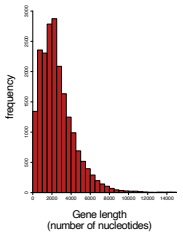
## Gaining further insights into data and biological problems (experimental or observational)

Displaying numerical data in the form of frequency distributions: table and histograms & other visual aids to understand the characteristics of data.




1

## Some raw data: Abundance of birds across species

**Table 2.2-2** Data on the abundance of each species of bird encountered during four surveys in Organ Pipe Cactus National Monument.

| Species | Abundance | Species | Abundance |
|---|---|---|---|
| Greater roadrunner | 1 | Turkey vulture | 23 |
| Black-chinned hummingbird | 1 | Violet-green swallow | 23 |
| Western kingbird | 1 | Lesser nighthawk | 25 |
| Great-tailed grackle | 1 | Scott's oriole | 28 |
| Bronzed cowbird | 1 | Purple martin | 33 |
| Great horned owl | 2 | Black-throated sparrow | 33 |
| Costa's hummingbird | 2 | Brown-headed cowbird | 59 |
| Canyon wren | 2 | Black vulture | 64 |
| Canyon towhee | 2 | Lucy's warbler | 67 |
| Harris's hawk | 3 | Gilded flicker | 77 |
| Loggerhead shrike | 3 | Brown-crested flycatcher | 128 |
| Hooded oriole | 4 | Mourning dove | 135 |
| Northern mockingbird | 5 | Gambel's quail | 148 |
| American kestrel | 7 | Black-tailed gnatcatcher | 152 |
| Rock dove | 7 | Ash-throated flycatcher | 173 |
| Bell's vireo | 10 | Curve-billed thrasher | 173 |
| Common raven | 12 | Cactus wren | 230 |
| Northern cardinal | 13 | Verdin | 282 |
| House sparrow | 14 | House finch | 297 |
| Ladder-backed woodpecker | 15 | Gila woodpecker | 300 |
| Red-tailed hawk | 16 | White-winged dove | 625 |
| Phainopepla | 18 | | |

Whitlock & Schluter, *The Analysis of Biological Data*, 3e © 2020 W. H. Freeman and Company

Total = 3215 individuals

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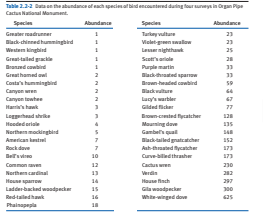
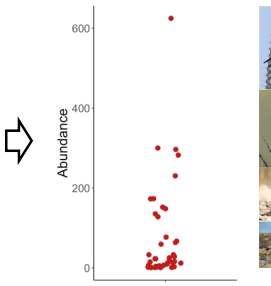
## Abundance of birds across species - plot of raw data






Stripchart
"one dimensional scatter plot"

Whitlock & Schluter, *The Analysis of Biological Data*, 3e © 2020 W. H. Freeman and Company

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## Displaying numerical data in the form of frequency distributions – the tabular (table) form

**Table 2.2-2** Data on the abundance of each species of bird encountered during four surveys in Organ Pipe Cactus National Monument.

| Species | Abundance | Species | Abundance |
|---|---|---|---|
| Greater roadrunner | 1 | Turkey vulture | 23 |
| Black-chinned hummingbird | 1 | Violet-green swallow | 23 |
| Western kingbird | 1 | Lesser nighthawk | 25 |
| Great-tailed grackle | 1 | Scott's oriole | 28 |
| Bronzed cowbird | 1 | Purple martin | 33 |
| Great horned owl | 2 | Black-threated sparrow | 33 |
| Costa's hummingbird | 2 | Brown-headed cowbird | 59 |
| Canyon wren | 2 | Black vulture | 66 |
| Canyon towhee | 2 | Lucy's warbler | 67 |
| Harris's hawk | 3 | Gilded flicker | 77 |
| Loggerhead shrike | 3 | Brown-crested flycatcher | 128 |
| Hooded oriole | 6 | Mourning dove | 135 |
| Northern mockingbird | 5 | Gambel's quail | 148 |
| American kestrel | 7 | Black-tailed gnatcatcher | 152 |
| Rock dove | 7 | Ash-throated flycatcher | 173 |
| Bell's vireo | 10 | Curve-billed thrasher | 173 |
| Common raven | 12 | Cactus wren | 230 |
| Northern cardinal | 13 | Verdin | 282 |
| House sparrow | 14 | House finch | 297 |
| Ladder-backed woodpecker | 15 | Gila woodpecker | 300 |
| Red-tailed hawk | 16 | White-winged dove | 625 |
| Phainopepla | 18 | | |

