Data Analysis Assignment #1 (50 points total)

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R markdown is a plain-text file format for integrating text and R code, and creating transparent, reproducible and interactive reports. An R markdown file (.Rmd) contains metadata, markdown and R code "chunks,"" and can be "knit" into numerous output types. Answer the test questions by adding R code to the fenced code areas below each item. There are questions that require a written answer that also need to be answered. Enter your comments in the space provided as shown below:

Answer: (Enter your answer here.)

Once completed, you will "knit" and submit the resulting .html document and the .Rmd file. The .html will present the output of your R code and your written answers, but your R code will not appear. Your R code will appear in the .Rmd file. The resulting .html document will be graded. Points assigned to each item appear in this template.

Before proceeding, look to the top of the .Rmd for the (YAML) metadata block, where the *title*, *author* and *output* are given. Please change *author* to include your name, with the format 'lastName, firstName.'

If you encounter issues with knitting the .html, please send an email via Canvas to your TA.

Each code chunk is delineated by six (6) backticks; three (3) at the start and three (3) at the end. After the opening ticks, arguments are passed to the code chunk and in curly brackets. **Please do not add or remove backticks, or modify the arguments or values inside the curly brackets.** An example code chunk is included here:

```
# Comments are included in each code chunk, simply as prompts

#...R code placed here

#...R code placed here
```

R code only needs to be added inside the code chunks for each assignment item. However, there are questions that follow many assignment items. Enter your answers in the space provided. An example showing how to use the template and respond to a question follows.

Example Problem with Solution:

Use *rbinom()* to generate two random samples of size 10,000 from the binomial distribution. For the first sample, use p = 0.45 and n = 10. For the second sample, use p = 0.55 and n = 10. Convert the sample frequencies to sample proportions and compute the mean number of successes for each sample. Present these statistics.

```
set.seed(123)
sample.one <- table(rbinom(10000, 10, 0.45)) / 10000
sample.two <- table(rbinom(10000, 10, 0.55)) / 10000

successes <- seq(0, 10)
```

```r
round(sum(sample.one*successes), digits = 1) # [1] 4.5
```

```
## [1] 4.5
```

```r
round(sum(sample.two*successes), digits = 1) # [1] 5.5
```

```
## [1] 5.5
```

Question: How do the simulated expectations compare to calculated binomial expectations?

Answer: The calculated binomial expectations are 10(0.45) = 4.5 and 10(0.55) = 5.5. After rounding the simulated results, the same values are obtained.

Submit both the .Rmd and .html files for grading. You may remove the instructions and example problem above, but do not remove the YAML metadata block or the first, "setup" code chunk. Address the steps that appear below and answer all the questions. Be sure to address each question with code and comments as needed. You may use either base R functions or ggplot2 for the visualizations.

The following code chunk will:

(a) load the "ggplot2", "gridExtra" and "knitr" packages, assuming each has been installed on your machine,
(b) read-in the abalones dataset, defining a new data frame, "mydata,"
(c) return the structure of that data frame, and
(d) calculate new variables, VOLUME and RATIO.

Do not include package installation code in this document. Packages should be installed via the Console or 'Packages' tab. You will also need to download the abalones.csv from the course site to a known location on your machine. Unless a *file.path()* is specified, R will look to directory where this .Rmd is stored when knitting.

```
## 'data.frame':    1036 obs. of  8 variables:
##  $ SEX   : Factor w/ 3 levels "F","I","M": 2 2 2 2 2 2 2 2 2 2 ...
##  $ LENGTH: num  5.57 3.67 10.08 4.09 6.93 ...
##  $ DIAM  : num  4.09 2.62 7.35 3.15 4.83 ...
##  $ HEIGHT: num  1.26 0.84 2.205 0.945 1.785 ...
##  $ WHOLE : num  11.5 3.5 79.38 4.69 21.19 ...
##  $ SHUCK : num  4.31 1.19 44 2.25 9.88 ...
##  $ RINGS : int  6 4 6 3 6 6 5 6 5 6 ...
##  $ CLASS : Factor w/ 5 levels "A1","A2","A3",..: 1 1 1 1 1 1 1 1 1 1 ...
```

