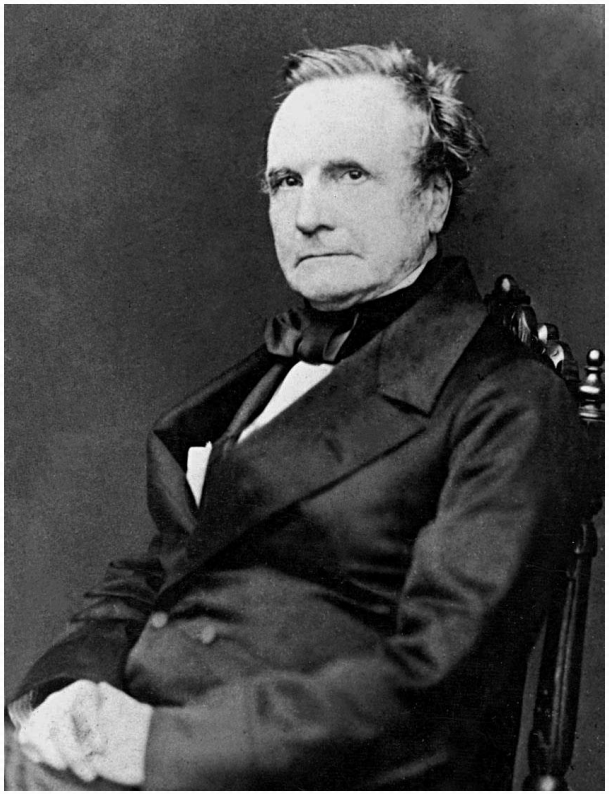
Building Java Programs

Chapter 2
Lecture 3: Variables and the `for` Loop

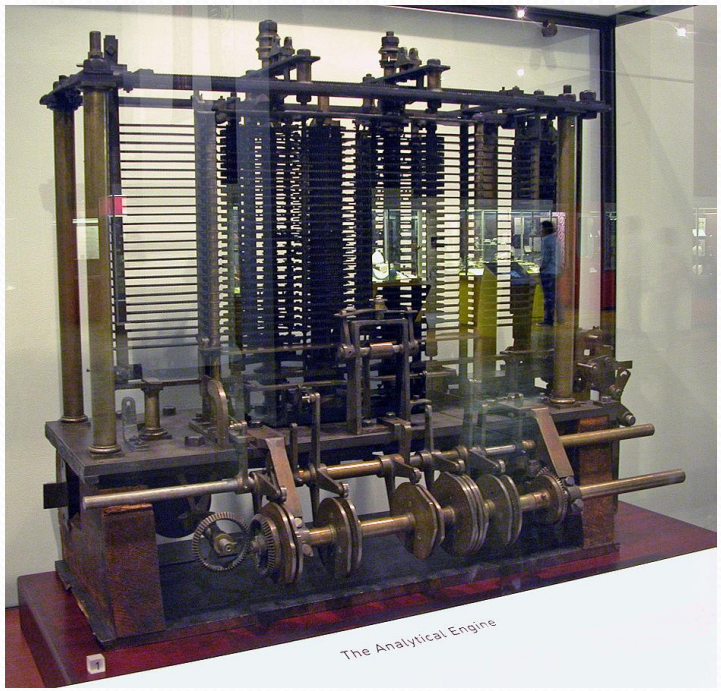
reading: 2.2 – 2.3

First Computer Program

Charles Babbage



1791 – 1871



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Ada Lovelace

1815 – 1852

Division

Discrete (int) Division

46 / 3 = 15 **46 % 3 = 1**

```
   15 r1
3 | 46
    3
   --
   16
   15
   --
    1
```

Continuous (double) Division

3.0 / 46.0 = 15.33…
3 / 46.0 = 15.33…
3.0 / 46 = 15.33…

```
   15.33…
3 | 46.00
    3
   --
   16
   15
   --
    10
     9
    --
    10
```

Variables

reading: 2.2

Variables

- **variable**: A piece of the computer's memory that is given a name and type, and can store a value.
  - Like preset stations on a car stereo, or cell phone speed dial:

  - Steps for using a variable:
    - *Declare* it - state its name and type
    - *Initialize* it - store a value into it
    - *Use* it - print it or use it as part of an expression

Declaration

- **variable declaration**: Sets aside memory for storing a value.
  - Variables must be declared before they can be used.