**Table 2.2-3** Frequency distribution of bird species abundance at Organ Pipe Cactus National Monument.

| Abundance | Frequency (Number of species) |
|---|---|
| 0–50 | 28 |
| 50–100 | 4 |
| 100–150 | 3 |
| 150–200 | 3 |
| 200–250 | 1 |
| 250–300 | 2 |
| 300–350 | 1 |
| 350–400 | 0 |
| 400–450 | 0 |
| 450–500 | 0 |
| 500–550 | 0 |
| 550–600 | 0 |
| 600–650 | 1 |
| Total | 43 |



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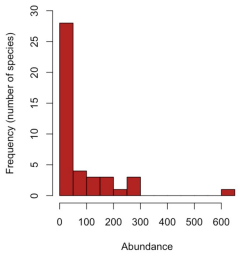
## Displaying numerical data in the form of frequency distributions – from tabular to graphical form (histograms)

**Table 2.2-3** Frequency distribution of bird species abundance at Organ Pipe Cactus National Monument.

| Abundance | Frequency (Number of species) |
|---|---|
| 0–50 | 28 |
| 50–100 | 4 |
| 100–150 | 3 |
| 150–200 | 3 |
| 200–250 | 1 |
| 250–300 | 2 |
| 300–350 | 1 |
| 350–400 | 0 |
| 400–450 | 0 |
| 450–500 | 0 |
| 500–550 | 0 |
| 550–600 | 0 |
| 600–650 | 1 |
| Total | 43 |



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## The formal definitions of frequency distributions

Frequency distribution is a representation, either in a graphical or tabular format, that displays the number of observations within a given interval of a quantitative variable (continuous or discrete).

The intervals must be *mutually exclusive* (each observation can only belong to one interval) and *exhaustive* (all observations must be included),

The interval size depends on the data being analyzed and the goals of the analyst.

- Adapted from: http://www.investopedia.com/terms/f/frequencydistribution.asp

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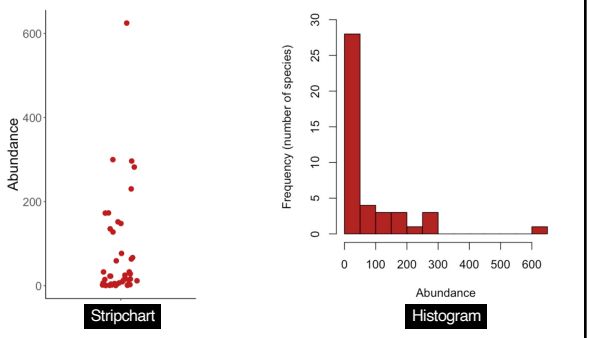
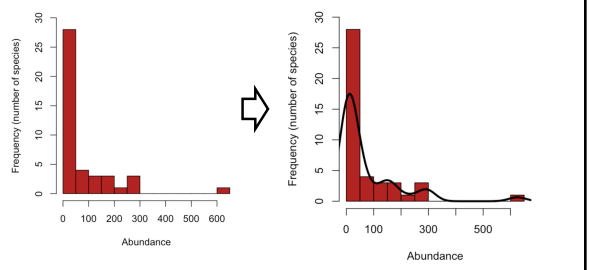
## Why frequencies and not the raw data?






