What is statistics?

- Statistics is the science of using data to make decisions and answer questions.
- Statistics involves
  - designing studies
  - collecting data
  - organizing and analyzing data
  - interpreting and reporting results

The Challenger:
How understanding of statistical methods might have prevented a tragedy

On 1/28/86 space shuttle Challenger exploded during launch

- 7 astronauts killed
- reason: gas leak through a joint that should have been sealed by two rubber O-rings
  - O-rings had lost resiliency due to cold temperature

References:


On the previous day, extensive discussions of whether or not it would be safe to launch

- predicted temperature for launch time: 26-29°F
- no shuttle had ever been launched at temperature lower than 53°F
- engineers who designed rocket faxed to NASA a recommendation not to launch due to risk of O-ring failure at low temperatures
- NASA officials pointed out weaknesses of engineers’ evidence
- after lengthy discussion, managers of rocket-making company changed their minds and recommended launch

The engineers’ evidence

- history of serious but non-catastrophic O-ring damage during previous cool-weather launches
- physics of resiliency of rubber
- experimental data
What was missing from the engineers’ argument?

- quantification of the relationship between joint temperature and O-ring failure
- prediction of the probability of O-ring failure at $29^\circ$, with assessment of degree of uncertainty

an appropriate statistical method: logistic regression

- Dalal et al. carried out such an analysis (after the fact) using data from the 23 shuttle launches prior to the Challenger
- found strong statistical evidence of a temperature effect on O-rings
- we will analyze these data later in the semester

Subjects, observations, and variables

In statistical studies, we generally choose a set of individuals or subjects on whom data is collected. We usually are interested in collecting a number of different kinds of information to describe each subject. A variable is a particular characteristic that may take on different values for different subjects. For example,

- age
- gender
- diagnosis

are three variables that might be included in a study of length of hospital stays of hospital patients.

For analysis by a computer, a set of data collected for a study is often organized as a table with a row for each subject and a column for each variable.

<table>
<thead>
<tr>
<th>Patient ID</th>
<th>Age</th>
<th>Gender</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>25</td>
<td>F</td>
<td>hepatitis A</td>
</tr>
<tr>
<td>102</td>
<td>38</td>
<td>F</td>
<td>cirrhosis</td>
</tr>
<tr>
<td>103</td>
<td>76</td>
<td>M</td>
<td>hepatitis C</td>
</tr>
</tbody>
</table>

Each row in such a table, corresponding to the data for a single subject, is called an observation.
Types of variables

- Qualitative (textbook calls this “categorical”)
  - Nominal
    * values fall into *unordered* categories
    * numbers may be used to represent categories, but they are just labels
    * example: variable called “occupational area” coded as
      - 1 = education
      - 2 = business
      - 3 = service
      - 4 = industry
      - etc., etc.
    * special case: *binary* data, which can take on only 2 possible values
  - Ordinal
    * data representing *ordered* categories
    * example: variable called “prognosis” taking on possible values “poor,” “fair,” “good”

What data type is each of the following?

- a variable defined for each pre-Challenger shuttle launch as the answer to the question “Were any primary O-rings damaged during launch (yes/no)?”
- a variable defined for each pre-Challenger shuttle launch as the total number of primary O-rings that were damaged (out of the 6 primary O-rings in a shuttle)
- a variable defined as outdoor temperature in degrees F at launch time of each shuttle

The *distribution* of a variables tells what values it takes and how frequently it takes them.

Exploratory data analysis

- initial examination to discover main features of data
- should begin with examining each variable one at a time
- may proceed to examining relationships between variables
- should begin with *graphs*
- may continue with numerical summaries

- Quantitative
  - Discrete
    * both *order* and *magnitude* are important
    * numbers represent measurable quantities
    * possible values are restricted, often to be integers
    * example: count of number of homicides in Johnson County in 1998
  - Continuous
    * numbers represent measurable quantities and are *not* restricted to a set of specified values
    * examples: temperature, blood pressure, annual profit
    * Special case: *censored* data
      - continuous data in which values for some subjects are not observable
      - some values are known only to be larger (or smaller) than some observed value
      - example: time-to-failure data
Describing binary, nominal, and ordinal data

- tables of frequencies and percents
- bar charts (also called bar graphs)
- pie charts

**frequency distribution** for nominal or ordinal data

- a set of classes or categories along with numerical counts of the number of members of each class

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Example: Study of nutrition in breakfast cereals

*Abstract:*

This datafile contains nutritional information and grocery shelf location for 77 breakfast cereals. Data was obtained from the Data and Story Library [http://lib.stat.cmu.edu/DASL](http://lib.stat.cmu.edu/DASL)

**Variable Names**

1. Name: Name of cereal
2. mfr: Manufacturer of cereal where A = American Home Food Products; G = General Mills; K = Kelloggs; N = Nabisco; P = Post; Q = Quaker Oats; R = Ralston Purina
3. type: cold or hot
4. calories: calories per serving
5. protein: grams of protein
6. fat: grams of fat
7. sodium: milligrams of sodium
8. fiber: grams of dietary fiber
9. carbo: grams of complex carbohydrates
10. sugars: grams of sugars
11. potass: milligrams of potassium
12. vitamins: vitamins and minerals - 0, 25, or 100, indicating the typical percentage of FDA recommended
13. shelf: display shelf (1, 2, or 3, counting from the floor)
14. weight: weight in ounces of one serving
15. cups: number of cups in one serving
16. rating: a rating of the cereals

