Building Java Programs
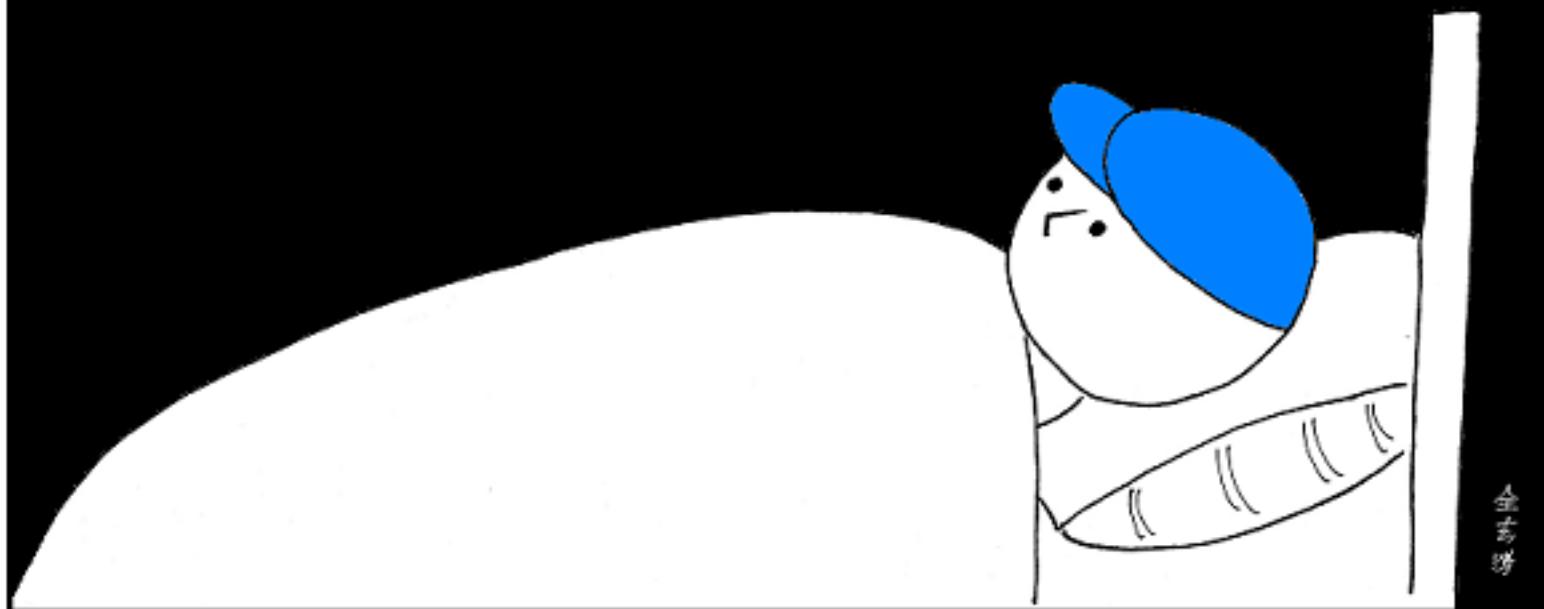
Chapter 5
Lecture 5-1: `while` Loops,
Fencepost Loops, and Sentinel Loops

reading: 5.1 – 5.2

A deceptive problem…

- Write a method `printLetters` that prints each letter from a word separated by commas.

  For example, the call:

  ```
  printLetters("Atmosphere")
  ```

  should print:

  ```
  A, t, m, o, s, p, h, e, r, e
  ```

Flawed solutions

- ```java
  public static void printLetters(String word) {
      for(int i = 0; i < word.length(); i++) {
          System.out.print(word.charAt(i) + ", ");
      }
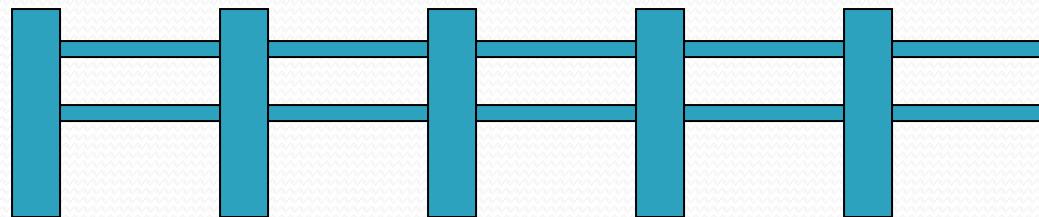   System.out.println();   // end line
  }
  ```
  - Output:  A, t, m, o, s, p, h, e, r, e,

- ```java
  public static void printLetters(String word) {
      for(int i = 0; i < word.length(); i++) {
          System.out.print(", " + word.charAt(i));
      }
      System.out.println();   // end line
  }
  ```
  - Output: , A, t, m, o, s, p, h, e, r, e

