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

```
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

```
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 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 to A (meaning **go back to A**)
  - Iteration might result in:

    Execute A

    Execute B

    Execute C

    Execute A

    Execute B

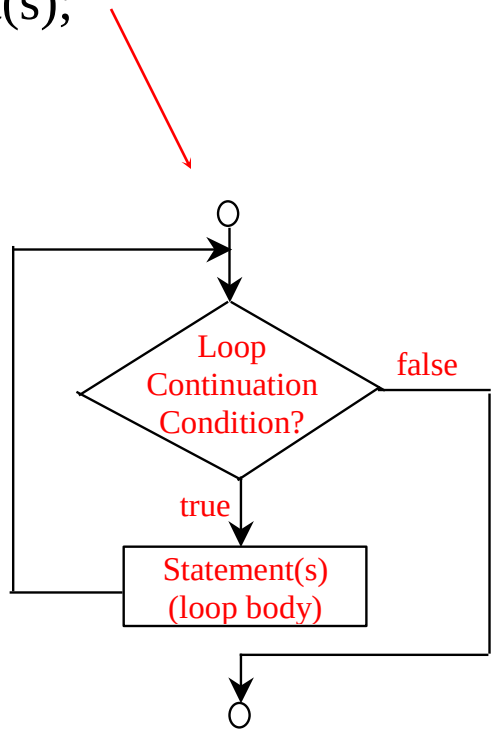
    …

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 4th kind of loop: for-each loop

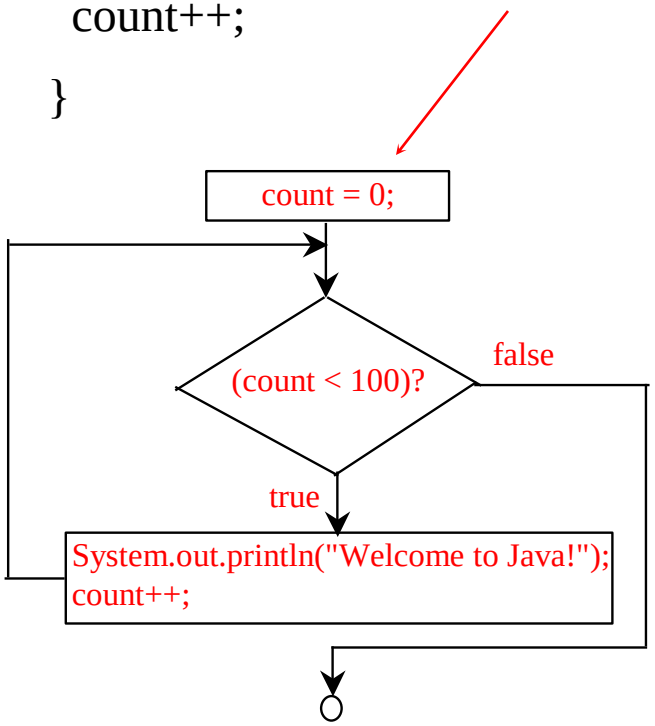
`while` Loop Flow Chart

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



(A)