Test Items starts from here - There are 6 sections - Total 50 points

##### Section 1: (6 points) Summarizing the data.

(1)(a) (1 point) Use *summary()* to obtain and present descriptive statistics from mydata. Use table() to present a frequency table using CLASS and RINGS. There should be 115 cells in the table you present.

```
##  SEX          LENGTH           DIAM            HEIGHT           WHOLE
##  F:326   Min.   : 2.73   Min.   : 1.995   Min.   :0.525   Min.   :  1.625
##  I:329   1st Qu.: 9.45   1st Qu.: 7.350   1st Qu.:2.415   1st Qu.: 56.484
##  M:381   Median :11.45   Median : 8.925   Median :2.940   Median :101.344
##          Mean   :11.08   Mean   : 8.622   Mean   :2.947   Mean   :105.832
##          3rd Qu.:13.02   3rd Qu.:10.185   3rd Qu.:3.570   3rd Qu.:150.319
##          Max.   :16.80   Max.   :13.230   Max.   :4.935   Max.   :315.750
##      SHUCK              RINGS        CLASS        VOLUME
##  Min.   :  0.5625   Min.   : 3.000   A1:108   Min.   :  3.612
##  1st Qu.: 23.3006   1st Qu.: 8.000   A2:236   1st Qu.:163.545
##  Median : 42.5700   Median : 9.000   A3:329   Median :307.363
##  Mean   : 45.4396   Mean   : 9.993   A4:188   Mean   :326.804
##  3rd Qu.: 64.2897   3rd Qu.:11.000   A5:175   3rd Qu.:463.264
##  Max.   :157.0800   Max.   :25.000            Max.   :995.673
##      RATIO
##  Min.   :0.06734
##  1st Qu.:0.12241
##  Median :0.13914
##  Mean   :0.14205
##  3rd Qu.:0.15911
##  Max.   :0.31176
```

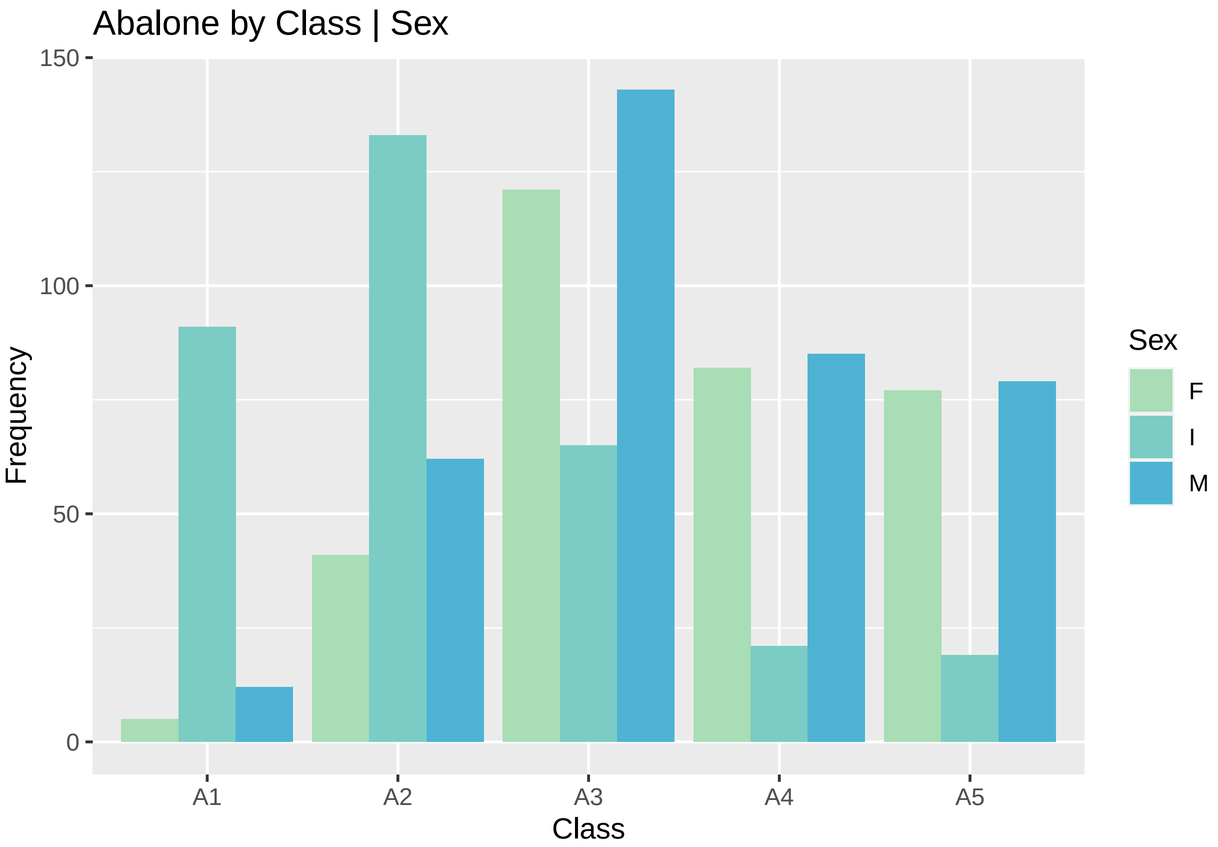
```
##
##          3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
##   A1    9    8   24   67    0    0    0    0    0    0    0    0    0    0    0    0    0    0
##   A2    0    0    0    0   91  145    0    0    0    0    0    0    0    0    0    0    0    0
##   A3    0    0    0    0    0    0  182  147    0    0    0    0    0    0    0    0    0    0
##   A4    0    0    0    0    0    0    0    0  125   63    0    0    0    0    0    0    0    0
##   A5    0    0    0    0    0    0    0    0    0    0   48   35   27   15   13    8    8    6
##
##         21   22   23   24   25
##   A1    0    0    0    0    0
##   A2    0    0    0    0    0
##   A3    0    0    0    0    0
##   A4    0    0    0    0    0
##   A5    4    1    7    2    1
```

