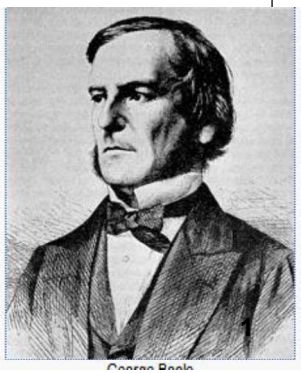
Topic 16
boolean logic

"No matter how correct a mathematical theorem may appear to be, one ought never to be satisfied that there was not something imperfect about it until it also gives the impression of being beautiful."

- George Boole



Type `boolean`

- **`boolean`**: A logical type whose values are `true` and `false`.
  - A logical ***<test>*** is actually a `boolean` expression.
  - Like other types, it is legal to:
    - create a `boolean` variable
    - pass a `boolean` value as a parameter
    - return a `boolean` value from methods
    - call a method that returns a `boolean` and use it as a test

```
boolean minor    = age < 18;
boolean isProf   = name.contains("Prof");
boolean lovesCS  = true;

// allow only CS-loving students over 21
if (minor || isProf || !lovesCS) {
    System.out.println("Can't enter the club!");
}
```


Using `boolean`

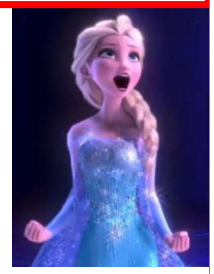
- Why is type `boolean` useful?
  - Can capture a complex logical test result and use it later
  - Can write a method that does a complex test and returns it
  - Makes code more readable
  - Can pass around the result of a logical test (as param/return)

```
boolean goodTemp     =  50 <= temp && temp <= 90;
boolean goodHumidity =  humidity <= 70;
boolean haveTime     =  time >= 90; // minutes
if ((goodTemp && goodHumidity) || haveTime) {
    System.out.println("Let's RIDE BIKES!!!!");
} else {
    System.out.println("Maybe tomorrow");
}
```


Returning `boolean`

```
public static boolean isPrime(int n) {
    int factors = 0;
    for (int i = 1; i <= n; i++) {
        if (n % i == 0) {
            factors++;
        }
    }
    // NOTE: GACKY STYLE AHEAD!! GACKY == BAD!!
    if (factors == 2) {
        return true;
    } else {
        return false;
    }
}
```

I CAN'T !!!!!!



- Calls to methods returning `boolean` can be used as tests:

```
if (isPrime(57)) {
    ...
}
```

Boolean question

- Improve our "rhyme" / "alliterate" program to use boolean methods to test for rhyming and alliteration.

```
Type two words: Bare blare
They rhyme!
They alliterate!
```


Boolean answer

```
    if (rhyme(word1, word2)) {
        System.out.println("They rhyme!");
    }
    if (alliterate(word1, word2)) {
        System.out.println("They alliterate!");
    }
    ...

// Returns true if s1 and s2 end with the same two letters.
// NOTE: GACKY STYLE AHEAD!!
public static boolean rhyme(String s1, String s2) {
    if (s2.length() >= 2 && s1.endsWith(s2.substring(s2.length() - 2))) {
        return true;
    } else {
        return false;
    }
}

// Returns true if s1 and s2 start with the same letter.
// NOTE: GACKY STYLE AHEAD!!
public static boolean alliterate(String s1, String s2) {
    if (s1.startsWith(s2.substring(0, 1))) {
        return true;
    } else {
        return false;
    }
}
```


"Boolean Zen", part 2

- Students new to `boolean` often test if a result is `true`:

```
if (isPrime(57) == true) {     // inelegant
    ...
}
```

- But this is unnecessary and redundant. Preferred:

```
if (isPrime(57)) {             // elegant, zen
    ...
}
```

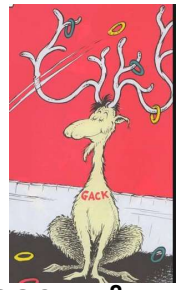
- A similar pattern can be used for a `false` test:

```
if (isPrime(57) == false) {    // inelegant
if (!isPrime(57)) {            // elegant, zen
```


"Boolean Zen", part 2

- Programmers often write methods that return `boolean` often have an `if/else` that returns `true` or `false`:

```
// NOTE: GACKY STYLE AHEAD!!
public static boolean bothOdd(int n1, int n2)
{
    if (n1 % 2 != 0 && n2 % 2 != 0) {
        return true;
    } else {
        return false;
    }
}
```



– But the code above is ***unnecessarily verbose***.

