# Loops

CSE 114: Introduction to Object-Oriented Programming

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# Motivation

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

```
Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
```

N? {
```
System.out.println("Welcome to Java!");
…
System.out.println("Welcome to Java!");
```

# Motivation

- Without iteration (or recursion) this would be impractical
  - We do not know N, when we are about to write the program
  - So, we need a cascade of if statements to check all cases for the value of N.

# Without iteration or recursion

```java
Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
if(N == 1)
  System.out.println("Welcome to Java!");
else if(N == 2){
  System.out.println("Welcome to Java!");
  System.out.println("Welcome to Java!");
}else if(N == 3){
  System.out.println("Welcome to Java!");
  System.out.println("Welcome to Java!");
  System.out.println("Welcome to Java!");
}…
```

**Inefficient coding (repetition)!**

# Loops Solution

- While loop:

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

# Motivation Example 2

- How would we write code to print N! (factorial), where N is a number entered by the user?

# Without iteration or recursion

```
Scanner input = new Scanner(System.in);
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/loops

```java
Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
int factorial = 1;
int i = 1;
while(i <= N)
    factorial *= i++;
System.out.println(factorial);
```

# What is Iteration?

- Repeating a set of instructions a <span style="color:red">specified number of times</span> or <span style="color:red">until a specific result is achieved</span>

- How do we repeat steps?
  - Imagine 3 instructions A, B, & C:

    Instruction A

    Instruction B

    Instruction C can be conditional jump to A (meaning **go back to A**)

  - Iteration might result in:

    Execute A

    Execute B

    Execute C

    Execute A

    Execute B

    …

# 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
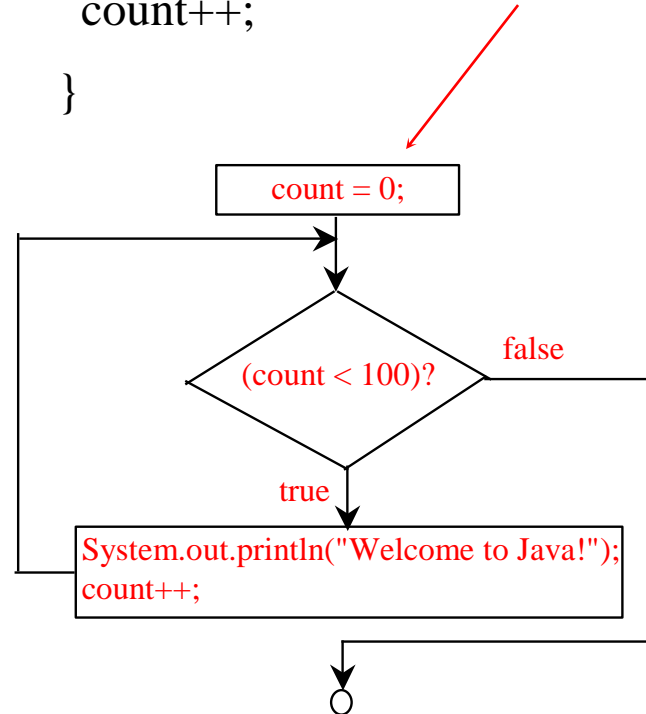- Note: When we will learn arrays, we will see a 4<sup>th</sup> kind of loop: for-each loop

# **while** Loop Flow Chart

```
while (loop-continuation-condition) {
  // loop-body;
  Statement(s);
}
```
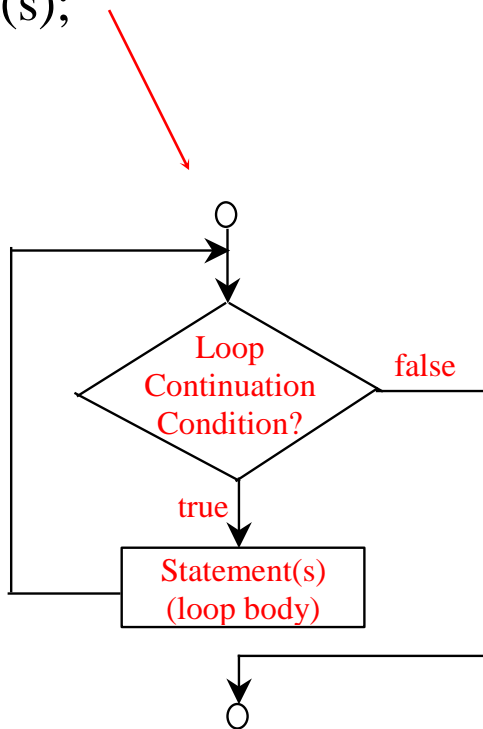
```
int count = 0;
while (count < 100) {
  System.out.println("Welcome to Java!");
  count++;
}
```



(A)



(B)

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# Trace while Loop

Initialize count