Question (1 point): Briefly discuss the variable types and distributional implications such as potential skewness and outliers.

Answer: Variables SEX and CLASS are both categorical or qualitative variables. All other variables are numeric or quantitative variables. HEIGHT appears to be the variable closest to a symmentrical normal distribution, with mean and median fairly similar and a skewness of -0.225262. appear to have fairly similar means and medians, respectively, and therefore have roughly symmetrical normal distributions. LENGTH (skewness=-.67) and DIAM (skewness=-0.62) are both negatively skewed, which suggest the presence of low outliers causing the mean to be less than the median. WHOLE (skewness=.047), SHUCK (skewness=0.64), RINGS (skewness=1.24), VOLUME (skewness=.44), and RATIO (skewness=.71) are all positively skewed, which suggests the presence of high outliers causing the mean to be greater than the median.

(1)(b) (1 point) Generate a table of counts using SEX and CLASS. Add margins to this table (Hint: There should be 15 cells in this table plus the marginal totals. Apply *table()* first, then pass the table object to *addmargins()* (Kabacoff Section 7.2 pages 144-147)). Lastly, present a barplot of these data; ignoring the marginal totals.

```
##
##          A1   A2   A3   A4   A5  Sum
##   F       5   41  121   82   77  326
##   I      91  133   65   21   19  329
##   M      12   62  143   85   79  381
##   Sum   108  236  329  188  175 1036
```

