"42 million of anything is a lot."
-Doug Burger, circa 2003
(commenting on the number of transistors in
the Pentium IV processor)
As of 2020 processors for
personal computers have, on
the order of, billions
of transistors.
What is output when method clicker2 is called?

```java
public static void clicker2() {
    int[] values = {1, 2};
    arrayManip(values);
    System.out.print(Arrays.toString(values));
}

public static void arrayManip(int[] values) {
    values[1] += 2;
    values[0] -= 2;
    System.out.print(Arrays.toString(values));
    values = new int[3];
    System.out.print(Arrays.toString(values));
}
```

A. [1, 2] [0, 0, 0] [1, 2]
B. [1, 2] [1, 2] [1, 2]
C. [-1, 4] [0, 0, 0] [0, 0, 0]
D. [-1, 4] [0, 0, 0] [1, 2]
E. [-1, 4] [0, 0, 0] [-1, 4]
Problem: Write a method `mostFrequentDigit` that returns the digit that occurs most frequently in a number.

- Example: The number 669260267 contains: one 0, two 2s, four 6es, one 7, and one 9. `mostFrequentDigit(669260267)` returns 6.

- If there is a tie, return the digit with the lower value. `mostFrequentDigit(57135203)` returns 3.
A multi-counter problem

- We could declare 10 counter variables ...
  ```
  int counter0, counter1, counter2, counter3, counter4,
  counter5, counter6, counter7, counter8, counter9;
  ```

- But a better solution is to use an array of size 10.
  - The element at index $i$ will store the counter for digit value $i$.
  - Example for 669260267:

    | index |
    |-------|
    | 0     |
    | 1     |
    | 2     |
    | 3     |
    | 4     |
    | 5     |
    | 6     |
    | 7     |
    | 8     |
    | 9     |

    | value |
    |-------|
    | 1     |
    | 0     |
    | 2     |
    | 0     |
    | 0     |
    | 0     |
    | 4     |
    | 1     |
    | 0     |
    | 0     |

- How do we build such an array? And how does it help?
Creating an array of tallies

// assume n = 669260267
int[] counts = new int[10];
while (n > 0) {
    // pluck off a digit and add to proper counter
    int digit = n % 10;
    counts[digit]++;
    n = n / 10;
}

<table>
<thead>
<tr>
<th>index</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
// Returns the digit value that occurs most frequently in n.  
// Breaks ties by choosing the smaller value.
public static int mostFrequentDigit(int n) {
    int[] counts = new int[10];
    while (n > 0) {
        int digit = n % 10;  // pluck off a digit and tally it
        counts[digit]++;
        n = n / 10;
    }

    // find the most frequently occurring digit
    int bestIndex = 0;
    for (int i = 1; i < counts.length; i++) {
        if (counts[i] > counts[bestIndex]) {
            bestIndex = i;
        }
    }

    return bestIndex;
}
Tally Problem

- Write a method to pick random numbers from 0 to 99.
- A parameters specifies the number of random numbers to pick
- The method returns the difference between the number of times the most and least picked number

Clicker 2: With 1,000,000 numbers what do you expect the difference to be?

A. 0  B. 1 - 10  C. 11 - 100  D. 101 - 1000  E. > 1000
Array histogram question

- Given a file of integer exam scores, such as:
  
  82
  66
  79
  63
  83
  83

  Write a program that will print a histogram of stars indicating the number of students who earned each unique exam score.

  85: *****
  86: ************
  87: ***
  88: *
  91: ****
/** Reads a file of test scores and shows a histogram of the score distribution.**

```java
import java.io.*;
import java.util.*;

public class Histogram {
    public static void main(String[] args) throws FileNotFoundException {
        Scanner input = new Scanner(new File("midterm.txt"));
        int[] counts = new int[101];  // counters of test scores 0 - 100
        while (input.hasNextInt()) {
            int score = input.nextInt();
            counts[score]++;  // if score is 87, then counts[87]++
        }

        for (int i = 0; i < counts.length; i++) {
            if (counts[i] > 0) {
                System.out.print(i + ": ");
                for (int j = 0; j < counts[i]; j++) {
                    System.out.print("*");
                }
                System.out.println();
            }
        }
    }
}
```
Text processing

reading: 4.3
Type `char`

- `char`: A primitive type representing single characters.
  - A `String` is stored internally as an array of `char`

```
String s = "Ali G.";
```