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Fence post analogy

- We print *n* letters but need only *n* - 1 commas.
- Similar to building a fence with wires separated by posts:
  - If we use a flawed algorithm that repeatedly places a post + wire, the last post will have an extra dangling wire.

```
for (length of fence) {
    place a post.
    place some wire.
}
```

Fencepost loop

- Add a statement outside the loop to place the initial "post."
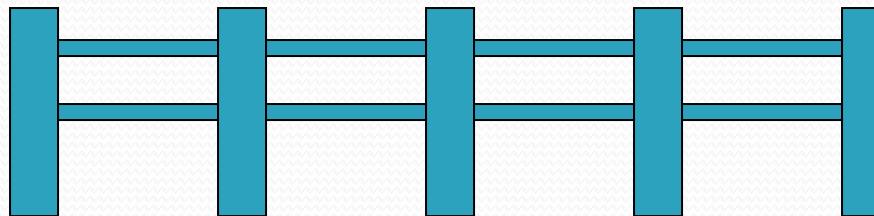 - Also called a *fencepost loop* or a "loop-and-a-half" solution.

> ***place a post.***
> *for (length of fence* ***- 1****) {*
>   ***place some wire.***
>   ***place a post.***
> *}*

Fencepost method solution

- ```
  public static void printLetters(String word) {
      System.out.print(word.charAt(0));
      for(int i = 1; i < word.length(); i++) {
          System.out.print(", " + word.charAt(i));
      }
      System.out.println();   // end line
  }
  ```

- Alternate solution: Either first or last "post" can be taken out:

  ```
  public static void printLetters(String word) {
      for(int i = 0; i < word.length() - 1; i++) {
          System.out.print(word.charAt(i) + ", ");
      }
      int last = word.length() - 1;
      System.out.println(word.charAt(last));   // end line
  }
  ```

Fencepost question

- Write a method `printPrimes` that prints all *prime* numbers up to a max.

  - Example: `printPrimes(50)` prints
    2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47

  - If the maximum is less than 2, print no output.

- To help you, write a method `countFactors` which returns the number of factors of a given integer.
  - `countFactors(20)` returns 6 due to factors 1, 2, 4, 5, 10, 20.

Fencepost answer

```java
// Prints all prime numbers up to the given max.
public static void printPrimes(int max) {
    if (max >= 2) {
        System.out.print("2");
        for (int i = 3; i <= max; i++) {
            if (countFactors(i) == 2) {
                System.out.print(", " + i);
            }
        }
        System.out.println();
    }
}

// Returns how many factors the given number has.
public static int countFactors(int number) {
    int count = 0;
    for (int i = 1; i <= number; i++) {
        if (number % i == 0) {
            count++;    // i is a factor of number
        }
    }
    return count;
}
```

while loops

reading: 5.1

Categories of loops

- **definite loop**: Executes a known number of times.
  - The `for` loops we have seen are definite loops.

    - Print "hello" 10 times.
    - Find all the prime numbers up to an integer *n*.
    - Print each odd number between 5 and 127.

- **indefinite loop**: One where the number of times its body repeats is not known in advance.

    - Prompt the user until they type a non-negative number.
    - Print random numbers until a prime number is printed.
    - Repeat until the user has typed "q" to quit.

The `while` loop

- **`while` loop**: Repeatedly executes its body as long as a logical test is true.

    ```
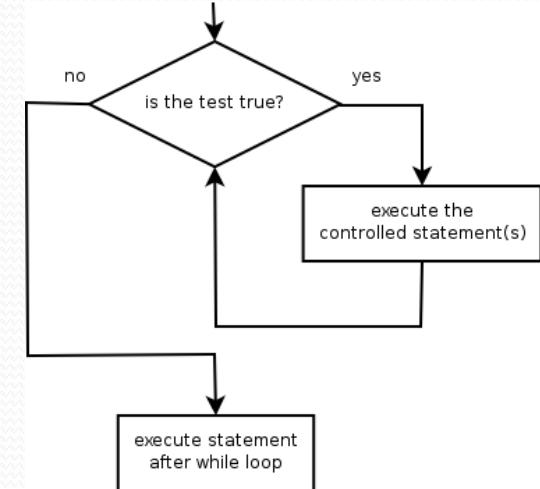    while (test) {
        statement(s);
    }
    ```


- Example:

    ```
    int num = 1;                        // initialization
    while (num <= 200) {                // test
        System.out.print(num + " ");
        num = num * 2;                  // update
    }
    // output:  1 2 4 8 16 32 64 128
    ```

Example `while` loop

```
// finds the first factor of 91, other than 1
int n = 91;
int factor = 2;
while (n % factor != 0) {
    factor++;
}
System.out.println("First factor is " + factor);

// output:   First factor is 7
```

- `while` is better than `for` because we don't know how many times we will need to increment to find the factor.

