# Loops

# Overview

- Like humans, programs should be able to repeat some actions while a condition is true
- In this module we will learn how to express repetitions in a program
- The program will repeat the same action  while a condition is `true` and stops when it is `false`
- Example:
    - `while` *`hungry is true`* `eat; when` *`hungry is false`* `stop eating`

# Learning Objectives

- To be able to write a while loop
- To be able to write a for loop
- To be familiar with the three parts of a loop
- To be able to trace a loop
- To be comfortable with nested loops
- To use a loop to solve problems involving String manipulation

# Iteration

- Repetition of a program block  while a condition is true
- Iterations allow us to control the flow of a program
- Two options:
    - `while` loop
    - `for` loop

# `while` loop

- Executes the body of the loop as long as (or while) a Boolean expression is **true**

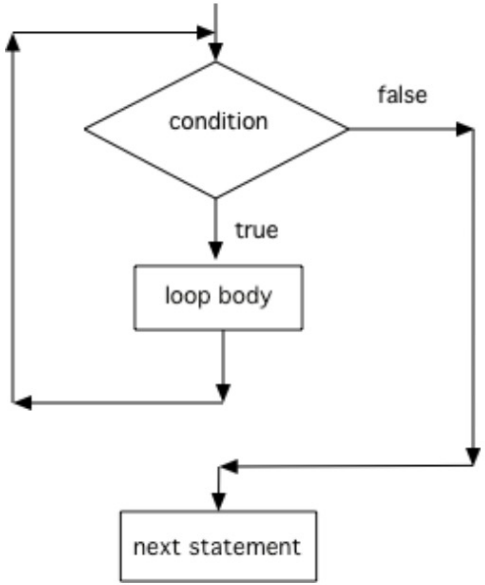



Figure 3: Control Flow in a while Loop

```
// while statements are repeated while the condition is true
while (condition)
{
  statements;
}
```

# Loop control variable

- The loop condition involves a **loop control variable**
- The **loop control variable** controls when the loop stops
- The loop condition tests that the value of the loop control variable matches a specific condition (>, <, >=, <=, ==, !=)

# Three steps of a `while` loop

1. Initialize the loop variable (before the while loop)
2. Test the loop variable (in the loop header)
3. Change the loop variable (in the while loop body at the end)

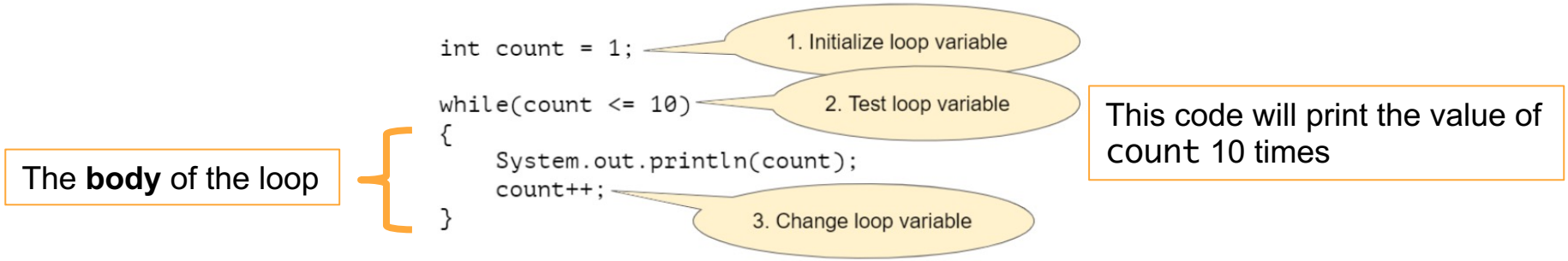
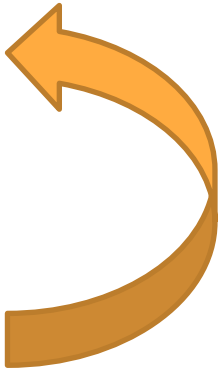



Figure 4: Three Steps of Writing a Loop

# Tracing a `while` loop

- Evaluate a Boolean expression
- If **true:**
    - Execute the body of the loop
    - Repeat
- If **false**, exit the loop



# Tracing a `while` loop

```
int count = 1;
while (count <= 5)
{
    System.out.println(count);
    count++;
}
```

# Tracing a `while` loop

```
int count = 1;
while (count <= 5)
{
    System.out.println(count);
    count++;
}
```

| count | Count <= 5 | Output |
|---|---|---|
| 1 | **true** | 1 |
| 2 | **true** | 2 |
| 3 | **true** | 3 |
| 4 | **true** | 4 |
| 5 | **true** | 5 |
| 6 | **false** | |

# Infinite loop

- A loop that never stops
- Happens when the condition is always true:
  - We forget to change the  loop control variable
  - We do not change the loop control variable correctly

```
int count = 1;
while (count <= 5)
{
    System.out.println(count);
}
```

```
int count = 1;
while (count <= 5)
{
    System.out.println(count);
    count--;
}
```

# Off-by-one error

- The loop run one too many time
- The loop run one too few times
- Happens when:
    - We use the incorrect relational operator in the test loop step

```
int count = 1;
while (count < 5)
{
    System.out.println(count);
    count++;
}
```

