# Loops

CSE 114, Computer Science 1

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http://www.cs.stonybrook.edu/~cse114

# Motivation

- Suppose that you need to print a string (e.g., "Welcome to Java!") a user-defined times N:

N? $\left\{ \begin{array}{l} \texttt{System.out.println("Welcome to Java!");} \\ \dots \\ \texttt{System.out.println("Welcome to Java!");} \end{array} \right.$

- While loop:

```
Scanner input = new Scanner(System.in);
int N = input.nextInt();
int count = 0;
while (count < N) {
    System.out.println("Welcome to Java");
    count++;
}
```

# What is Iteration?

- Repeating a set of instructions a specified number of times or until a specific result is achieved
- How do we repeat steps?
  - Imagine 3 instructions A, B, & C:

    Instruction A

    Instruction B

    Instruction C can be conditional jump A (meaning go back to A)
  - Iteration might result in:

    Execute A

    Execute B

    Execute C

    Execute A

    Execute B

    …

# Why use Iteration?

- To make our code more practical, efficient, flexible and dynamic
- Example:
  - How would we write code to print N! (factorial), where N is a number entered by the user?
  - Without iteration (or recursion) this would be impractical
    - We do not know N, when we are about to write the program

# Without iteration or recursion

```
System.out.print("Enter N: ");
int N = input.nextInt();
int factorial = 1;
if ((N == 1) || (N == 0)) factorial = 1;
else if (N == 2) factorial = 2 * 1;
else if (N == 3) factorial = 3 * 2 * 1;
else if (N == 4) factorial = 4 * 3 * 2 * 1;
else if (N == 5) factorial = 5 * 4 * 3 * 2 * 1;
…
System.out.println(factorial);
```

**Inefficient coding (repetition)!**

# With iteration

```
System.out.print("Enter N: ");
int N = input.readInt();
int factorial = 1;
int i = 1;
while(i<N)
    factorial *= i++;
System.out.println(factorial);
```

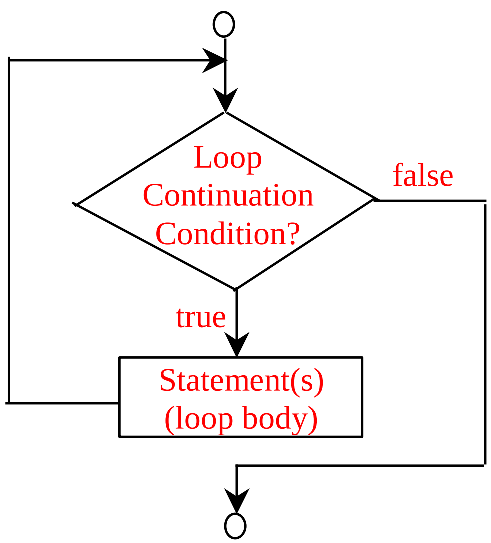
# Java and iteration

- We have 3 types of iterative statements
  - **a while loop**
  - **a do … while loop**
  - **a for loop**
- All 3 can be used to do similar things
- Which one should you use?
  - a matter of individual preference/convenience
- Note: When we will learn arrays, we will see a $4^{th}$ kind of loop: for-each loop

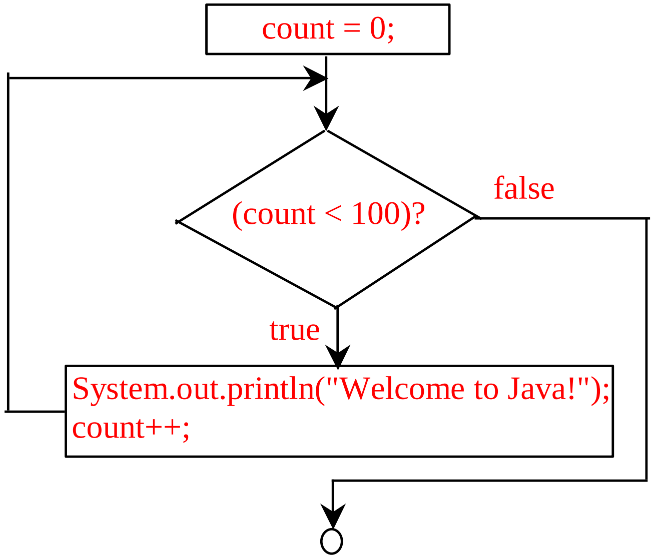
# `while` Loop Flow Chart

```
while (loop-continuation-condition) {
  // loop-body;
  Statement(s);
}
```

```
int count = 0;
while (count < 100) {
  System.out.println("Welcome to Java!");
  count++;
}
```