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**The FREQ Procedure**

<table>
<thead>
<tr>
<th>type</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>74</td>
<td>96.10</td>
<td>74</td>
<td>96.10</td>
</tr>
<tr>
<td>Hot</td>
<td>3</td>
<td>3.90</td>
<td>77</td>
<td>100.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>mfr</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Home</td>
<td>1</td>
<td>1.30</td>
<td>1</td>
<td>1.30</td>
</tr>
<tr>
<td>General Mills</td>
<td>22</td>
<td>28.57</td>
<td>23</td>
<td>29.87</td>
</tr>
<tr>
<td>Kelloggs</td>
<td>23</td>
<td>29.87</td>
<td>46</td>
<td>59.74</td>
</tr>
<tr>
<td>Nabisco</td>
<td>6</td>
<td>7.79</td>
<td>52</td>
<td>67.53</td>
</tr>
<tr>
<td>Post</td>
<td>9</td>
<td>11.69</td>
<td>61</td>
<td>79.22</td>
</tr>
<tr>
<td>Quaker Oats</td>
<td>8</td>
<td>10.39</td>
<td>69</td>
<td>89.61</td>
</tr>
<tr>
<td>Ralston Purina</td>
<td>8</td>
<td>10.39</td>
<td>77</td>
<td>100.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>shelf</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom</td>
<td>20</td>
<td>25.97</td>
<td>20</td>
<td>25.97</td>
</tr>
<tr>
<td>Middle</td>
<td>21</td>
<td>27.27</td>
<td>41</td>
<td>53.25</td>
</tr>
<tr>
<td>Top</td>
<td>36</td>
<td>46.75</td>
<td>77</td>
<td>100.00</td>
</tr>
</tbody>
</table>
A frequency distribution may be tabulated for a **quantitative variable** if the range of possible values for the variable is first divided into non-overlapping intervals.

<table>
<thead>
<tr>
<th>Sodium</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-&lt;80</td>
<td>14</td>
<td>18.18</td>
<td>14</td>
<td>18.18</td>
</tr>
<tr>
<td>80-&lt;160</td>
<td>18</td>
<td>23.38</td>
<td>32</td>
<td>41.56</td>
</tr>
<tr>
<td>160-&lt;240</td>
<td>33</td>
<td>42.86</td>
<td>65</td>
<td>84.42</td>
</tr>
<tr>
<td>240-320</td>
<td>12</td>
<td>15.58</td>
<td>77</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**Relative frequency**

- The **relative frequency** for a class is the **percentage** of the total number of observations that are in that class.
- It is computed as \( \frac{\text{number in class}}{\text{total number of observations}} \times 100 \)
- Relative frequencies are particularly useful for comparing sets of data with different total numbers of observations
- SAS just calls this “Percent”

**Example**

<table>
<thead>
<tr>
<th>Sodium</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-&lt;80</td>
<td>3</td>
<td>13.04</td>
<td>3</td>
<td>13.04</td>
</tr>
<tr>
<td>80-&lt;160</td>
<td>6</td>
<td>26.09</td>
<td>9</td>
<td>39.13</td>
</tr>
<tr>
<td>160-&lt;240</td>
<td>9</td>
<td>39.13</td>
<td>18</td>
<td>78.26</td>
</tr>
<tr>
<td>240-320</td>
<td>5</td>
<td>21.74</td>
<td>23</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**Cumulative relative frequency**

- Cumulative relative frequency for a category of an ordinal variable is the percentage of the total number of observations that have a value less than or equal to the category value.
- Cumulative relative frequency for an interval of a continuous variable is the percentage of the total number of observations that have a value less than or equal to the upper limit of the interval.
- SAS calls this “cumulative percent.”
### mfr=General Mills

The FREQ Procedure

<table>
<thead>
<tr>
<th>sodium</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-&lt;160</td>
<td>4</td>
<td>18.18</td>
<td>4</td>
<td>18.18</td>
</tr>
<tr>
<td>160-&lt;240</td>
<td>13</td>
<td>59.09</td>
<td>17</td>
<td>77.27</td>
</tr>
<tr>
<td>240-320</td>
<td>5</td>
<td>22.73</td>
<td>22</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### mfr=Kelloggs

The FREQ Procedure

<table>
<thead>
<tr>
<th>sodium</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-&lt;80</td>
<td>3</td>
<td>13.04</td>
<td>3</td>
<td>13.04</td>
</tr>
<tr>
<td>80-&lt;160</td>
<td>6</td>
<td>26.09</td>
<td>9</td>
<td>39.13</td>
</tr>
<tr>
<td>160-&lt;240</td>
<td>9</td>
<td>39.13</td>
<td>18</td>
<td>78.26</td>
</tr>
<tr>
<td>240-320</td>
<td>5</td>
<td>21.74</td>
<td>23</td>
<td>100.00</td>
</tr>
</tbody>
</table>