7

## Why frequencies and not the raw data?



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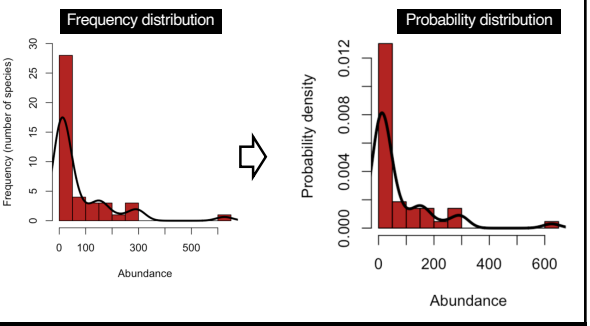
## Why frequencies and not the raw data?




From frequencies to probabilities



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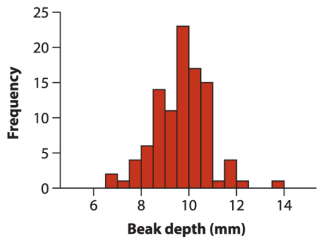
## Why frequencies and not the raw data?


The large-beaked ground finch on the Galápagos Islands.

*Geospiza magnirostris*




Total of 100 individual birds



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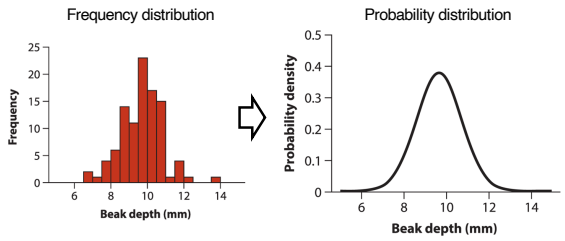
## From frequencies to probabilities




Frequency distributions are important because they describe shapes of numerical variables. Distributional shapes allow to determine proper population probability distributions for inferential statistics (i.e., use samples to estimate population parameters; & convey uncertainty)



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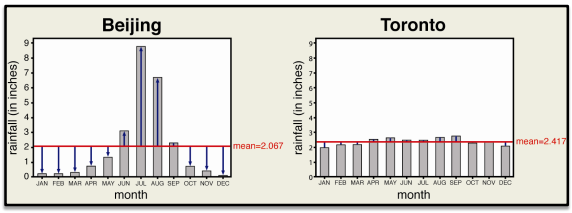
## Variability in bar graphs (categorical) *versus* histograms (numerical)

**Where does rain vary the most?**

[the case of categorial variables]




- Source: Cooper & Shore; Journal of Statistics Education (vol. 18, #2)

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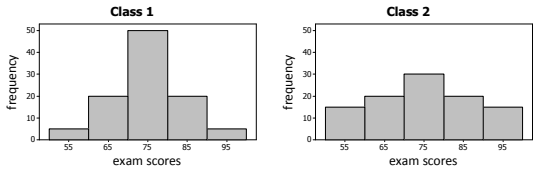
## Variability in bar graphs (categorical) versus histograms (numerical)

Which class has the most variation in exam scores?

[the case of continuous variables]




Note: scales (X and Y axis limits) are exactly the same

- Source: Cooper & Shore; Journal of Statistics Education (vol. 18, #2)

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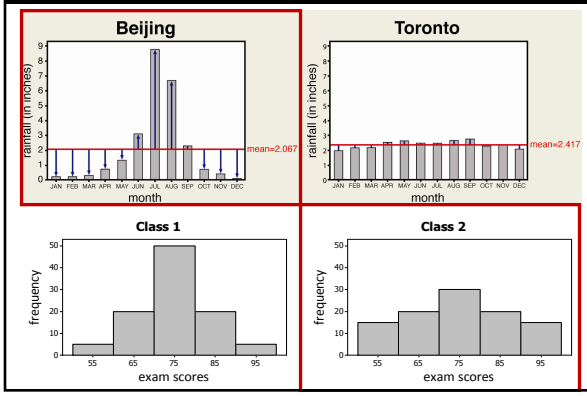
## Variability in bar graphs (categorical) versus histograms (numerical) – where do data vary the most?