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



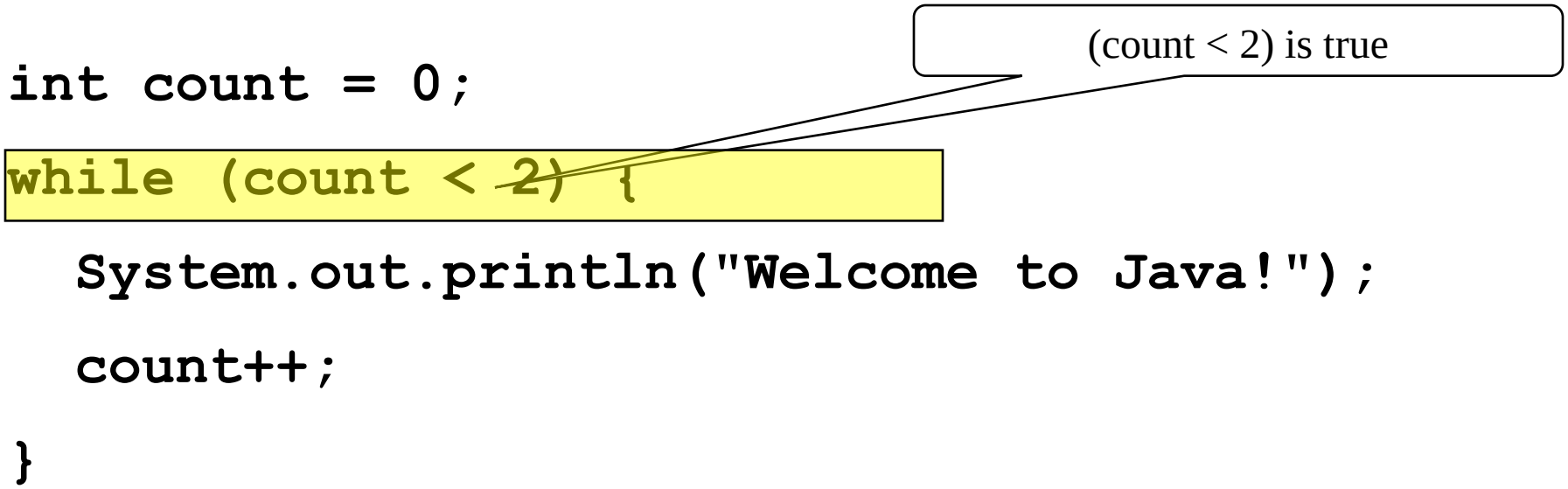
(B)

Trace while Loop

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

Initialize count

Trace while Loop



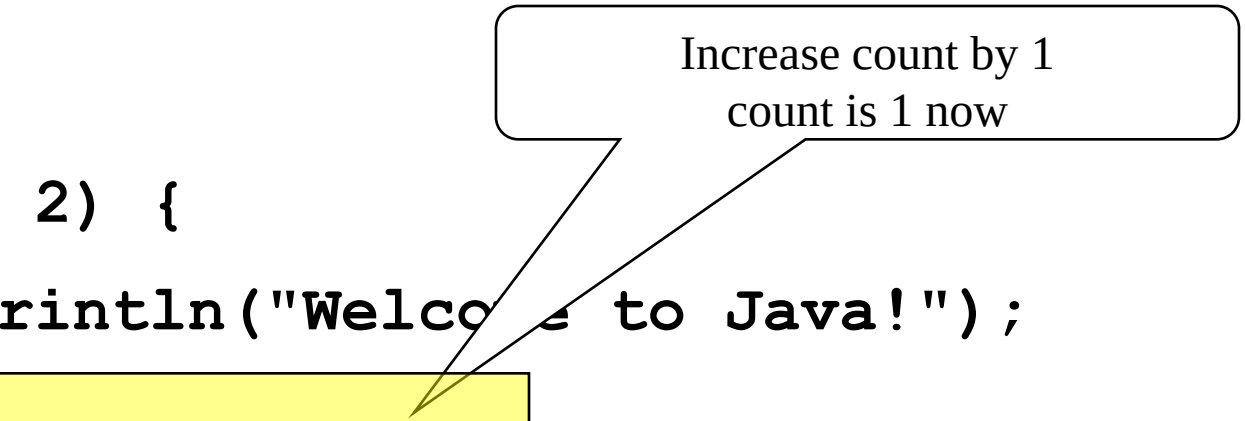
Trace while Loop


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

```
Welcome to Java!
```

Trace while Loop

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




```
Welcome to Java!
```