<table>
<thead>
<tr>
<th>index</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>'A'</td>
</tr>
<tr>
<td>1</td>
<td>'l'</td>
</tr>
<tr>
<td>2</td>
<td>'i'</td>
</tr>
<tr>
<td>3</td>
<td>' '</td>
</tr>
<tr>
<td>4</td>
<td>'G'</td>
</tr>
<tr>
<td>5</td>
<td>'.'</td>
</tr>
</tbody>
</table>

- It is legal to have variables, parameters, returns of type `char`
  - surrounded with apostrophes: 'a' or '4' or '\n' or '\'

```
char letter = 'T';
System.out.println(letter);     // T
System.out.println(letter + "exas!");  // Texas!
```
The `charAt` method

- The **chars** in a **String** can be accessed using the `charAt` method.
  - accepts an **int** index parameter and returns the **char** at that index

```java
String food = "cookie";
char firstLetter = food.charAt(0);    // 'c'
System.out.println(firstLetter + " is for " + food);
```

- You can use a **for** loop to print or examine each character.

```java
String major = "CS!";
for (int i = 0; i < major.length(); i++) {
    char c = major.charAt(i);        // output:
    System.out.println(c);           // C
}                                   // S
```

```java
12
```
Comparing `char` values

- You can compare `char`s with `==`, `!=`, and other operators:

```java
String word = console.next();
char last = word.charAt(word.length() - 1);
if (last == 's') {
    System.out.println(word + " is plural.");
}
```

// prints the alphabet
for (char c = 'a'; c <= 'z'; c++) {
    System.out.print(c);
}
```
char vs. int

- Each char is mapped to an integer value internally
  - Called an ASCII value

  'A' is 65  'B' is 66  ' ' is 32
  'a' is 97  'b' is 98  '*' is 42

- Mixing char and int causes automatic conversion to int.
  'a' + 10 is 107,  'A' + 'A' is 130

- To convert an int into the equivalent char, type-cast it.
  (char) ('a' + 2) is 'c'
char vs. String

- "h" is a String, but 'h' is a char (they are different)

- A String is an object; it contains methods.

```
String s = "h";
s = s.toUpperCase(); // "H"
int len = s.length(); // 1
char first = s.charAt(0); // 'H'
```

- A char is primitive; you can't call methods on it.