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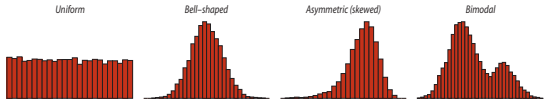
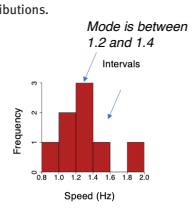
## Frequency distributions are important because they describe shapes of numerical variables. Distributional shapes allow to determine proper population probability distributions for inferential statistics




Some possible shapes of frequency distributions.

The ***mode*** is the **interval** corresponding to the highest peak in the frequency distribution. A distribution is said bimodal when it has two dominant peaks.

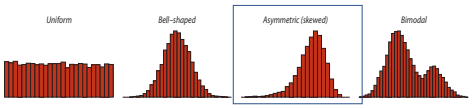
***Skew*** refers to asymmetry in the shape of a frequency distribution for a numerical variable.






15

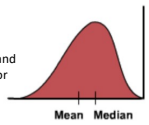
Frequency distributions are important because they describe shapes of numerical variables. Distributional shapes allow to determine proper population probability distributions for inferential statistics



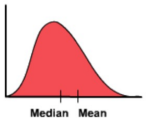

Asymmetric distributions can be either left or positive skewed.

The rule based on the relationship between the mean and median is particularly effective for large datasets (greater than 30 observations).

Left (or Negative) skewed




Right (or Positive skewed)



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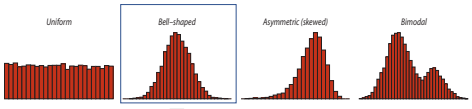
Frequency distributions are important because they describe shapes of numerical variables. Distributional shapes allow to determine proper population probability distributions for inferential statistics




Symetric Distribution

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Let's take a small break – 1 minute

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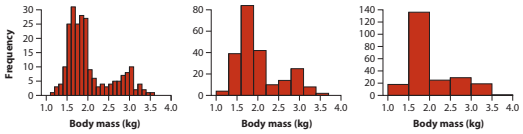
## Building a frequency distribution

*How many intervals (classes of abundance) should be used?*

**No strict** rules need to be imposed, but rather a number that best show patterns and exceptions in data.




Body mass of 228 female sockeye salmon sampled from Pick Creek in Alaska (Hendry et al. 1999). The same data are shown in each case, but the interval widths are different : 0.1 kg (left), 0.3 kg (middle), and 0.5 kg (right).

Remember that histograms are graphical representations of frequency distributions



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## Building a frequency distribution – How many intervals?

"Flying" paradise tree snake (*Chrysopelea paradisi*). To better understand how lift is generated, Socha (2002) videotaped glides (from a 10-m tower) of 8 snakes. Rate of side-to-side undulation was measured in hertz (number of cycles per second). The values recorded were:

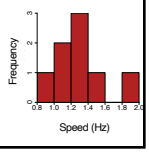
**0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0**

**No strict** rules should be used, but rather a number that best show patterns and exceptions in data. Rules exist, however, example:

The Sturges' rule: number of intervals = 1 + ln(n) / ln(2),

For the snake data: 1 + ln(8) / ln(2) = 4 classes.

NOTE: 1 + ln(n) / ln(2) = 1 + $\log_2(n)$
(as often expressed in some sources).



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## Building a frequency distribution – The interval size

**0.9**, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, **2.0**

Snake data: 1 + ln(8) / ln(2) = 4 classes

Let's establish the speed intervals (let's say we decide on 4 intervals):

(max(value) - min (value)) / number of classes:

**(2.0-0.9) / 4 = 0.275**

NOTE: Intervals of frequency distributions are commonly referred to as "classes" as well

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## Remember

The intervals must be ***mutually exclusive*** (each observation can only belong to one interval) and ***exhaustive*** (all observations must be included), and the interval size depends on the data being analyzed and the goals of the analyst.