(A)




(B)

# Trace while Loop

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

Initialize count

# Trace while Loop

(count < 2) is true

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

# Trace while Loop

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

Print Welcome to Java

**Welcome to Java!**

# Trace while Loop

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

Increase count by 1
count is 1 now

```
Welcome to Java!
```

# Trace while Loop

(count < 2) is still true since count is 1

```
int count = 0;
while (count < 2) {
   System.out.println("Welcome to Java!");
   count++;
}
```

```
Welcome to Java!
```

# Trace while Loop

Print Welcome to Java

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

```
Welcome to Java!
Welcome to Java!
```

# Trace while Loop

Increase count by 1
count is 2 now

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

```
Welcome to Java!
Welcome to Java!
```

# Trace while Loop

(count < 2) is false since count is 2 now

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

```
Welcome to Java!
Welcome to Java!
```

# Trace while Loop

```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

The loop exits. Execute the next statement after the loop.

```
Welcome to Java!
Welcome to Java!
```

# Caution: don't use equality for reals

- **Don't use floating-point values for equality checking** in a loop control - because floating-point values are **approximations** for some values
- Example: the following code for computing 1 + 0.9 + 0.8 + … + 0.1:

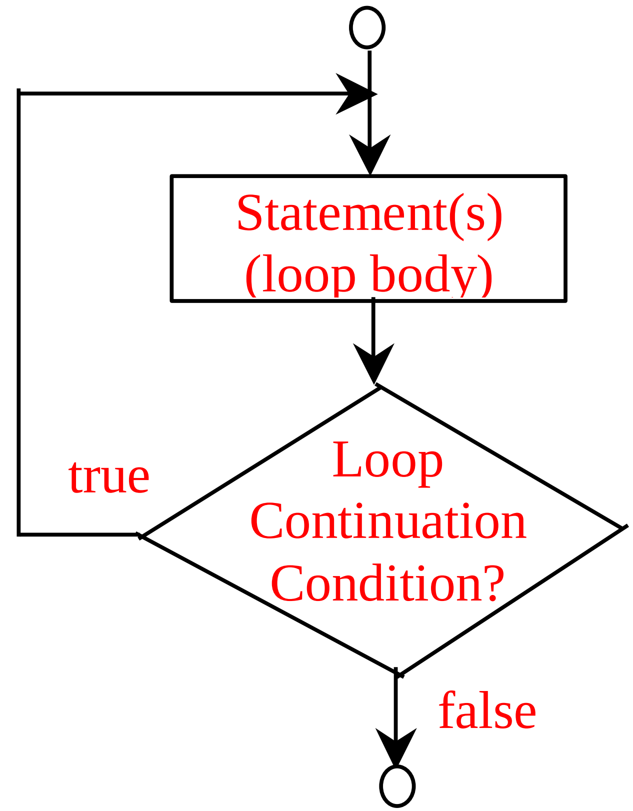
```
double item = 1; double sum = 0;
while (item != 0) { // No guarantee item will be 0 or 0.0
  sum += item;      // change the condition: item >= 0
  item -= 0.1;
}
System.out.println(sum);
```

  - Variable item starts with 1 and is reduced by 0.1 every time the loop body is executed
  - The loop should terminate when item becomes 0
  - There is no guarantee that item will be exactly 0, because the floating-point arithmetic is approximated
  - It is actually an infinite loop!

```
System.out.print(1 - 0.1 - 0.1 - 0.1);
0.7000000000000001
```

# do-while Loop

```
do {
  // Loop body;
  Statement(s);
} while (loop-continuation-condition);
```



# Why use do ... while?

- For when you have a loop body that must execute at least once.
- Example: a program menu