```
char c = 'h';
c = c.toUpperCase(); // ERROR
s = s.charAt(0).toUpperCase(); // ERROR
```

- What is s + 1? What is c + 1?
- What is s + s? What is c + c?
String traversals

- We can write algorithms to traverse strings to compute information.

- What useful information might the following string have?

"GDRGRRGDRRGDLGDGRRRGRGRGGDGDDDRRDRDGDGGD"
Data takes many forms

// string stores voters' votes
// (R)EPUBLICAN, (D)EMOCRAT, (G)REEN, (L)IBERTARIAN
String votes = "GDRGRRGDRRRGDLGDGRRGRGRGGGDGDGDYYYRDRRDGGGGRAM"
int[] counts = new int[4]; // R -> 0, D -> 1, G -> 2, L -> 3
for (int i = 0; i < votes.length(); i++) {
    char c = votes.charAt(i);
    if (c == 'R') {
        counts[0]++;
    } else if (c == 'D') {
        counts[1]++;
    } else if (c == 'B') {
        counts[2]++;
    } else { // c == 'M'
        counts[3]++;
    }
}
System.out.println(Arrays.toString(counts));

Output:
[13, 12, 14, 1]
Section attendance question

Read a file of section attendance (see next slide):
ynyyynayaynnyyayanyyyaynayyayyanayyyanyayna
ayyanyyyyyayanaayyanayyyanayayaynayayynyna
yyayaynyyyayyanynyayyanayaynanannyayyayayny

And produce the following output:

Section 1
Student points: [20, 17, 19, 16, 13]
Student grades: [100.0, 85.0, 95.0, 80.0, 65.0]

Section 2
Student points: [17, 20, 16, 16, 10]
Student grades: [85.0, 100.0, 80.0, 80.0, 50.0]

Section 3
Student points: [17, 18, 17, 20, 16]
Student grades: [85.0, 90.0, 85.0, 100.0, 80.0]

• Students earn 3 points for each section attended up to 20.
Section input file

- Each line represents a section.
- A line consists of 9 weeks' worth of data.
  - Each week has 5 characters because there are 5 students.
- Within each week, each character represents one student.
  - a means the student was absent (+0 points)
  - n means they attended but didn't do the problems (+2 points)
  - y means they attended and did the problems (+3 points)
import java.io.*;
import java.util.*;

public class Sections {
    public static void main(String[] args) throws FileNotFoundException {
        Scanner input = new Scanner(new File("sections.txt"));
        int section = 1;
        while (input.hasNextLine()) {
            String line = input.nextLine(); // process one section
            int[] points = new int[5];
            for (int i = 0; i < line.length(); i++) {
                int student = i % 5;
                int earned = 0;
                if (line.charAt(i) == 'y') { // c == 'y' or 'n'
                    earned = 3;
                } else if (line.charAt(i) == 'n') {
                    earned = 2;
                }
                points[student] = Math.min(20, points[student] + earned);
            }
            double[] grades = new double[5];
            for (int i = 0; i < points.length; i++) {
                grades[i] = 100.0 * points[i] / 20.0;
            }
            System.out.println("Section " + section);
            System.out.println("Student points: " + Arrays.toString(points));
            System.out.println("Student grades: " + Arrays.toString(grades));
            System.out.println();
            section++;
        }
    }
}
Data transformations

- In many problems we transform data between forms.
  - Example: digits \( \rightarrow \) count of each digit \( \rightarrow \) most frequent digit
  - Often each transformation is computed/stored as an array.
  - For structure, a transformation is often put in its own method.

- Sometimes we map between data and array indexes.
  - by position (store the \( i^{th} \) value we read at index \( i \))
  - tally (if input value is \( i \), store it at array index \( i \))
  - explicit mapping (count 'J' at index 0, count 'X' at index 1)

- *Exercise:* Modify the Sections program to use static methods that use arrays as parameters and returns.
// This program reads a file representing which students attended
// which discussion sections and produces output of the students'
// section attendance and scores.

import java.io.*;
import java.util.*;

public class Sections2 {
    public static void main(String[] args) throws FileNotFoundException {
        Scanner input = new Scanner(new File("sections.txt"));
        int section = 1;
        while (input.hasNextLine()) {
            // process one section
            String line = input.nextLine();
            int[] points = countPoints(line);
            double[] grades = computeGrades(points);
            results(section, points, grades);
            section++;
        }
    }

    // Produces all output about a particular section.
    public static void results(int section, int[] points, double[] grades) {
        System.out.println("Section " + section);
        System.out.println("Student scores: " + Arrays.toString(points));
        System.out.println("Student grades: " + Arrays.toString(grades));
        System.out.println();
    }

    ...
}
Array param/return answer

...  

// Computes the points earned for each student for a particular section.
public static int[] countPoints(String line) {
    int[] points = new int[5];
    for (int i = 0; i < line.length(); i++) {
        int student = i % 5;
        int earned = 0;
        if (line.charAt(i) == 'y') { // c == 'y' or c == 'n'
            earned = 3;
        } else if (line.charAt(i) == 'n') {
            earned = 2;
        }
        points[student] = Math.min(20, points[student] + earned);
    }
    return points;
}

// Computes the percentage for each student for a particular section.
public static double[] computeGrades(int[] points) {
    double[] grades = new double[5];
    for (int i = 0; i < points.length; i++) {
        grades[i] = 100.0 * points[i] / 20.0;
    }
    return grades;
}