]

[2]You may see PRNG in `https://en.wikipedia.org/wiki/Pseudorandom_number_generator`.

```java
...
        // (1) generate random integers
        int x = (int) (Math.random() * 10);
        int y = (int) (Math.random() * 10);
        int answer = x + y;

        // (2) display the math expression
        System.out.println(x + " + " + y + " =  ?");

        // (3) user input
        Scanner input = new Scanner(System.in);
        int z = input.nextInt();

        // (4) judgement
        if (z == answer)
            System.out.println("Correct.");
        else
            System.out.println("Wrong. Answer: " + answer);
        input.close();
...
```

- Can you extend this program for all arithmetic expressions (i.e., $+ - \times \div$)?

"Exploring the unknown requires tolerating uncertainty."

– Brian Greene

"I can live with doubt, and uncertainty, and not knowing. I think it is much more interesting to live not knowing than have answers which might be wrong."

– Richard Feynman

Exercise

Find Max

Write a program which determines the maximum value in 3 random integers whose range from 0 to 99.

- How many variables do we need?
- How to compare?
- How to keep the maximum value?

```java
...
        int x = (int) (Math.random() * 100);
        int y = (int) (Math.random() * 100);
        int z = (int) (Math.random() * 100);

        int max = x;
        if (y > max) max = y;
        if (z > max) max = z;
        System.out.println("max = " + max);
...
```

- In this case, a scalar variable is not convenient. (Why?)
- So we need arrays and loops.

switch-case Statements

A switch-case structure takes actions depending on the target variable.

```
...
        switch (target) {
            case v1:
                // statements
                break;
            case v2:
                .
                .
            case vk:
                // statements
                break;
            default:
                // statements
        }
...
```

- A switch-case statement is more convenient than an if statement for multiple discrete conditions.
- The variable *target*, always enclosed in parentheses, must yield a value of char, byte, short, int, or **String** type.
- The value $v_1, \ldots,$ and v_k must have the same data type as the variable *target*.
- In each case, a break statement is a must.[3]
    - break is used to break a construct!
- The default case, which is optional, can be used to perform actions when none of the specified cases matches *target*.
    - Counterpart to else statements.

[3] If not, there will be a fall-through behavior.

Example

```java
...
        // RED: 0
        // YELLOW: 1
        // GREEN: 2
        int trafficLight = (int) (Math.random() * 3);
        switch (trafficLight) {
            case 0:
                System.out.println("Stop!!!");
                break;
            case 1:
                System.out.println("Slow down!!");
                break;
            case 2:
                System.out.println("Go!");
        }
...
```

Conditional Operators

A conditional expression evaluates an expression based on the specified condition and returns a value accordingly.

```
...
        someVar = booleanExpr ? exprA : exprB;
...
```

- This is the only ternary operator in Java.
- If the boolean expression is evaluated true, then return expr A; otherwise, expr B.

- For example,

```
...
        if (num1 > num2)
            max = num1;
        else
            max = num2;
...
```

- Alternatively, one can use a conditional expression like this:

```
...
        max = num1 > num2 ? num1 : num2;
...
```

```java
class Lecture4 {

                    "Loops"

}

// keywords:
while, do, for, break, continue
```

Loops[4]

A loop can be used to make a program execute statements repeatedly without having to code the same statements.

- For example, output "Hello, Java." for 100 times.

```
...
        System.out.println("Hello, Java.");
        System.out.println("Hello, Java.");
        .
        . // copy and paste for 100 times
        .
        System.out.println("Hello, Java.");
...
```

[4] You may try https://www.google.com/doodles/celebrating-50-years-of-kids-coding.

```java
...
        int cnt = 0;
        while (cnt < 100) {
            System.out.println("Hello, Java.");
            cnt++;
        }
...
```

- This is a toy example to show the power of loops.
- In practice, any routine which repeats couples of times[5] can be done by folding them into a loop.

[5] I prefer to call these routines "patterns."