```
int count = 0;

while (count < 2) {

    System.out.println("Welcome to Java!");

    count++;

}
```

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# Trace while Loop

```
int count = 0;

while (count < 2) {

    System.out.println("Welcome to Java!");

    count++;

}
```

(count < 2) is true

# Trace while Loop

```java
int count = 0;

while (count < 2) {

  System.out.println("Welcome to Java!");

  count++;

}
```
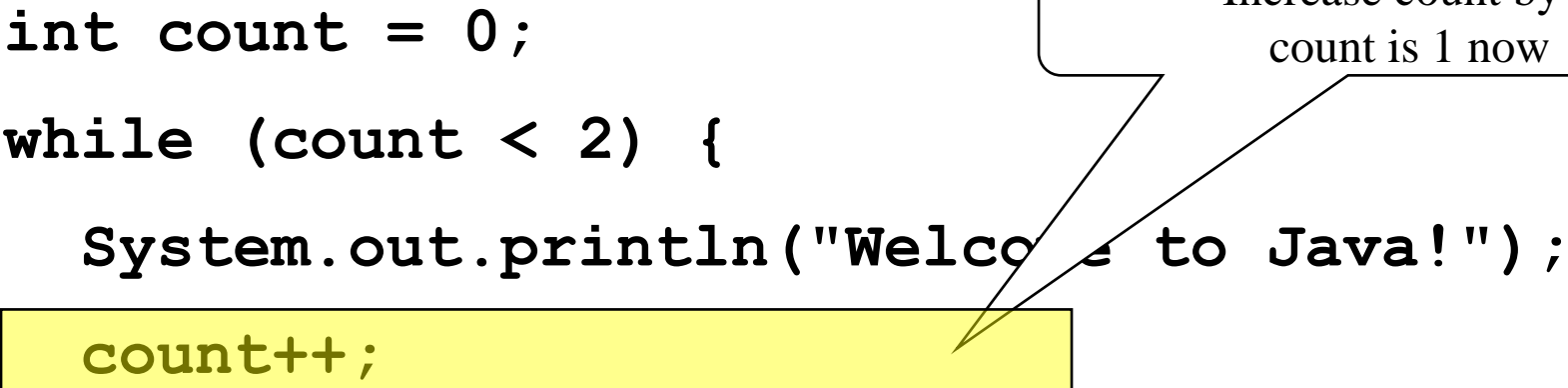
Print Welcome to Java

```
        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

```
int count = 0;

while (count < 2) {

    System.out.println("Welcome to Java!");

    count++;

}
```

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

```
        Welcome to Java!
```

