

# PrintStream and printf

You have already seen multiple times a basic way to print text and messages in programs:

```
System.out.println("hello!");
```

If we deconstruct this, we see three parts:

- `System.out` is the object that provides a service;
- `println` is the service provided, to print a message;
- `"hello!"` is the argument to the service, the message to be printed.

Next to `println`, `System.out` provides other services to *print out* values towards the user.

`System.out` is an object of type `PrintStream`. The services offered by `System.out` are provided by any object of the type `PrintStream`.

## Services provided by `PrintStream`

The full documentation of the services offered by `PrintStream` is available [in the JDK manual](#); for the time being, you need only remember the following:

`println(...)` Print a message, then begin a new line of text afterwards. You knew this already.

`print(...)` Print a message, but do not begin a new line of text afterwards. The next use of `print` or `println` will append its message to the same line of output. For example:

```
System.out.print("hello");  
System.out.print("world");
```

will print “helloworld” on a single line.

`printf(...)` Format zero or more values according to a format specification. See below for details.

## Formatted output

A common task to perform in programs is “alignment”: print data in columns, ensuring that values under each other are properly aligned. Another common task is to format numbers according to some application-defined standard, for example “all grades should be printed with one decimal of accuracy” to say the program should print “7.0” and not simply “7”.

Unfortunately, `print` and `println` do not know anything about alignment, decimal places and the like. To perform these additional tasks, the service `printf` is provided.

It is defined as follows:

```
printf(String format, ...)
```

This syntax indicates `printf` takes at least one argument, something that evaluates to a string, and then zero or more additional arguments, which can be of any type.

The semantics of `printf` are as follows:

1. `printf` begins processing at the start of the format string;
2. if the current character in the format string is not a “%” character, it is printed to the output as-is (unchanged);
3. otherwise, `printf` looks after the % sign until it encounters one of the following:
  - a “d”: the next argument in the remaining argument list is printed out in decimal;
  - a “s”: the next argument in the remaining argument list is printed as a string;
  - a “c”: the next argument in the remaining argument list is printed as a character;
  - a “f”: the next argument is printed as a number with a decimal point;
  - a “e”: the next argument is printed as a decimal number in scientific notation;
  - a “%”: the character “%” is printed;
4. if there are more characters in the format string, then `printf` moves to the next character and proceeds at step #2 above.

Some examples:

Program text	What is printed
<code>printf("")</code>	(nothing)
<code>printf("hello")</code>	hello
<code>printf("hi %d", 123)</code>	hi 123
<code>printf("hi %d, again", 123)</code>	hi 123, again
<code>printf("%d - %d: %d", 4, 8, 12)</code>	4 - 8: 12
<code>printf("hi %s!", "bob")</code>	hi bob!
<code>printf("%s%s", "your", "world")</code>	yourworld
<code>printf("score = %d%%.", 13)</code>	score = 13%.
<code>printf("pi = %f", 3.14)</code>	pi = 3.140000
<code>printf("10^3 = %e", 1000)</code>	10^3 = 1.000000e+03

As you can see, each combination of % followed by a character in the format string becomes a “hole” to be filled in by one of the remaining arguments. This group formed by a % followed by a special character is called a *format specifier*. The last character in a format specifier (s, c, d, f, etc) is called the *format conversion*. There exist other conversions, but in this course you will mostly use %d, %s, %c, %f and %%.

## Format specifier

The definition above says about specifiers, “`printf` looks after the `%` sign *until* it encounters one of the following”. So there it is possible to express additional information between the “`%`” sign and the conversion, the special character that decides the type of value to convert. This extra information is used to control *how the formatting is done*.

In this course, you will use the following format specifiers:

Conversion	Meaning	Example	Prints
<code>%f</code>	Print the data as-is	<code>printf(":%d:", 12)</code>	<code>:12:</code>
<code>%Nf</code>	Print at least N columns, align right	<code>printf(":%5d:", 12)</code>	<code>:      12:</code>
<code>%.Mf</code>	Print M decimals (for floats only)	<code>printf("%.3f:", 3.14)</code>	<code>:3.140:</code>
<code>%N.Mf</code>	Align right to N columns, print M decimals	<code>printf(":%5.1f:", 3.14)</code>	<code>:      3.1:</code>
<code>%ONf</code>	Print at least N columns, align right, fill with 0	<code>printf(":%05d:", 12)</code>	<code>:00012:</code>
<code>%-Nf</code>	Print at least N columns, align left	<code>printf("%-5d:", 12)</code>	<code>:12      :</code>

## New line special character

`printf` behaves like `print` in that it never starts a new line in the output by itself. So if you have the following code:

```
System.out.printf("hello %d", 123);  
System.out.printf("world");
```

the program will print “hello 123world” on a single line.

It is possible to force new lines using a special character combination: “`\n`” (a backslash, then small letter `n`). So you can reproduce the behavior of `println` for example as follows:

```
System.out.printf("hello\n");
```

It is also possible to use “`\n`” in the middle of a format string, for example:

```
System.out.println("hello,\nworld!\n");
```

will print “hello,” on a first line, then “world!” on a second line.

### Tip

“`\n`” is one of multiple special combinations that can be found in strings. This will be handled in a later lecture on [strings and character literals](#).

## Important concepts

- the difference between `print`, `println` and `printf`;
- how `printf` interprets its *format string*;

- the difference between *format conversion* (1 character `s`, `f`, etc.) and *format specifier* (the entire group from `%` to conversion);
- the “basic” *format conversions*: `s`, `f`, `d`, `c`, `%`;
- how to extend format specifiers for alignment and changing the number of decimals;
- using the special combination “`\n`”.

## Further reading

- Introduction to Programming, section 2.4.1 (pp. 38-39)
  - Absolute Java, section 2.1 (pp. 58-67), also exercises 1-7
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