成也迴圈，敗也迴圈

- Loops provide substantial computational power.
- Loops bring an efficient way of programming.
- Loops could consume a lot of time.[6]

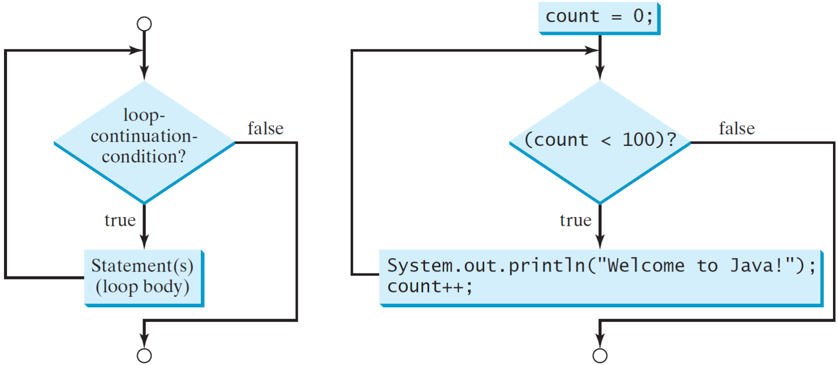
[6]We will introduce the analysis of algorithms soon.

while Loops

A while loop executes statements repeatedly while the condition is true.

```
...
        while (condition) {
            // loop body
        }
...
```

- The condition should be a boolean expression which determines whether or not the execution of the body occurs.
- If true, the loop body is executed and check the condition again.
- Otherwise, the entire loop terminates.


loop-
continuation-
condition?
false
true
Statement(s)
(loop body)
count = 0;
(count < 100)?
false
true
System.out.println("Welcome to Java!");
count++;

Example

Write a program which sums up all integers from 1 to 100.

- In math, the question can be written as:

$$\text{sum} = 1 + 2 + \cdots + 100.$$

- But this form is not doable in the machine.[7]

[7] We need to develop computational thinking. Read
http://rsta.royalsocietypublishing.org/content/366/1881/3717.full
or
http://blog.orangeapple.tw/posts/what-is-computational-thinking/.

- Normally, the machine executes the instructions sequentially.
- So one needs to decompose the math equation into several steps, like:

```
...
        int sum = 0;
        sum = sum + 1;
        sum = sum + 2;
        .
        .
        .
        sum = sum + 100;
...
```

- It is obvious that many similar statements can be found.

- Using a while loop, the program can be rearranged as follows:

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

- You should guarantee that the loop will terminate as expected.
- In practice, the number of loop steps (iterations) is unknown until the input data is given.

Malfunctioned Loops

- It is really easy to make an infinite loop.

```
...
        while (true);
...
```

- The common errors of the loops are:
  - never start
  - never stop
  - not complete
  - exceed the expected number of iterations

Example

Write a program which asks the sum of two random integers and lets the user repeatedly enter a new answer until correct.

```
...
        Scanner input = new Scanner(System.in);
        int x = (int) (Math.random() * 10);
        int y = (int) (Math.random() * 10);
        int ans = x + y;

        System.out.println(x + " + " + y + " = ? ");
        int z = input.nextInt();

        while (z != ans) {
            System.out.println("Try again? ");
            z = input.nextInt();
        }
        System.out.println("Correct.");
        input.close();
...
```

Loop Design Strategy

- Writing a correct loop is not an easy task for novice programmers.
- Consider 3 steps when writing a loop:
  - Find the pattern: identify the statements that need to be repeated.
  - Wrap by loops: put these statements in the loop.
  - Set the continuation condition: translate the criterion from the real world problem into computational conditions.[8]

[8] Not unique.

Sentinel-Controlled Loops

Another common technique for controlling a loop is to designate a special value when reading and processing a set of values.

- This special input value, known as a sentinel value, signifies the end of the loop.
- For example, the operating systems and the GUI apps.