Solution w/ `boolean` variable

- We could store the result of the logical test.

```
public static boolean bothOdd(int n1, int n2) {
  boolean test = (n1 % 2 != 0 && n2 % 2 != 0);
  // NOTE: BAD STYLE AHEAD!!
  if (test) {    // test == true
      return true;
  } else {       // test == false
      return false;
  }
}
```

  - Notice: Whatever `test` is, we want to return that.
    - If `test` is `true` , we want to return `true`.
    - If `test` is `false`, we want to return `false`.

Solution w/ "Boolean Zen"

- Observation: The `if/else` is unnecessary.
  - The variable `test` stores a `boolean` value; its value is exactly what you want to return. So return that!

```
public static boolean bothOdd(int n1, int n2) {
    boolean test = (n1 % 2 != 0 && n2 % 2 != 0);
    return test;
}
```

- An even shorter version:
  - We don't even need the variable `test`. We can just perform the test and return its result in one step.

```
public static boolean bothOdd(int n1, int n2) {
    return (n1 % 2 != 0 && n2 % 2 != 0);
}
```


"Boolean Zen" template

- Replace

```
public static boolean <name>(<parameters>) {
    if (<test>) {
        return true;
    } else {
        return false;
    }
}
```

- with

```
public static boolean <name>(<parameters>) {
    return <test>;
}
```


Improved `isPrime` method

- The following version utilizes Boolean Zen:

```
public static boolean isPrime(int n) {
    int factors = 0;
    for (int i = 1; i <= n; i++) {
        if (n % i == 0) {
            factors++;
        }
    }
    return factors == 2;  // if n has 2 factors -> true
}
```

- Modify the Rhyme program to use Boolean Zen.

Boolean Zen answer

```
public static void main(String[] args) {
    Scanner console = new Scanner(System.in);
    System.out.print("Type two words: ");
    String word1 = console.next().toLowerCase();
    String word2 = console.next().toLowerCase();

    if (rhyme(word1, word2)) {
        System.out.println("They rhyme!");
    }
    if (alliterate(word1, word2)) {
        System.out.println("They alliterate!");
    }
}

// Returns true if s1 and s2 end with the same two letters.
public static boolean rhyme(String s1, String s2) {
    return s2.length() >= 2 && s1.endsWith(s2.substring(s2.length() - 2));
}

// Returns true if s1 and s2 start with the same letter.
public static boolean alliterate(String s1, String s2) {
    return s1.startsWith(s2.substring(0, 1));
}
```


De Morgan's Law

- **De Morgan's Law**: Rules used to negate boolean tests.
- !(a && b) == !a || !b
- !(a || b) == !a && !b
  - Useful when you want the opposite of an existing test.

Original Expression	Negated Expression	Alternative
`a && b`	`!a || !b`	`!(a && b)`
`a || b`	`!a && !b`	`!(a || b)`

  - Example:

Original Code	Negated Code

`if (x == 7 && y > 3) {`
`  ...`
`}`
	`if (x != 7 || y <= 3) {`
	`  ...`
	`}`

Clicker 1

- Which of the following is equivalent to the boolean expression? x, y, and z's are ints

```
!((x >= y) || (z != x))
```

A. `!(x >= y) && !(z != x)`

B. `!(x >= y) || !(z != x)`

C. `(x == y) && (z >= x)`

D. `(x < y) && (z == x)`

E. More than one of A - D is correct

Boolean practice questions

- Write a method named `isVowel` that returns whether a `String` is a vowel (a, e, i, o, or u), case-insensitively.
  - `isVowel("q")` returns `false`
  - `isVowel("A")` returns `true`
  - `isVowel("e")` returns `true`
- Write a method `isNonVowel` that returns whether a `String` is any character except a vowel.
  - `isNonVowel("q")` returns `true`
  - `isNonVowel("A")` returns `false`
  - `isNonVowel("e")` returns `false`