- Syntax:

  type name;

  - The name is an *identifier*.

  - `int zipcode;`

  - `double myGPA;`

Assignment

- **assignment**: Stores a value into a variable.
  - The value can be an expression; the variable stores its result.

- Syntax:

```
name = expression;
```

- `int zipcode;`
  `zipcode = 90210;`

zipcode	90210

- `double myGPA;`
  `myGPA = 1.0 + 2.25;`

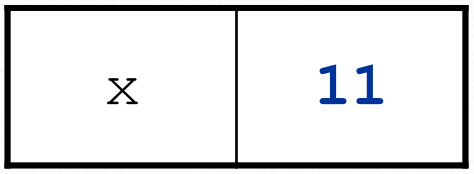
myGPA	3.25

Using variables

- Once given a value, a variable can be used in expressions:

```
int x;
x = 3;
System.out.println("x is " + x);      // x is 3
System.out.println(5 * x - 1);        // 5 * 3 - 1
```

- You can assign a value more than once:




```
int x;
x = 3;
System.out.println(x + " here");      // 3 here

x = 4 + 7;
System.out.println("now x is " + x); // now x is 11
```

Declaration/initialization

- A variable can be declared/initialized in one statement.

- Syntax:

```
type name = value;
```

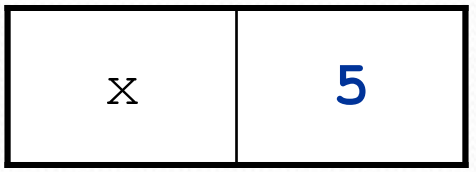
  - `double myGPA = 3.95;`

  - `int x = (11 % 3) + 12;`

Assignment and algebra

- Assignment uses = , but it is not an algebraic equation.
  - = means, *"store the value at right in variable at left"*
    - The right side expression is evaluated first, and then its result is stored in the variable at left.
- What happens here?

```
int x = 3;
x = x + 2;   // ???
```



Assignment and types

- A variable can only store a value of its own type.
  - `int x = 2.5;` **`// ERROR: incompatible types`**
- An `int` value can be stored in a `double` variable.
  - The value is converted into the equivalent real number.
  - `double myGPA = 4;`

myGPA	4.0

  - `double avg = 11 / 2;`
    - Why does `avg` store `5.0` and not `5.5` ?

avg	**5.0**

Compiler errors

- A variable can't be used until it is assigned a value.
  - ```
    int x;
    System.out.println(x);    // ERROR: x has no value
    ```
- You may not declare the same variable twice.
  - ```
    int x;
    int x;                    // ERROR: x already exists
    ```
  - ```
    int x = 3;
    int x = 5;                // ERROR: x already exists
    ```
    - How can this code be fixed?
    ```

Printing a variable's value

- Use + to print a string and a variable's value on one line.
  - ```
    double grade = (95.1 + 71.9 + 82.6) / 3.0;
    System.out.println("Your grade was " + grade);

    int students = 11 + 17 + 4 + 19 + 14;
    System.out.println("There are " + students +
                       " students in the course.");
    ```
  - Output:

    ```
    Your grade was 83.2
    There are 65 students in the course.
    ```
    ```

Receipt question

Improve the receipt program using variables.

```
public class Receipt {
    public static void main(String[] args) {
        // Calculate total owed, assuming 8% tax / 15% tip
        System.out.println("Subtotal:");
        System.out.println(38 + 40 + 30);

        System.out.println("Tax:");
        System.out.println((38 + 40 + 30) * .08);

        System.out.println("Tip:");
        System.out.println((38 + 40 + 30) * .15);

        System.out.println("Total:");
        System.out.println(38 + 40 + 30 +
                           (38 + 40 + 30) * .15 +
                           (38 + 40 + 30) * .08);
    }
}
```