- Adapted from: http://www.investopedia.com/terms/f/frequencydistribution.asp

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## Building intervals

*Let's establish the speed intervals:* **0.9**, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, **2.0**

(max(value) - min (value)) / number of classes:

(**2.0**-**0.9**) / 4 = 0.275

1st class: individuals with speeds between **0.900** and 1.175 (**0.900** + 0.275)

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## Building intervals

*Let's establish the speed intervals:* **0.9**, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, **2.0**

(max(value) - min (value)) / number of classes:

(2.0-0.9) / 4 = 0.275

1st class: individuals with speeds between 0.900 and 1.175 (0.900 + 0.275)

2nd class: individuals with speeds between 1.175 and 1.450 (1.175 + 0.275)

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## Building intervals

*Let's establish the speed intervals:* **0.9**, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, **2.0**

(max(value) - min (value)) / number of classes:

(2.0-0.9) / 4 = 0.275

1st class: individuals with speeds between 0.900 and 1.175 (0.900 + 0.275)

2nd class: individuals with speeds between 1.175 and 1.450 (1.175 + 0.275)

3rd class: individuals with speeds between 1.450 and 1.725 (1.450 + 0.275)

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## Building intervals

*Let's establish the speed intervals:* **0.9**, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, **2.0**

(max(value) - min (value)) / number of classes:

(2.0-0.9) / 4 = 0.275

1st class: individuals with speeds between 0.900 and 1.175 (0.900 + 0.275)

2nd class: individuals with speeds between 1.175 and 1.450 (1.175 + 0.275)

3rd class: individuals with speeds between 1.450 and 1.725 (1.450 + 0.275)

4th class: individuals with speeds between 1.725 and 2.000 (1.725 + 0.275)

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## Counting number of observations (frequencies)

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

Let's use: left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| 0.900 - 1.175 | |
| 1.175 - 1.450 | |
| 1.450 - 1.725 | |
| 1.725 - 2.000 | |

Intervals are either left-closed & right-open, e.g., 0.900 - 1.175 would contains snakes with rates between 0.9 Hz (included) and 1.175 Hz (not included) = [0.900,1.175).

OR left-open & right-closed, e.g., 0.900 - 1.175 would contains snakes with rates between 0.9 Hz (not included) and 1.175 Hz (included) = (0.900,1.175].

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## Counting number of observations (frequencies)

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| [0.900 - 1.175) | **1** |
| [1.175 - 1.450) | |
| [1.450 - 1.725) | |
| [1.725 - 2.000) | |

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## Counting number of observations (frequencies)

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| [0.900 - 1.175) | 1 |
| [1.175 - 1.450) | **5** |
| [1.450 - 1.725) | |
| [1.725 - 2.000) | |

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## Counting number of observations (frequencies)

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| 0.900 - 1.175 | 1 |
| 1.175 - 1.450 | 5 |
| 1.450 - 1.725 | **1** |
| 1.725 - 2.000 | |

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## Counting number of observations (frequencies)

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0 ?

left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| [0.900 - 1.175) | 1 |
| [1.175 - 1.450) | 5 |
| [1.450 - 1.725) | 1 |
| [1.725 - 2.000) | ??? |


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## Counting number of observations (frequencies)

? 0.9 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

Let's try left-open & right-closed (a,b]

| Classes | Frequency |
|---|---|
| (0.900 - 1.175] | ??? |
| (1.175 - 1.450] | |
| (1.450 - 1.725] | |
| (1.725 - 2.000] | |


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## Counting number of observations (frequencies)

**Let's try a different number of classes (5) and interval size (0.275)**

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| [0.900 - 1.175) | 1 |
| [1.175 - 1.450) | 5 |
| [1.450 - 1.725) | 1 |
| [1.725 - 2.000) | 0 |
| [2.000 - 2.275 ) | 1 |

left-open & right-closed (a,b]

| Classes | Frequency |
|---|---|
| (0.625 - 0.900] | 1 |
| (0.900 - 1.175] | 0 |
| (1.175 - 1.450] | 5 |
| (1.450 - 1.725] | 1 |
| (1.725 - 2.000] | 1 |

It works, but the classes may not print well. They have too many decimals. We can change the number of classes to try to fix this issue (let's try 7 classes next).