# Trace while Loop

```
int count = 0;

while (count < 2) {

  System.out.println("Welcome to Java!");

  count++;

}
```
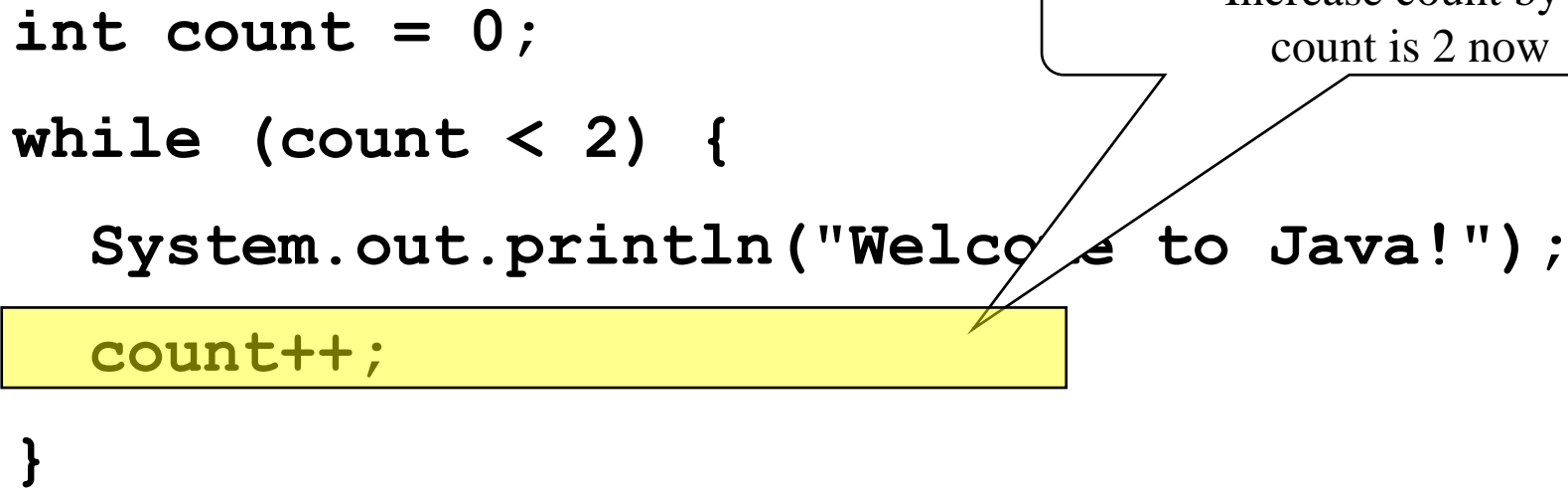
Print Welcome to Java

```
        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 2 now

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

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# Trace while Loop

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

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

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

# Trace while Loop

```java
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

  *System.out.print(1 - 0.1 - 0.1 - 0.1);*
  prints 0.7000000000000001

- Loop example: the following code for computing $\underline{1 + 0.9 + 0.8 + \ldots + 0.1}$:

```
double item = 1, 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.printf("%.1f",sum);
```

- It is actually an infinite loop!
  - 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
    - However, there is no guarantee that item will be exactly 0, because the floating-point arithmetic is approximated
    - So, it continues running forever

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# do-while Loop

```
do {

  // Loop body;

  Statement(s);

} while (loop-continuation-condition);
```
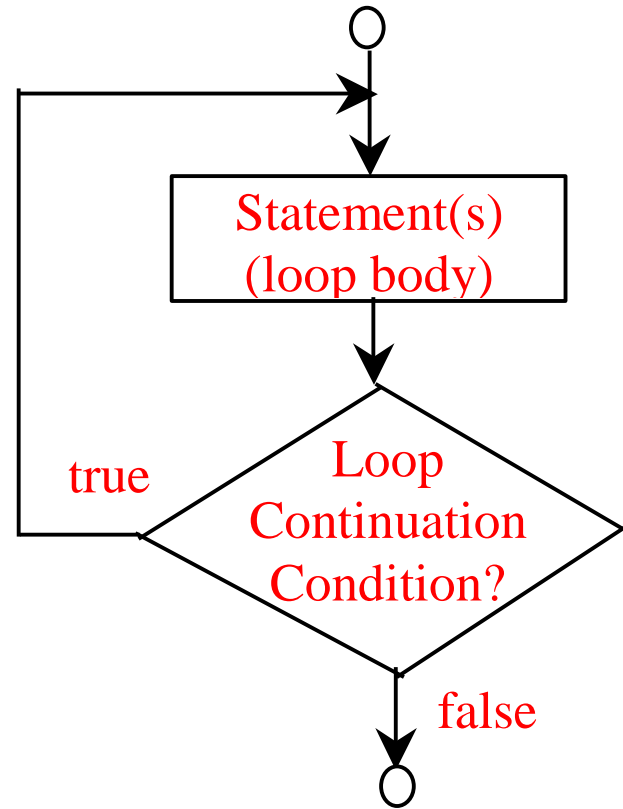
# Why use do ... while?