```
Scanner in = new Scanner(System.in);
String selection;
int counter = 0;
do{
    System.out.println("Choose a Menu Option:");
    System.out.println("P) Print Counter");
    System.out.println("Q) Quit");
    System.out.print("ENTER: ");
    selection = in.nextLine();
    if (selection.toUpperCase().equals("P"))
        System.out.println("Counter: " + counter++);
}while(!selection.toUpperCase().equals("Q"));
System.out.println("Goodbye!");
```

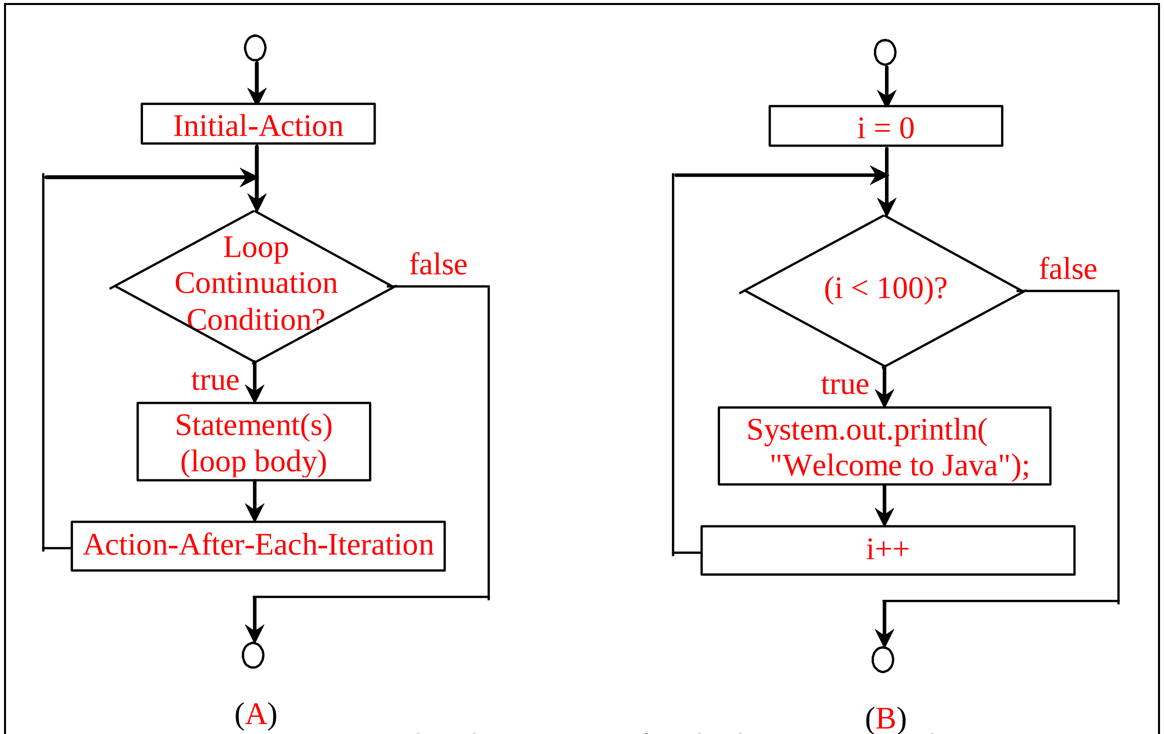
## An Example Session

```
Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: P
Counter: 0
Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: A
Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: P
Counter: 1
Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: Q
Goodbye!
```

# `for` Loops

```
for (initial-action;
      loop-continuation-condition;
      action-after-each-iteration) {
   // loop body;
   Statement(s);
}
```

```
int i;
for (i = 0; i < 100; i++){
   System.out.println(
      "Welcome to Java!");
}
```



# for loops and counting

- for loops are popular for counting loops
  - through the indices of a string
  - through the indices of an array (later)
  - through iterations of an algorithm
- Good for algorithms that require a known number of iterations
  - counter-controlled loops

# Trace for Loop

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

Declare i

# Trace for Loop

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

Execute initializer
i is now 0

# Trace for Loop

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

(i < 2) is true
since i is 0

# Trace for Loop

Print Welcome to Java

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

```
Welcome to Java!
```

# Trace for Loop

Execute adjustment statement
i now is 1

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

```
    Welcome to Java!
```

# Trace for Loop

(i < 2) is still true
since i is 1

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

```
Welcome to Java!
```

# Trace for Loop

Print Welcome to Java

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
    "Welcome to Java!");
}
```

```
Welcome to Java!
Welcome to Java!
```

# Trace for Loop

Execute adjustment statement
i now is 2

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

```
Welcome to Java!
Welcome to Java!
```

# Trace for Loop

(i < 2) is false
since i is 2

```
int i;
for (i = 0; i < 2; i++) {
   System.out.println(
      "Welcome to Java!");
}
```

```
Welcome to Java!
Welcome to Java!
```

# Trace for Loop

Exit the loop. Execute the next statement after the loop

```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
     "Welcome to Java!");
}
```

```
Welcome to Java!
Welcome to Java!
```

# for loops

The initial-action in a for loop can be a list of zero or more comma-separated expressions.