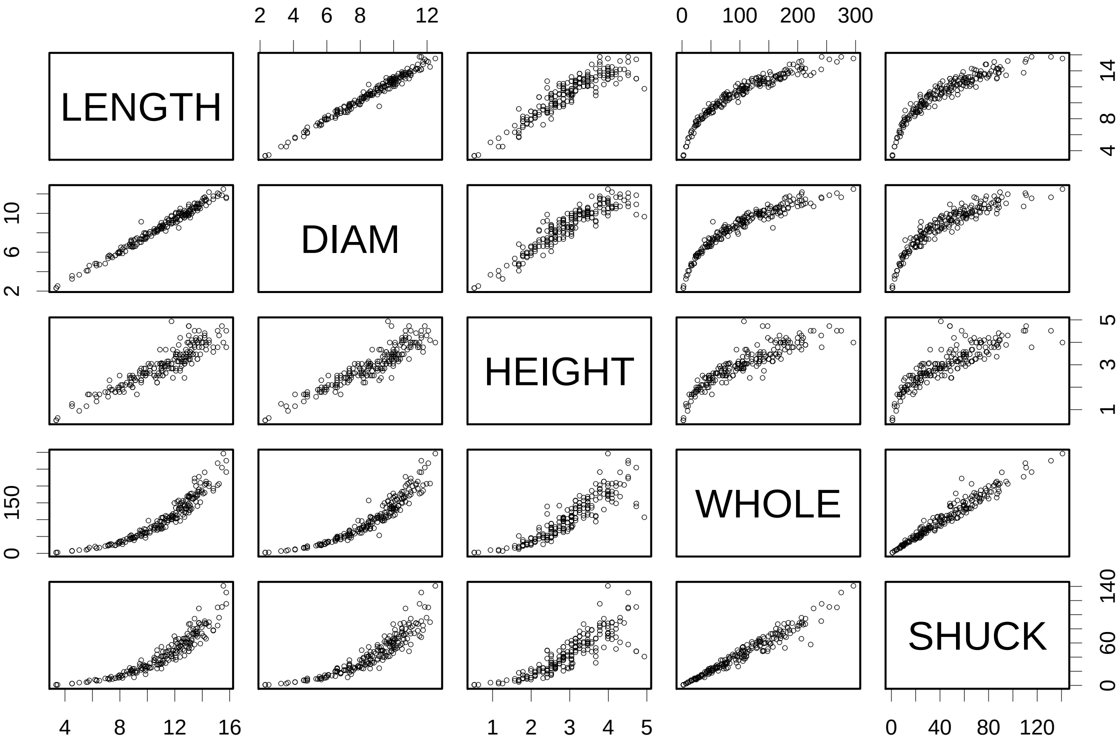


Essay Question (2 points): Discuss the sex distribution of abalones. What stands out about the distribution of abalones by CLASS?

Answer: It is surprising that there is a good number of infants in both A4 and A5, which are supposed to be the oldest classes. It is likely that these abalones could not be classified as male or female. Additionally, there are more infants in A2 than in A1, which suggests that counting rings is an inaccurate or difficult method for determining age.