- 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!");
```

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- **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!
```
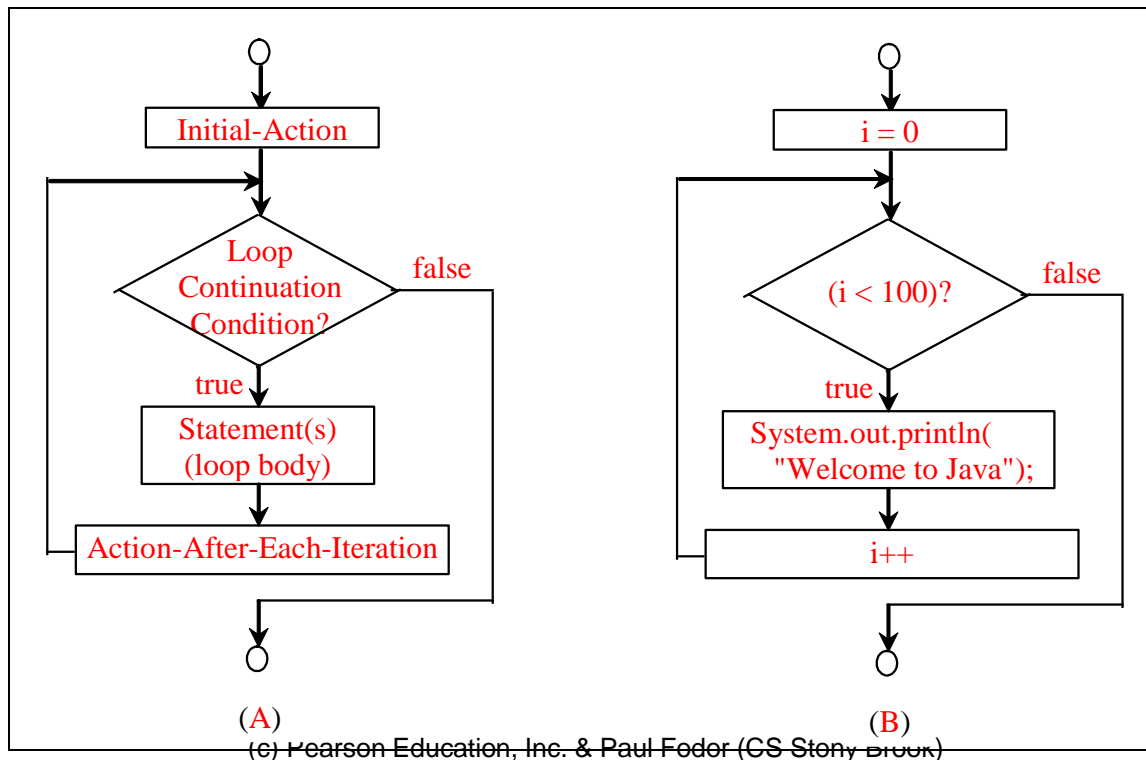
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# for Loops

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

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



(A)

(B)

# 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

Declare i

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

# 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

```java
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

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

> Execute adjustment statement
> i now is 2

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

# Trace for Loop

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

> (i < 2) is false
> since i is 2

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

# Trace for Loop

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

Exit the loop. Execute the next statement after the loop

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

# for loops

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

The <u>action-after-each-iteration</u> in a <u>for</u> 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 = 0; i < 100; System.out.println(i++)) ;
```

# Caution ;

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

```
for (int i=0; i<10; i++) ;
{
  System.out.println("i is " + i);
}       // i does not exist anymore
        // it is a syntax error
```
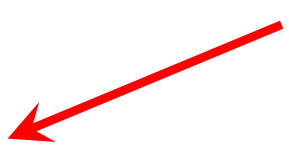
# Same Caution ; for while

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

```
int i=0;
while (i < 10);          Logic Error
{
    System.out.println("i is " + i);
    i++;
}
    this will cause an infinite loop
```

# Infinite loops

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

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

Equivalent

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

(a)

(b)

# Which Loop to Use?

## while, do-while, and for 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)

# Caution: Loop variables

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

# Product

```
int product = 1;
for (int i=1; i<=4; i++)
  product = product * i;
```

# Nested Loops

```java
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
```

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# 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++){
    ...
}
System.out.print(i);
// Compile Error: i is garbage collected
```

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# 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)

```java
for(int i=1; i<=10; i++) {
  double x = 10;
  //...
}
```

```java
double x;
for(int i=1; i<=10; i++) {
  x = 10;
  //...
}
```

# 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**

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# Keywords break and continue

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

```java
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