The loop will execute 4 times instead of 5. Because we used < instead of <=

# for loop

- Used when you know how many times you want the loop to execute

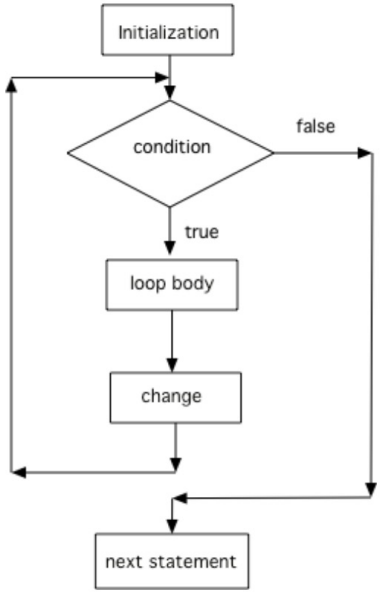


Figure 2: Control flow in a for loop

```
for (initialize; test condition; change)
{
    loop body
}
```

# for vs while loop

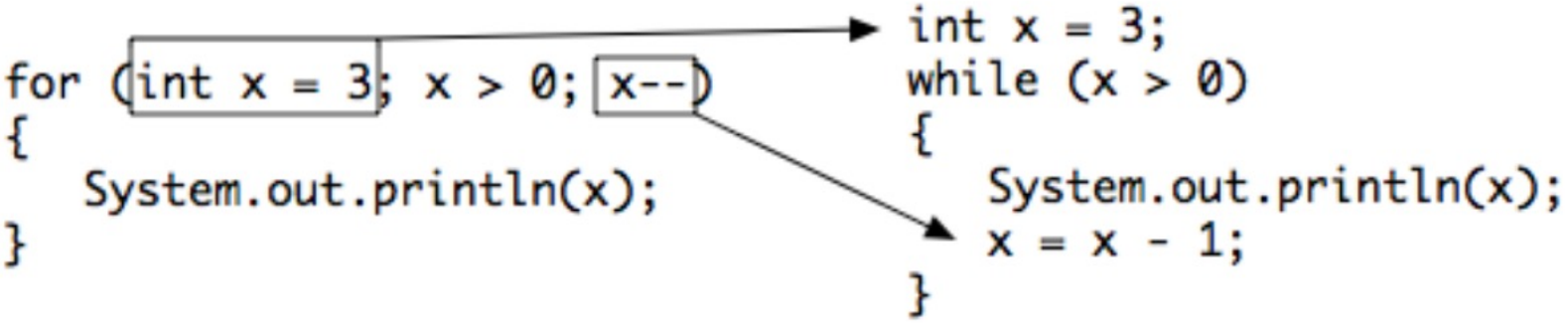



Figure 3: Showing how a for loop maps to a while loop

# for loop patterns

```java
// These loops both run 10 times
// If you start at 0, use <
for(int i = 0; i < 10; i++)
{
   System.out.println(i);
}
// If you start at 1, use <=
for(int i = 1; i <= 10; i++)
{
   System.out.println(i);
}
```

# Loops and Strings

- Loops are often used for **String Traversals** or **String Processing**
- **Traversing** a string involves going through a string character by character
- Characters are located based on their position(or index) in the string
- The **first character** in a Java String is at **index 0** and the **last character** is at **length() – 1**


Figure 1: A string with the position (index) shown above each character

# Loops and Strings

```
String s = “welcome”;
int count = 0;
while (count < s.length())
{
  System.out.println(s.charAt(count));
  count++;
}
```

```
String s = “welcome”;
for (int i =0; i < s.length(); i++)
{
   System.out.println(s.charAt(i));
}
```

Both programs will print the characters in s one at a time

# Nested loops

- When a loop is located inside another one
- In each iteration of the outer loop, the inner loop will be re-started.
- The inner loop must finish all of its iterations before the outer loop can continue to its next iteration

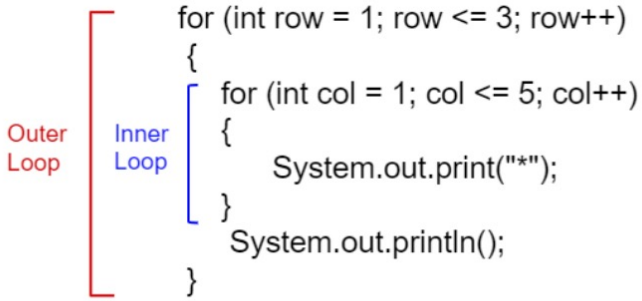



Figure 1: Nested Loops

# Tracing nested loops

Outer Loop

Inner Loop

```
for (int row = 1; row <= 3; row++)
{
    for (int col = 1; col <= 5; col++)
    {
        System.out.print("*");
    }
    System.out.println();
}
```

Figure 1: Nested Loops

| row | row <= 3 | Output |
|---|---|---|
| 1 | true | |
| 2 | true | |
| 3 | true | |
| 4 | false | |

| col | col <= 5 | Output |
|---|---|---|
| 1 | true | * |
| 2 | true | ** |
| 3 | true | *** |
| 4 | true | **** |
| 5 | true | ***** |
| 6 | false | |

| col | col <= 5 | Output |
|---|---|---|
| 1 | true | ***** |
| 2 | true | ****** |
| 3 | true | ******* |
| 4 | true | ******** |
| 5 | true | ********* |
| 6 | false | |