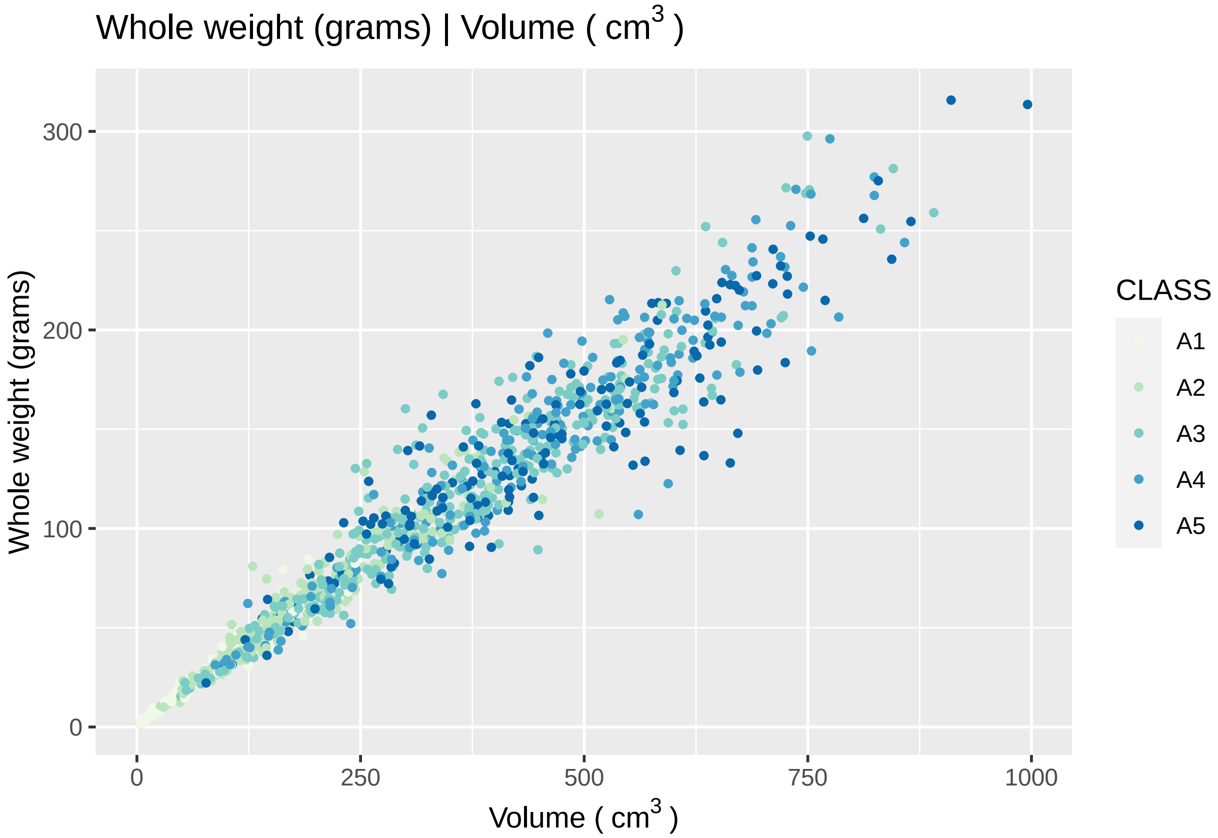
(1)(c) (1 point) Select a simple random sample of 200 observations from "mydata" and identify this sample as "work." Use *set.seed(123)* prior to drawing this sample. Do not change the number 123. Note that *sample()* "takes a sample of the specified size from the elements of x." We cannot sample directly from "mydata." Instead, we need to sample from the integers, 1 to 1036, representing the rows of "mydata." Then, select those rows from the data frame (Kabacoff Section 4.10.5 page 87).