Receipt answer

```
public class Receipt {
    public static void main(String[] args) {
        // Calculate total owed, assuming 8% tax / 15% tip
        int subtotal = 38 + 40 + 30;
        double tax = subtotal * .08;
        double tip = subtotal * .15;
        double total = subtotal + tax + tip;

        System.out.println("Subtotal: " + subtotal);
        System.out.println("Tax: " + tax);
        System.out.println("Tip: " + tip);
        System.out.println("Total: " + total);
    }
}
```

For loops

reading: 2.3

Repetition with `for` loops

- So far, repeating an action results in redundant code:

```
makeBatter();
bakeCookies();
bakeCookies();
bakeCookies();
bakeCookies();
bakeCookies();
frostCookies();
```

- Java's **`for` loop** statement performs a task many times.

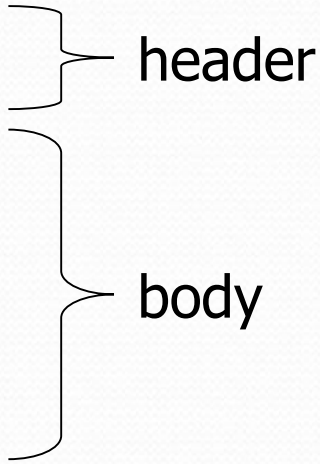
```
makeBatter();

for (int i = 1; i <= 5; i++) {    // repeat 5 times
    bakeCookies();
}

frostCookies();
```

`for` loop syntax

```
for (initialization; test; update) {
    statement;
    statement;
    ...
    statement;
}
```



- Perform **initialization** once.
- Repeat the following:
  - Check if the **test** is true. If not, stop.
  - Execute the **statement**s.
  - Perform the **update**.

Example flow

- Initialization
  - Test
    - Body
    - Update
  - Test
    - Body
    - Update
  - Test
    - Exit For Loop

Control structures

- **Control structure**: a programming construct that affects the flow of a program's execution
- Controlled code may include one or more statements
- The for loop is an example of a looping control structure

Initialization

```
for (int i = 1; i <= 6; i++) {
    System.out.println("I am so smart");
}
```

- Tells Java what variable to use in the loop
  - The variable is called a *loop counter*
    - can use any name, not just `i`
    - can start at any value, not just `1`
    - only valid in the loop
  - Performed once as the loop begins

Test

```
for (int i = 1; i <= 6; i++) {
    System.out.println("I am so smart");
}
```

- Tests the loop counter variable against a limit
  - Uses comparison operators:

    `<` less than

    `<=` less than or equal to

    `>` greater than

    `>=` greater than or equal to

Increment and decrement

shortcuts to increase or decrease a variable's value by 1

Shorthand	Equivalent longer version
variable++;	**variable** = **variable** + 1;
variable--;	**variable** = **variable** - 1;

```
int x = 2;
x++;                    // x = x + 1;
                        // x now stores 3

double gpa = 2.5;
gpa--;                  // gpa = gpa - 1;
                        // gpa now stores 1.5
```

Modify-and-assign operators

shortcuts to modify a variable's value

Shorthand	Equivalent longer version
variable += **value**;	**variable** = **variable** + **value**;
variable -= **value**;	**variable** = **variable** - **value**;
variable *= **value**;	**variable** = **variable** * **value**;
variable /= **value**;	**variable** = **variable** / **value**;
variable %= **value**;	**variable** = **variable** % **value**;

```
x += 3;                  // x = x + 3;

gpa -= 0.5;              // gpa = gpa - 0.5;

number *= 2;             // number = number * 2;
```

Repetition over a range

```
System.out.println("1 squared = " + 1 * 1);
System.out.println("2 squared = " + 2 * 2);
System.out.println("3 squared = " + 3 * 3);
System.out.println("4 squared = " + 4 * 4);
System.out.println("5 squared = " + 5 * 5);
System.out.println("6 squared = " + 6 * 6);
```

- Intuition: "I want to print a line for each number from 1 to 6"

- The `for` loop does exactly that!

```
for (int i = 1; i <= 6; i++) {
    System.out.println(i + " squared = " + (i * i));
}
```