The action-after-each-iteration in a for loop can be a list of zero or more comma-separated statements.

```
for (int i = 0, j = 0; (i + j < 10); i++, j++) {
  // Do something
}
```

The loop body can be the no-op statement:

```
for (int i = 1; i < 100; System.out.println(i++));
```

# Infinite loops

If the loop-continuation-condition in a for loop is omitted, it is implicitly true.

```
for ( ; ; ) {
  // Do something
}
```

(a)

Equivalent

```
while (true) {
  // Do something
}
```

(b)

# Caution ;

Adding a semicolon at the end of the for clause before the loop body is a common mistake:

Logic Error

```
for (int i=0; i<10; i++);
{
   System.out.println("i is " + i);
}
```

# Caution ;

Adding a semicolon at the end of the <u>while</u> clause before the loop body is a common mistake:

Logic Error

```
int i=0;
while (i < 10);
{
  System.out.println("i is " + i);
  i++;
}
```

# Which Loop to Use?

<u>while</u>, <u>do-while</u>, and <u>for</u> loops are expressively equivalent

```
while (loop-continuation-condition) {
  // Loop body
}
```

(a)

Equivalent

```
for ( ; loop-continuation-condition; )
  // Loop body
}
```

(b)

```
for (initial-action;
     loop-continuation-condition;
     action-after-each-iteration) {
  // Loop body;
}
```

(a)

Equivalent

```
initial-action;
while (loop-continuation-condition) {
  // Loop body;
  action-after-each-iteration;
}
```

(b)

# Loop variables

```
int sum = 0;
for (int j=1; j<=4; j++){
  sum = sum + j;
  j++;
}
```

**Be careful not to double the update of your counting variable**

# Sums

```
int sum = 0;
for (int i=1; i<=4; i++)
  sum = sum + i;
```

| **sum** | **i** |
|---|---|
| 0 | 1 |
| 1 | 2 |
| 3 | 3 |
| 6 | 4 |
| 10 | 5 |

# Nested Loops

```
for (int i = 1; i <= 10; i++){
  for (int j = 1; j <= 10; j++){
      int product = i*j;
      System.out.print(product + " ");
  }
  System.out.println();
}
```

```
1 2 3 4 5 6 7 8 9 10
2 4 6 8 10 12 14 16 18 20
3 6 9 12 15 18 21 24 27 30
...
10 20 30 40 50 60 70 80 90 100
```

# Local Variables and Blocks

- A variable declared inside a block is known only inside that block
  - it is ***local*** to the block, therefore it is called a *local variable*
  - when the block finishes executing, local variables disappear
  - references to it outside the block cause a compiler error
  - That includes ***Init field*** of for loops:

```
for(int i=0; i < 10; i++){...}
```

# Java Good programming Practice

- Do not declare variables inside loops it takes time during execution to create and destroy variables, so it is better to do it just once for loops)

# Keywords break and continue

- You can also use **`break`** in a loop to immediately terminate the loop:

```
public static void main(String[] args) {
   int sum = 0;
   int number = 0;
   while (number < 20) {
      number++;
      sum += number;
      if (sum >= 100) // increments until the sum is
          break;     // greater than 100
   }
   System.out.println("The number is " + number);
   System.out.println("The sum is " + sum);
}
```

The number is 14

The sum is 105

# Keywords break and continue

- You can also use **`continue`** in a loop to <u>end the current iteration</u> and program control goes to the end of the loop body (and continues the loop):

```
public static void main(String[] args) {
  int sum = 0;
  int number = 0;
  while (number < 20) { // adds integers from 1 to 20
    number++;             // except 10 and 11 to sum
    if (number ==10 || number == 11)
        continue;
    sum += number;
  }
  System.out.println("The number is " + number);
  System.out.println("The sum is " + sum);
}
```

The number is 20

The sum is 189