Trace while Loop

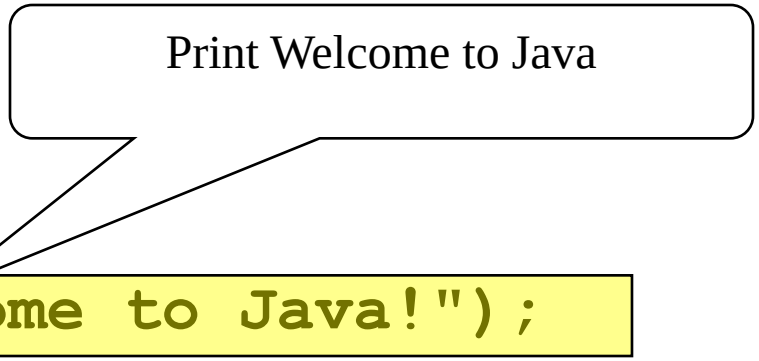
```
int count = 0;

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

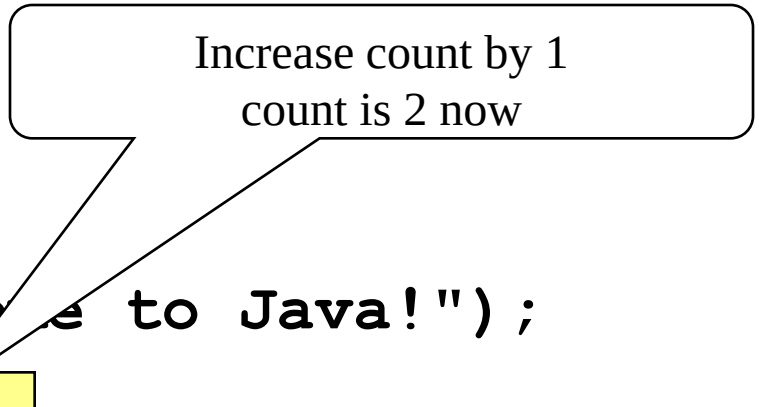
```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```




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

Trace while Loop

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




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

Trace while Loop

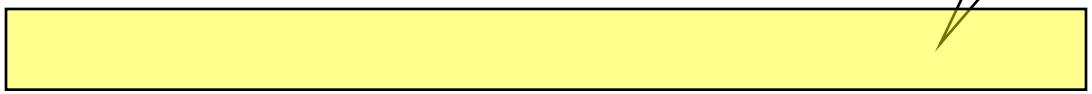
```
int count = 0;
while (count < 2) {
  System.out.println("Welcome to Java!");
  count++;
}
```

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

```
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

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

prints `0.7000000000000001`

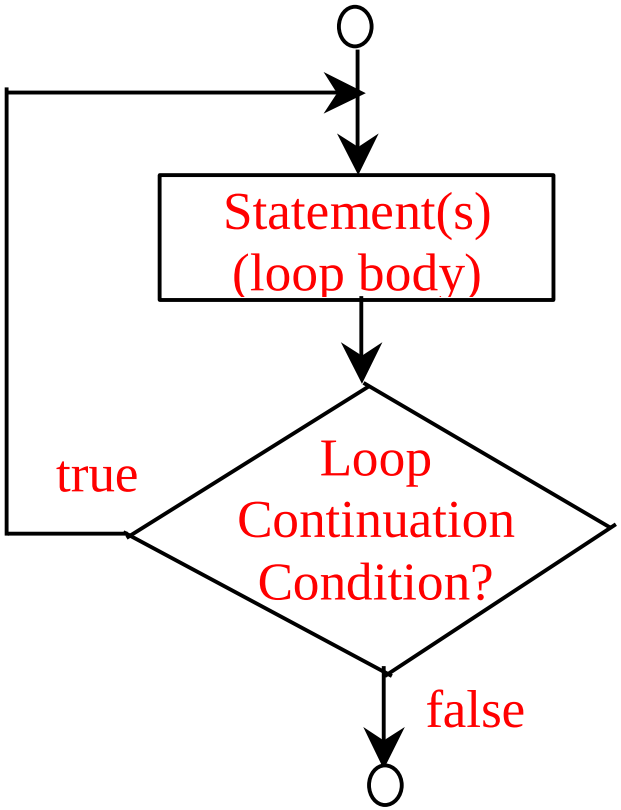
- Loop example: the following code for computing 1 + 0.9 + 0.8 + … + 0.1:

```
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

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!");
```

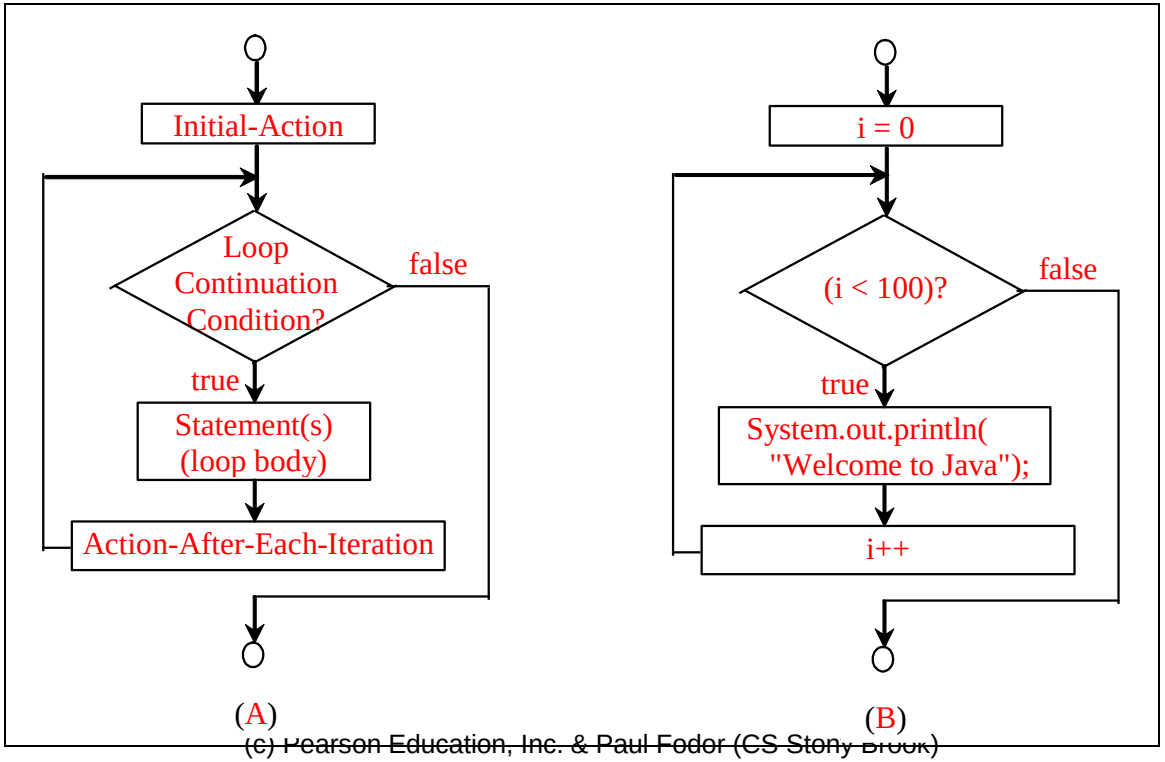
- **An Example Session**