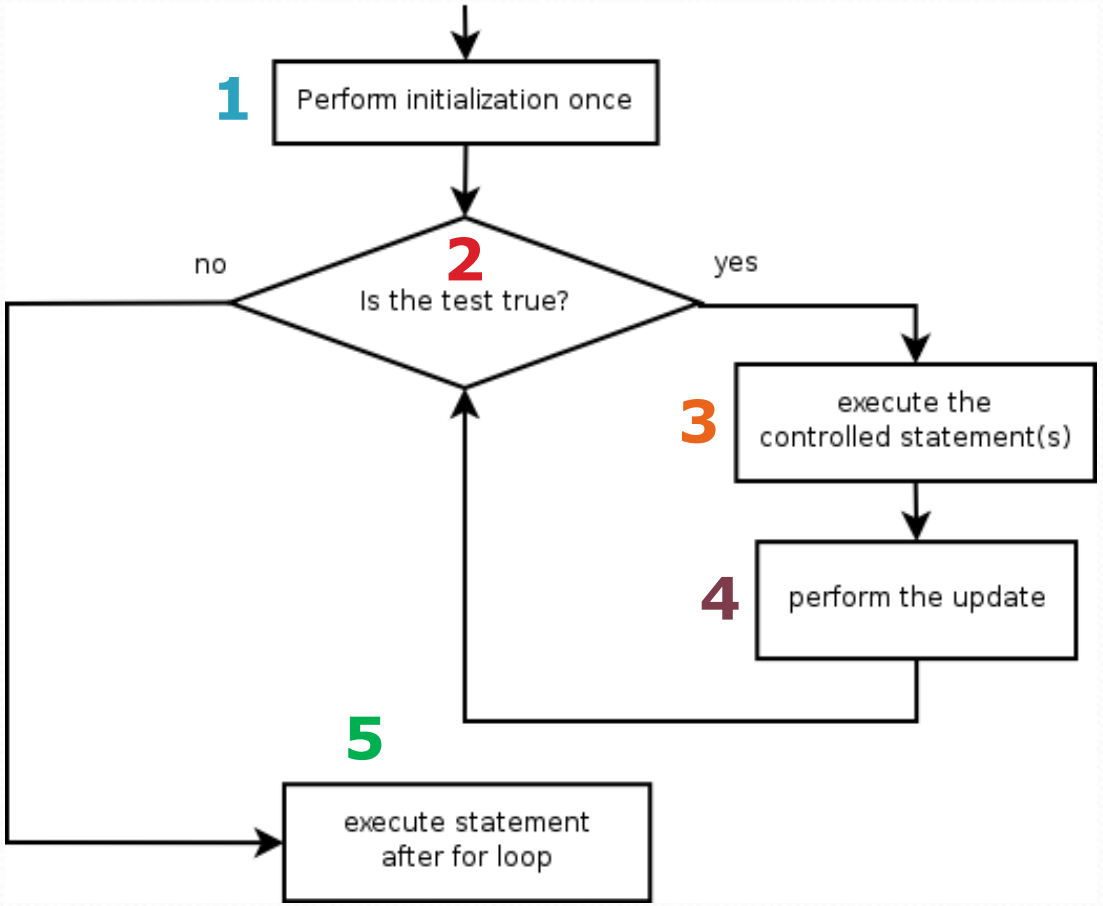
- "For each integer **i** from 1 through 6, print ..."

Loop walkthrough

```
          1        2     4
for (int i = 1; i <= 4; i++) {
  3 System.out.println(i + " squared = " + (i * i));
}
5 System.out.println("Whoo!");
```

Output:

```
1 squared = 1
2 squared = 4
3 squared = 9
4 squared = 16
Whoo!
```



Multi-line loop body

```
System.out.println("+----+");
for (int i = 1; i <= 3; i++) {
    System.out.println("\\    /");
    System.out.println("/    \\");
}
System.out.println("+----+");
```

- Output:

```
+----+
\    /
/    \
\    /
/    \
\    /
/    \
+----+
```

Expressions for counter

```
int highTemp = 5;
for (int i = -3; i <= highTemp / 2; i++) {
    System.out.println(i * 1.8 + 32);
}
```