Using "work", construct a scatterplot matrix of variables 2-6 with *plot(work[, 2:6])* (these are the continuous variables excluding VOLUME and RATIO). The sample "work" will not be used in the remainder of the assignment.

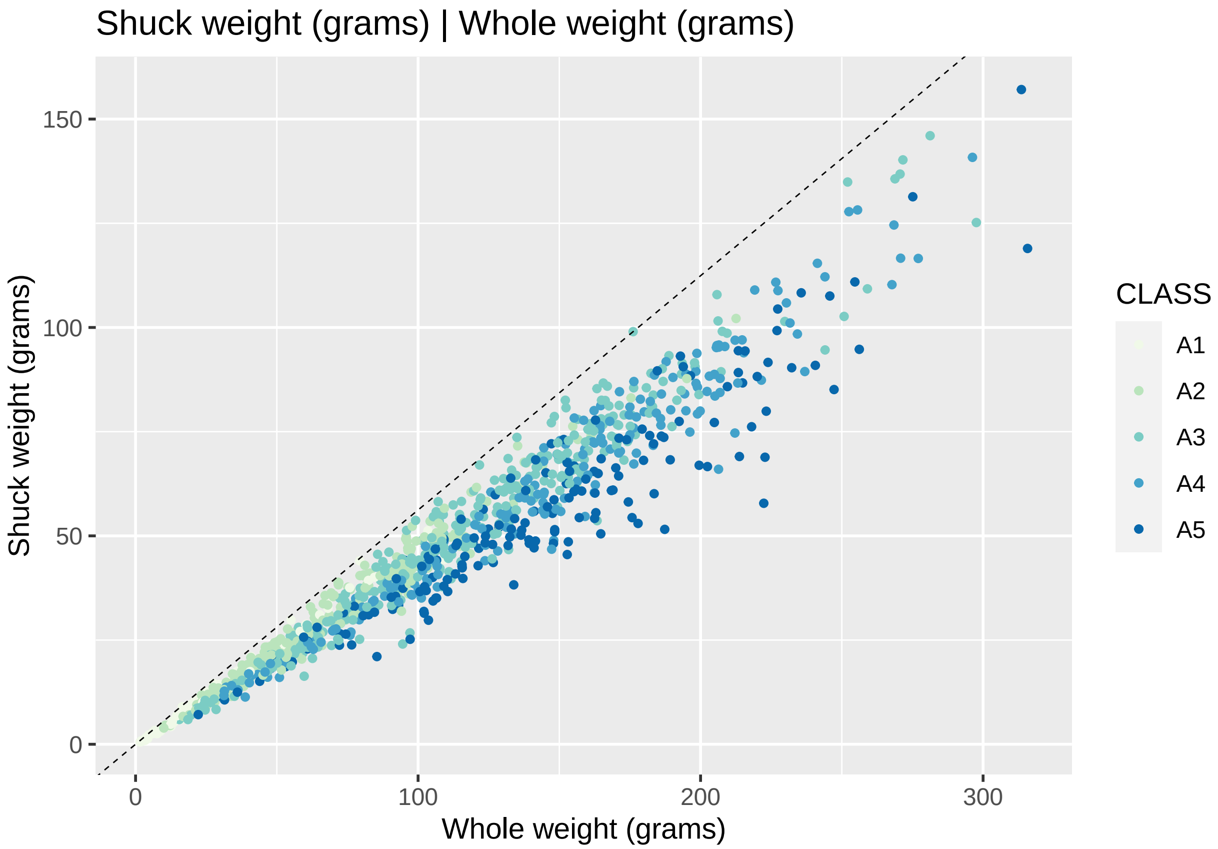


##### Section 2: (5 points) Summarizing the data using graphics.

(2)(a) (1 point) Use “mydata” to plot WHOLE versus VOLUME. Color code data points by CLASS.



(2)(b) (2 points) Use “mydata” to plot SHUCK versus WHOLE with WHOLE on the horizontal axis. Color code data points by CLASS. As an aid to interpretation, determine the maximum value of the ratio of SHUCK to WHOLE. Add to the chart a straight line with zero intercept using this maximum value as the slope of the line. If you are using the ‘base R’ *plot()* function, you may use *abline()* to add this line to the plot. Use *help(abline)* in R to determine the coding for the slope and intercept arguments in the functions. If you are using ggplot2 for visualizations, *geom_abline()* should be used.