```
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);
}
```

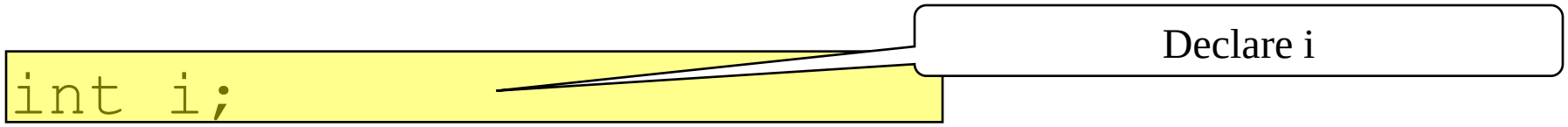
```
int i;
for (i = 0; i < N; i++)
  System.out.println(
     "Welcome to Java!");
```



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*

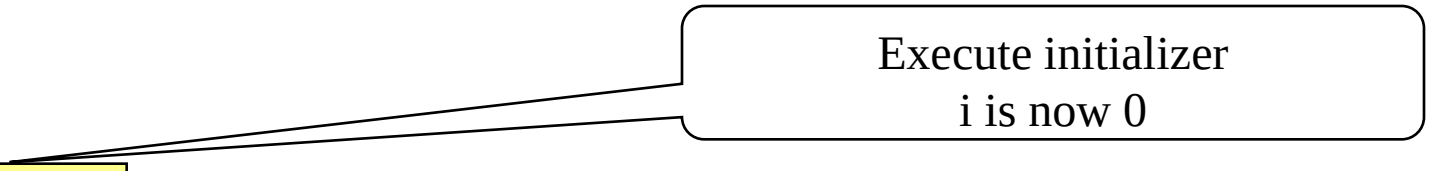
Trace for Loop




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

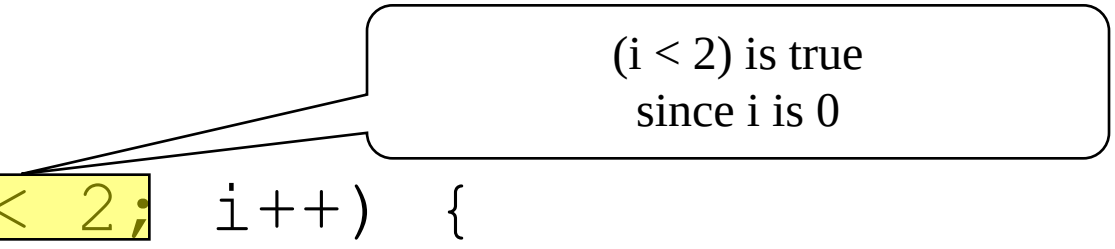
Trace for Loop

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

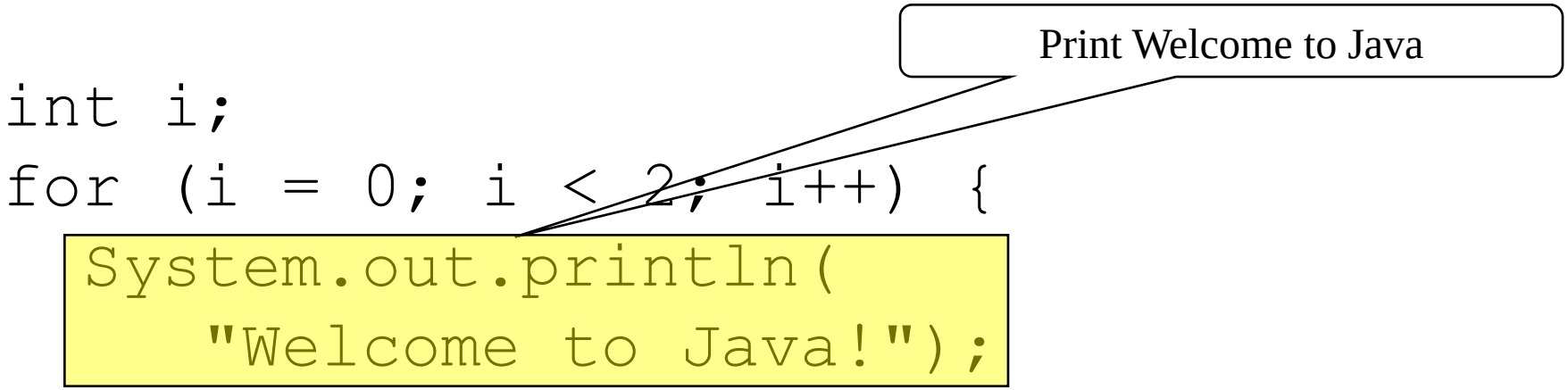


Trace for Loop

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



Trace for Loop