Example: Cashier Problem

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

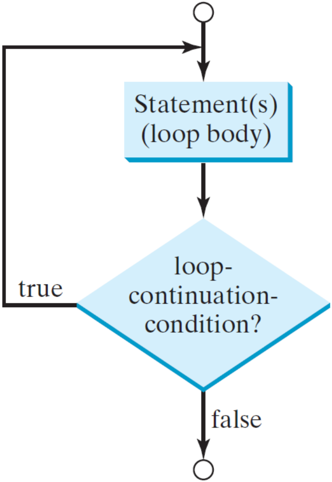
```
1  ...
2          int total = 0, price = 0;
3          Scanner input = new Scanner(System.in);
4  
5          System.out.println("Enter price?");
6          price = input.nextInt();
7          while (price > 0) {
8              total += price;
9              System.out.println("Enter price?");
10             price = input.nextInt();
11             // These two lines above repeat Line 5 and 6?!
12         }
13 
14         System.out.println("Total = " + total);
15         input.close();
16 ...
```

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 is a semicolon at the end of the do-while loop.
- 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*: set a criterion for loop continuation
- *increment*: how the variable changes after each iteration
- Note that these terms are separated by semicolons.

Example

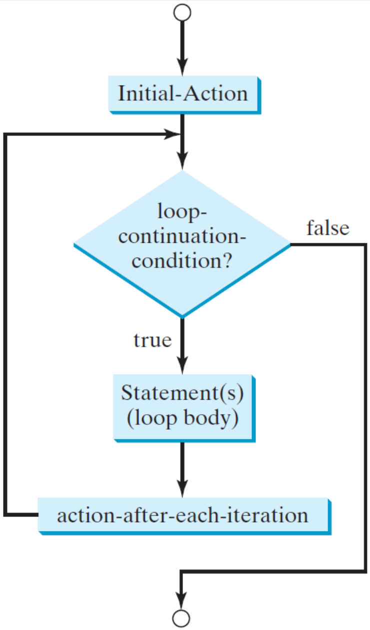
Sum from 1 to 100

Write a program which sums from 1 to 100.

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

- Compared to the while version,

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


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

Example: Selection Resided in Loop

Display all even numbers

Write a program which displays all even numbers smaller than 100.

- An even number is an integer of the form $x = 2k$, where k is an integer.

- 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?

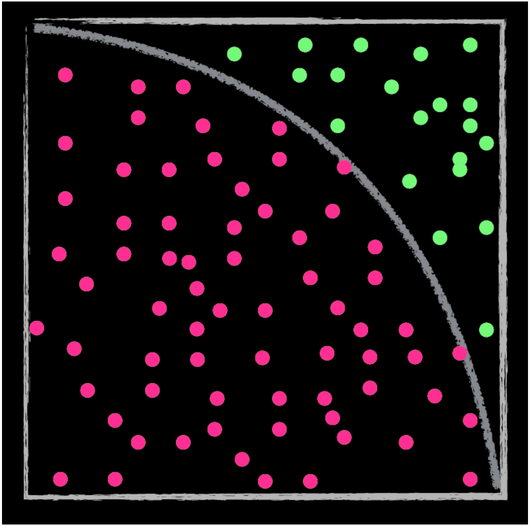
Numerical Example: Monte Carlo Simulation[9]

- 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

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

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

[9] See `https://en.wikipedia.org/wiki/Monte_Carlo_method`.

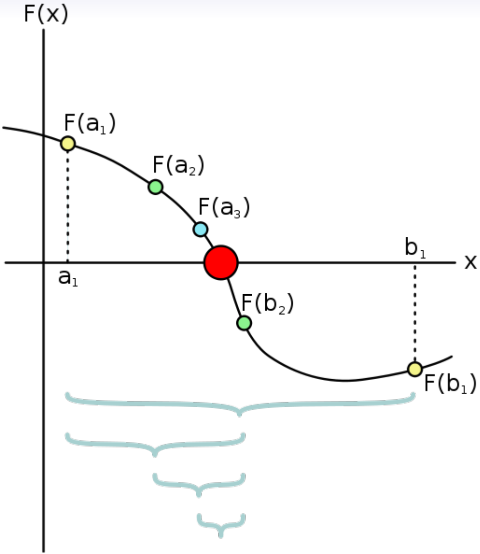


Numerical Example: Bisection Method for Root-Finding[11]

- Assume that $f(x) = x^3 - x - 2$.
- Consider to find a root between $[a, b] = [1, 2]$ as initial guess.[10]
- Write a program which calculates the approximate root $\hat{r}$ under this requirement by using the bisection method.
  - In particular, you may set an error tolerance, say $\epsilon = 1e-9$, to strike a balance between efficiency and accuracy.

[10] 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.

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



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