Boolean practice answers

```
// Enlightened version.  I have seen the true way (and false way)
public static boolean isVowel(String s) {
    return s.equalsIgnoreCase("a") || s.equalsIgnoreCase("e")
           || s.equalsIgnoreCase("i")
           || s.equalsIgnoreCase("o")
           || s.equalsIgnoreCase("u");
}


// Enlightened "Boolean Zen" version
public static boolean isNonVowel(String s) {
   return !s.equalsIgnoreCase("a") && !s.equalsIgnoreCase("e")
          && !s.equalsIgnoreCase("i")
          && !s.equalsIgnoreCase("o")
          && !s.equalsIgnoreCase("u");

    // or, return !isVowel(s);
}
```


When to return?

- Methods with loops and return values can be tricky.
  - When and where should the method return its result?
- Write a method `seven` that accepts a `Random` parameter and uses it to draw up to ten lotto numbers from 1-30.
  - If any of the numbers is a lucky 7, the method should stop and return `true`. If none of the ten are 7 it should return `false`.
  - The method should print each number as it is drawn.

```
15 29 18 29 11 3 30 17 19 22 (first call)
29 5 29 4 7                  (second call)
```


Flawed solution

```
// Draws 10 lotto numbers; returns true if one is 7.
public static boolean seven(Random rand) {
    for (int i = 1; i <= 10; i++) {
        int num = rand.nextInt(30) + 1;
        System.out.print(num + " ");
        if (num == 7) {
            return true;
        } else {
            return false;
        }
    }
}
```

- The method always returns immediately after the first roll.
- This is wrong if that draw isn't a 7; we need to keep drawing.

Returning at the right time

```
// Draws 10 lotto numbers; returns true if one is 7.
public static boolean seven(Random rand) {
    for (int i = 1; i <= 10; i++) {
        int num = rand.nextInt(30) + 1;
        System.out.print(num + " ");
        if (num == 7) {    // found lucky 7; can exit now
            return true;
        }
    }
    return false;   // if we get here, there was no 7
}
```

- Returns `true` immediately if 7 is found.
- If 7 isn't found, the loop continues drawing lotto numbers.
- If all ten aren't 7, the loop ends and we return `false`.

Boolean return questions

- `hasAnOddDigit` : returns `true` if any digit of an integer is odd.
  - `hasAnOddDigit(4822116)` returns `true`
  - `hasAnOddDigit(2448)` returns `false`
- `allDigitsOdd` : returns `true` if every digit of an integer is odd.
  - `allDigitsOdd(135319)` returns `true`
  - `allDigitsOdd(9174529)` returns `false`
- `isAllVowels` : returns `true` if every char in a `String` is a vowel.
  - `isAllVowels("eIeIo")` returns `true`
  - `isAllVowels("oink")` returns `false`
    - These problems are available in our Practice-It! system under **5.x**.

Boolean return answers

```
public static boolean hasAnOddDigit(int n) {
    while (n != 0) {
        if (n % 2 != 0) {   // check whether last digit is odd
            return true;
        }
        n = n / 10;
    }
    return false;
}
public static boolean allDigitsOdd(int n) {
    while (n != 0) {
        if (n % 2 == 0) {   // check whether last digit is even
            return false;
        }
        n = n / 10;
    }
    return true;
}
public static boolean isAllVowels(String s) {
    for (int i = 0; i < s.length(); i++) {
        String letter = s.substring(i, i + 1);
        if (!isVowel(letter)) {
            return false;
        }
    }
    return true;
}
```


`while` loop question

- Write a method `digitSum` that accepts an integer parameter and returns the sum of its digits.
  - Assume that the number is non-negative.
  - Example: `digitSum(29107)` returns 2+9+1+0+7 or `19`
  - Hint: Use the `%` operator to extract a digit from a number.

`while` loop answer

```
public static int digitSum(int n) {
    n = Math.abs(n); // handle negatives

    int sum = 0;
    while (n > 0) {
        // add last digit
        sum = sum + (n % 10);
        // remove last digit
        n = n / 10;
    }

    return sum;
}
```