```
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 1

```
    Welcome to Java!
```

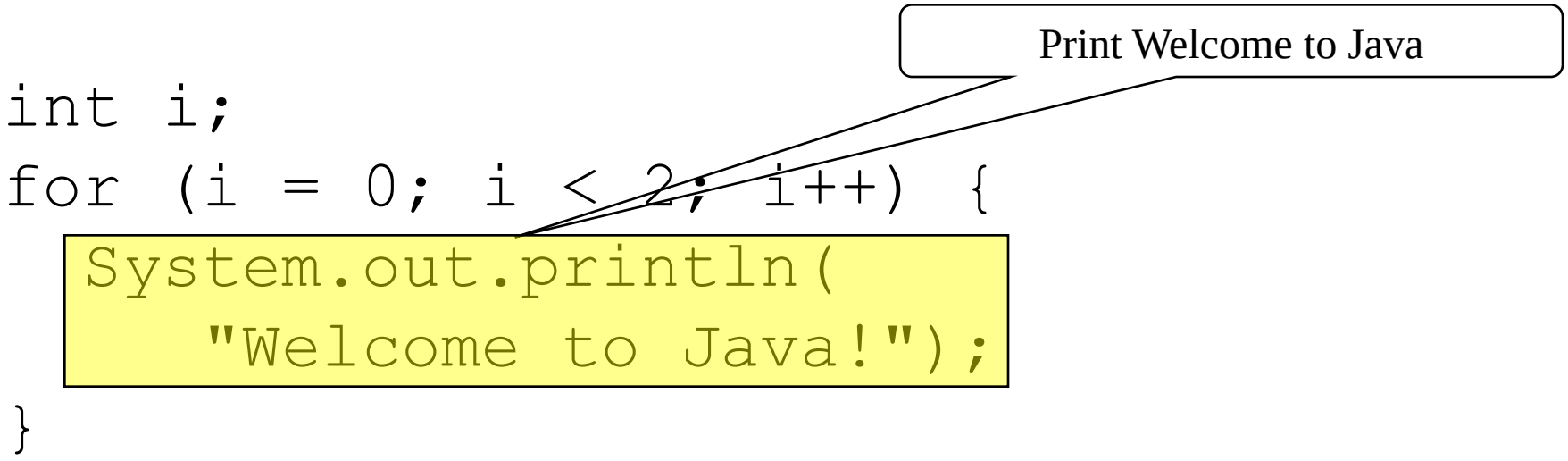
Trace for Loop

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

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

```
    Welcome to Java!
```

Trace for Loop




```
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

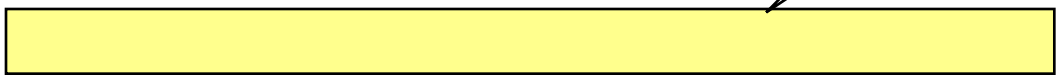
```
int i;
for (i = 0; i < 2; i++) {
  System.out.println(
    "Welcome to Java!");
}
```

(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 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 = 0; i < 100; System.out.println(i++)) ;
```

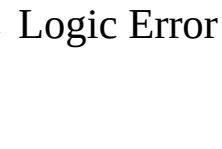
Caution ;

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




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

this will cause an infinite loop

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)

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++;
}
```

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

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

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)

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

```
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

Keywords break and continue

- You can also use **`continue`** in a loop to end the current iteration 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
```