- Output:

```
26.6
28.4
30.2
32.0
33.8
35.6
```

System.out.print

- Prints without moving to a new line
  - allows you to print partial messages on the same line

```
int highestTemp = 5;
for (int i = -3; i <= highestTemp / 2; i++) {
    System.out.print((i * 1.8 + 32) + "  ");
}
```

  - Output:

```
26.6  28.4  30.2  32.0  33.8  35.6
```

    - Concatenate `"  "` to separate the numbers

Counting down

- The **update** can use `--` to make the loop count down.
  - The **test** must say `>` instead of `<`

```
System.out.print("T-minus ");
for (int i = 10; i >= 1; i--) {
     System.out.print(i + ", ");
}
System.out.println("blastoff!");
System.out.println("The end.");
```

  - Output:

```
T-minus 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, blastoff!
The end.
```

Nested loops

reading: 2.3

Nested loops

- **nested loop**: A loop placed inside another loop.

```
for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= 10; j++) {
        System.out.print("*");
    }
    System.out.println();    // to end the line
}
```

- Output:

```
**********
**********
**********
**********
**********
```

- The outer loop repeats 5 times; the inner one 10 times.
  - "sets and reps" exercise analogy

Nested `for` loop exercise

- What is the output of the following nested `for` loops?

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

- Output:

```
*
**
***
****
*****
```

Nested `for` loop exercise

- What is the output of the following nested `for` loops?

```
for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= i; j++) {
        System.out.print(i);
    }
    System.out.println();
}
```

- Output:

```
1
22
333
4444
55555
```

Common errors

- Both of the following sets of code produce *infinite loops*:

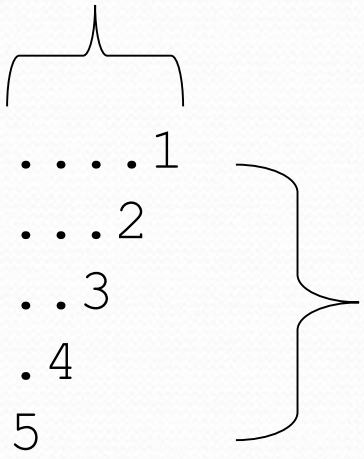
```
for (int i = 1; i <= 5; i++) {
    for (int j = 1; i <= 10; j++) {
        System.out.print("*");
    }
    System.out.println();
}
```

```
for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= 10; i++) {
        System.out.print("*");
    }
    System.out.println();
}
```

Complex lines

- What nested `for` loops produce the following output?

inner loop (repeated characters on each line)



outer loop (loops 5 times because there are 5 lines)

- We must build multiple complex lines of output using:
  - an *outer "vertical" loop* for each of the lines
  - *inner "horizontal" loop(s)* for the patterns within each line

Outer and inner loop

- First write the outer loop, from 1 to the number of lines.

```
for (int line = 1; line <= 5; line++) {
    ...
}
```

- Now look at the line contents. Each line has a pattern:
  - some dots (0 dots on the last line), then a number

```
....1
...2
..3
.4
5
```

  - Observation: the number of dots is related to the line number.

Mapping loops to numbers

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

- What statement in the body would cause the loop to print:

  4 7 10 13 16

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

Loop tables

- What statement in the body would cause the loop to print:

```
2 7 12 17 22
```

- To see patterns, make a table of `count` and the numbers.
  - Each time count goes up by 1, the number should go up by 5.
  - But `count * 5` is too great by 3, so we subtract 3.