Sentinel values

- **sentinel**: A value that signals the end of user input.
  - **sentinel loop**: Repeats until a sentinel value is seen.

- Example: Write a program that prompts the user for text until the user types nothing, then output the total number of characters typed.
  - (In this case, the *empty* string is the sentinel value.)

```
Type a line (or nothing to exit): hello
Type a line (or nothing to exit): this is a line
Type a line (or nothing to exit):
You typed a total of 19 characters.
```

Solution?

```java
Scanner console = new Scanner(System.in);
int sum = 0;
String response = "dummy"; // "dummy" value, anything but ""

while (!response.equals("")) {
    System.out.print("Type a line (or nothing to exit): ");
    response = console.nextLine();
    sum += response.length();
}

System.out.println("You typed a total of " + sum + " characters.");
```

Changing the sentinel value

- Modify your program to use "`quit`" as the sentinel value.
    - Example log of execution:

    ```
    Type a line (or "quit" to exit): hello
    Type a line (or "quit" to exit): this is a line
    Type a line (or "quit" to exit): quit
    You typed a total of 19 characters.
    ```

Changing the sentinel value

- Changing the sentinel's value to `"quit"` does not work!

```
Scanner console = new Scanner(System.in);
int sum = 0;
String response = "dummy";  // "dummy" value, anything but "quit"

while (!response.equals("quit")) {
    System.out.print("Type a line (or \"quit\" to exit): ");
    response = console.nextLine();
    sum += response.length();
}

System.out.println("You typed a total of " + sum + " characters.");
```

- This solution produces the wrong output. Why?

```
You typed a total of 23 characters.
```

The problem with our code

- Our code uses a pattern like this:

  sum = 0.
  while (input is not the sentinel) {
      prompt for input; read input.
      add input length to the sum.

   }

- On the last pass, the sentinel's length (4) is added to the sum:

      prompt for input; read input (`"quit"`*).*

      add input length (4) to the sum.

- This is a fencepost problem.
  - Must read *N* lines, but only sum the lengths of the first *N*-1.

A fencepost solution

sum = 0.
prompt for input; read input.   *// place a "post"*

while (input is not the sentinel) {
   add input length to the sum.   *// place a "wire"*
   prompt for input; read input.   *// place a "post"*
}

- Sentinel loops often utilize a fencepost "loop-and-a-half" style solution by pulling some code out of the loop.

Correct code

```
Scanner console = new Scanner(System.in);
int sum = 0;

// pull one prompt/read ("post") out of the loop
System.out.print("Type a line (or \"quit\" to exit): ");
String response = console.nextLine();

while (!response.equals("quit")) {
    sum += response.length();      // moved to top of loop
    System.out.print("Type a line (or \"quit\" to exit): ");
    response = console.nextLine();
}

System.out.println("You typed a total of " + sum + " characters.");
```

Sentinel as a constant

```java
public static final String SENTINEL = "quit";
...

Scanner console = new Scanner(System.in);
int sum = 0;

// pull one prompt/read ("post") out of the loop
System.out.print("Type a line (or \"" + SENTINEL + "\" to exit): ");
String response = console.nextLine();

while (!response.equals(SENTINEL)) {
    sum += response.length();      // moved to top of loop
    System.out.print("Type a line (or \"" + SENTINEL + "\" to exit): ");
    response = console.nextLine();
}

System.out.println("You typed a total of " + sum + " characters.");
```

And with some cleanup…

```java
public static final String SENTINEL = "quit";

public static void main(String[] args) {
    Scanner console = new Scanner(System.in);
    int sum = 0;

    // pull one prompt/read ("post") out of the loop
    String response = getLine(console);

    while (!response.equals(SENTINEL)) {
        sum += response.length();    // moved to top of loop
        response = getLine(console);
    }

    System.out.println("You typed a total of " + sum + " characters.");
}

public static String getLine(Scanner console) {
    System.out.print("Type a line (or \"" + SENTINEL + "\" to exit): ");
    return console.nextLine();
}
```