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## Counting number of observations (frequencies)

Let's try a different number of classes (7) and interval size (0.2)

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

Let's use: left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| [0.8 - 1.0) | 1 |
| [1.0 - 1.2) | 0 |
| [1.2 - 1.4) | 3 |
| [1.4 - 1.6) | 2 |
| [1.6 - 1.8) | 1 |
| [1.8 - 2.0) | 0 |
| [2.0 - 2.2) | 1 |
| Total = | 8 |

Note: some software may include 2.0 in this interval even though is opened. This may happen when the last values in the data fall here. (R does that)

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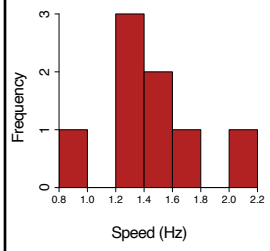
## From frequency distribution tables to histograms

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0




left-closed & right-open [a,b)

| Classes | Frequency |
|---|---|
| [0.8 - 1.0) | 1 |
| [1.0 - 1.2) | 0 |
| [1.2 - 1.4) | 3 |
| [1.4 - 1.6) | 2 |
| [1.6 - 1.8) | 1 |
| [1.8 - 2.0) | 0 |
| [2.0 - 2.2) | 1 |

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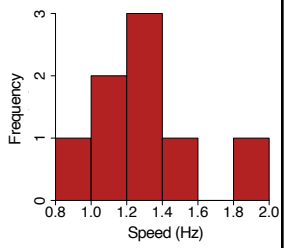
## From frequency distribution tables to histograms

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

left-open & right-closed (a,b]

| Classes | Frequency |
|---|---|
| (0.80 - 1.00] | 1 |
| (1.00 - 1.20] | 2 |
| (1.20 - 1.40] | 3 |
| (1.40 - 1.60] | 1 |
| (1.60 - 1.80] | 0 |
| (1.80 - 2.00] | 1 |

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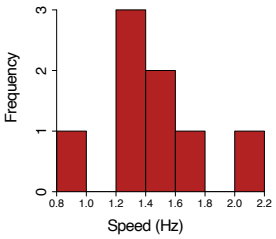
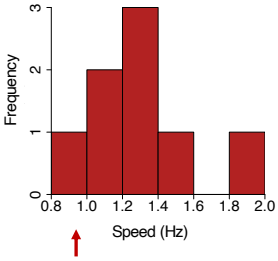
## From frequency distribution tables to histograms

0.9, 1.2, 1.2, 1.3, 1.4, 1.4, 1.6, 2.0

left-closed & right-open




left-open & right-closed




Perhaps choose this one. Less intervals and only one empty interval.

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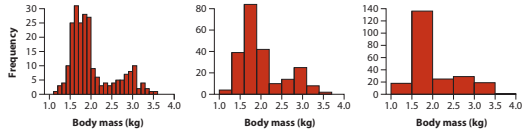
## Again, number of classes and interval size depend on the goal of the analyst & often based on trying different options




Body mass of 228 female sockeye salmon sampled from Pick Creek in Alaska (Hendry et al. 1999). The same data are shown in each case, but the interval widths are different : 0.1 kg (left), 0.3 kg (middle), and 0.5 kg (right).



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## Next lecture: describing data

Samples and populations are often made of lots of individual (observational) units and their associated information (observations, variables).

We need to be able to describe samples by summary statistics (mean, median, variance, etc) so that these summaries can serve as an estimate of the same summaries for their statistical populations.

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