`count`	number to print	`5 * count`
1	2	5
2	7	10
3	12	15
4	17	20
5	22	25

`5 * count - 3`
2
7
12
17
22

Loop tables question

- What statement in the body would cause the loop to print:

```
17 13 9 5 1
```

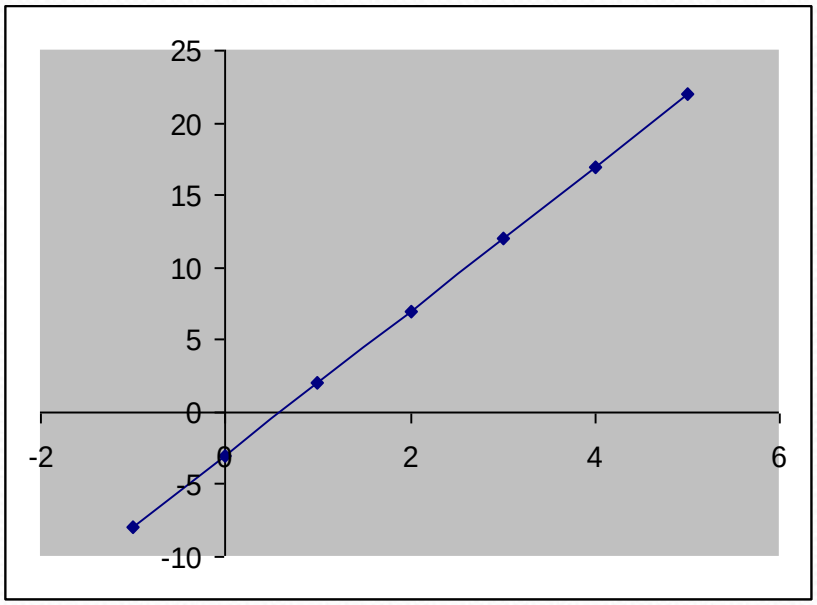
- Let's create the loop table together.
  - Each time `count` goes up 1, the number printed should ...
  - But this multiple is off by a margin of ...

`count`	number to print
1	17
2	13
3	9
4	5
5	1

`-4 * count`	`-4 * count + 21`
-4	17
-8	13
-12	9
-16	5
-20	1

Another view: Slope-intercept

- The next three slides present the mathematical basis for the loop tables. Feel free to skip it.



count (x)	number to print (y)
1	2
2	7
3	12
4	17
5	22

Another view: Slope-intercept

- *Caution*: This is algebra, not assignment!
- Recall: slope-intercept form (`y = mx + b`)
- Slope is defined as "rise over run" (i.e. rise / run). Since the "run" is always `1` (we increment along `x` by 1), we just need to look at the "rise". The rise is the difference between the `y` values. Thus, the slope (`m`) is the difference between `y` values; in this case, it is `+5`.
- To compute the y-intercept (`b`), plug in the value of `y` at `x = 1` and solve for `b`. In this case, `y = 2`.

```
y = m * x + b
2 = 5 * 1 + b
```

Then `b = -3`

- So the equation is

```
y = m * x + b
y = 5 * x - 3
y = 5 * count - 3
```

`count (x)`	number to print (`y`)
1	2
2	7
3	12
4	17
5	22

Another view: Slope-intercept

- Algebraically, if we always take the value of `y` at `x = 1`, then we can solve for `b` as follows:

```
y = m * x + b
y1 = m * 1 + b
y1 = m + b
b = y1 - m
```

- In other words, to get the `y`-intercept, just subtract the slope from the first `y` value (`b = 2 - 5 = -3`)
  - This gets us the equation

```
y = m * x + b
y = 5 * x - 3
y = 5 * count - 3
```

(which is exactly the equation from the previous slides)

Nested `for` loop exercise

- Make a table to represent any patterns on each line.

```
....1
...2
..3
.4
5
```

line	# of dots
1	4
2	3
3	2
4	1
5	0

-1 * line	-1 * line + 5
-1	4
-2	3
-3	2
-4	1
-5	0

- To print a character multiple times, use a `for` loop.

```
for (int j = 1; j <= 4; j++) {
    System.out.print(".");          // 4 dots
}
```

Nested `for` loop solution

- Answer:

```
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    System.out.println(line);
}
```

- Output:

```
....1
...2
..3
.4
5
```

Nested `for` loop exercise

- What is the output of the following nested `for` loops?

```
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    for (int k = 1; k <= line; k++) {
        System.out.print(line);
    }
    System.out.println();
}
```

- Answer:

```
....1
...22
..333
.4444
55555
```

Nested `for` loop exercise

- Modify the previous code to produce this output:

```
....1
...2.
..3..
.4...
5....
```

- Answer:

```
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    System.out.print(line);
    for (int j = 1; j <= (line - 1); j++) {
        System.out.print(".");
    }
    System.out.println();
}
```