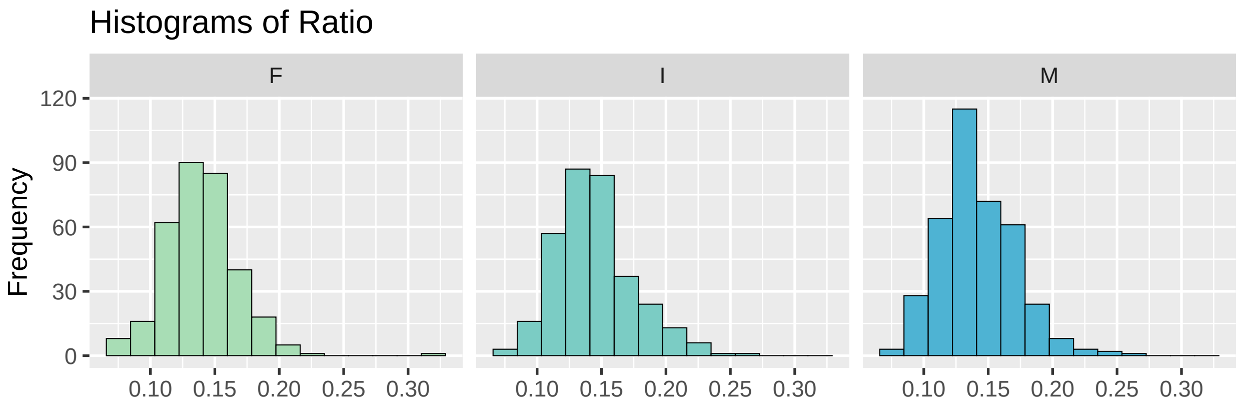


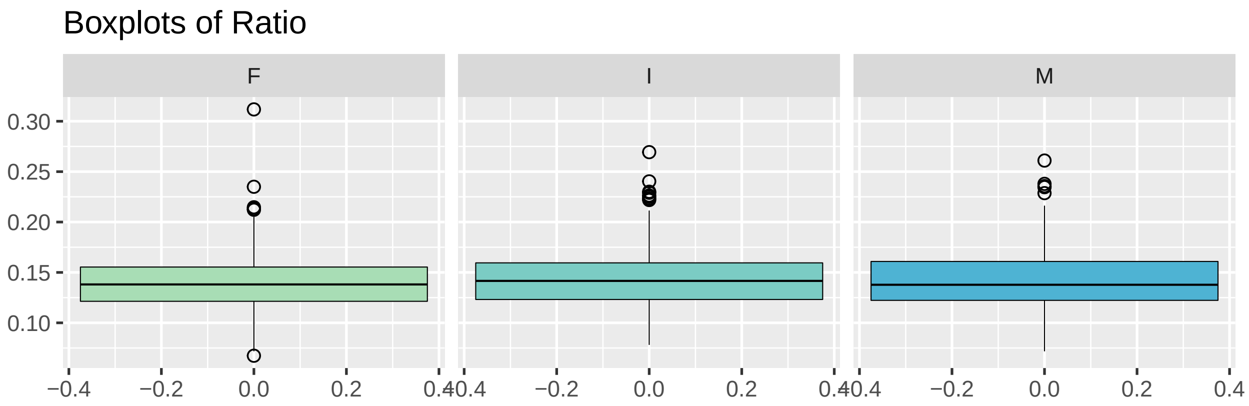
Essay Question (2 points): How does the variability in this plot differ from the plot in (a)? Compare the two displays. Keep in mind that SHUCK is a part of WHOLE. Consider the location of the different age classes.

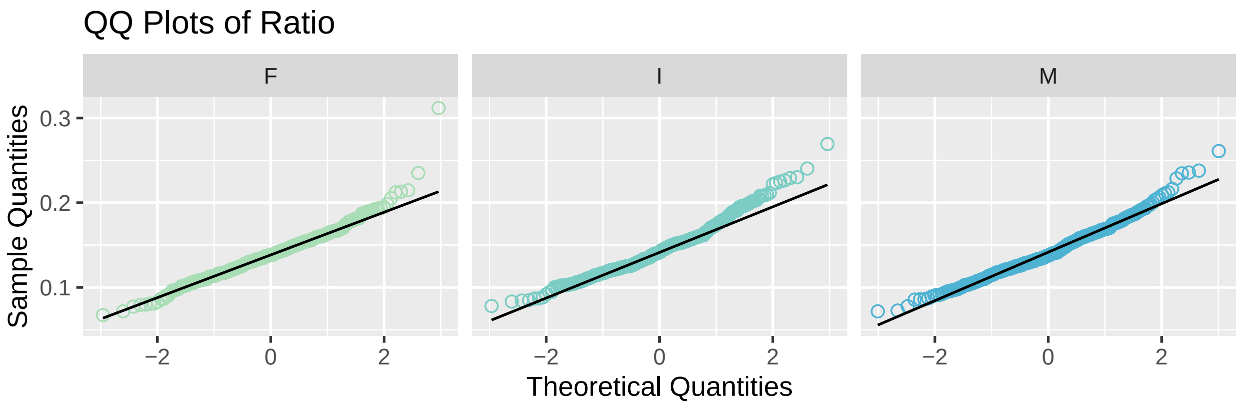
Answer: The first plot appears more variable than the second plot. This indicates that there is a stronger correlation between the two weights (shuck versus whole) than between volume and weight. There does not appear to be a strong pattern when considering classes in the first plot, other than that both volume and whole weight increase proportionally as the abalone matures. In the second plot, however, shells appear to increase in weight as an abalone matures, as exhibited by A5 abalones having the highest whole-to-shuck ratio.

### Section 3: (8 points) Getting insights about the data using graphs.

(3)(a) (2 points) Use "mydata" to create a multi-figured plot with histograms, boxplots and Q-Q plots of RATIO differentiated by sex. This can be done using *par(mfrow = c(3,3))* and base R or *grid.arrange()* and ggplot2. The first row would show the histograms, the second row the boxplots and the third row the Q-Q plots. Be sure these displays are legible.







Essay Question (2 points): Compare the displays. How do the distributions compare to normality? Take into account the criteria discussed in the sync sessions to evaluate non-normality.

Answer: From the displays, we see that all distributions are skewed to the right, and appear at first glance to be non-normally distributed. This is likely due to the mild and extreme outliers in a three graphs, but in particular in the female and infant distributions. All three plots for each graph support this: the histograms display long right tails, the boxplots have IQRs on the left with outliers on right, and the QQ plot values trend above the QQ line, especially for the most positive values.

(3)(b) (2 points) Use the boxplots to identify RATIO outliers (mild and extreme both) for each sex. Present the abalones with these outlying RATIO values along with their associated variables in "mydata" (Hint: display the observations by passing a data frame to the kable() function).

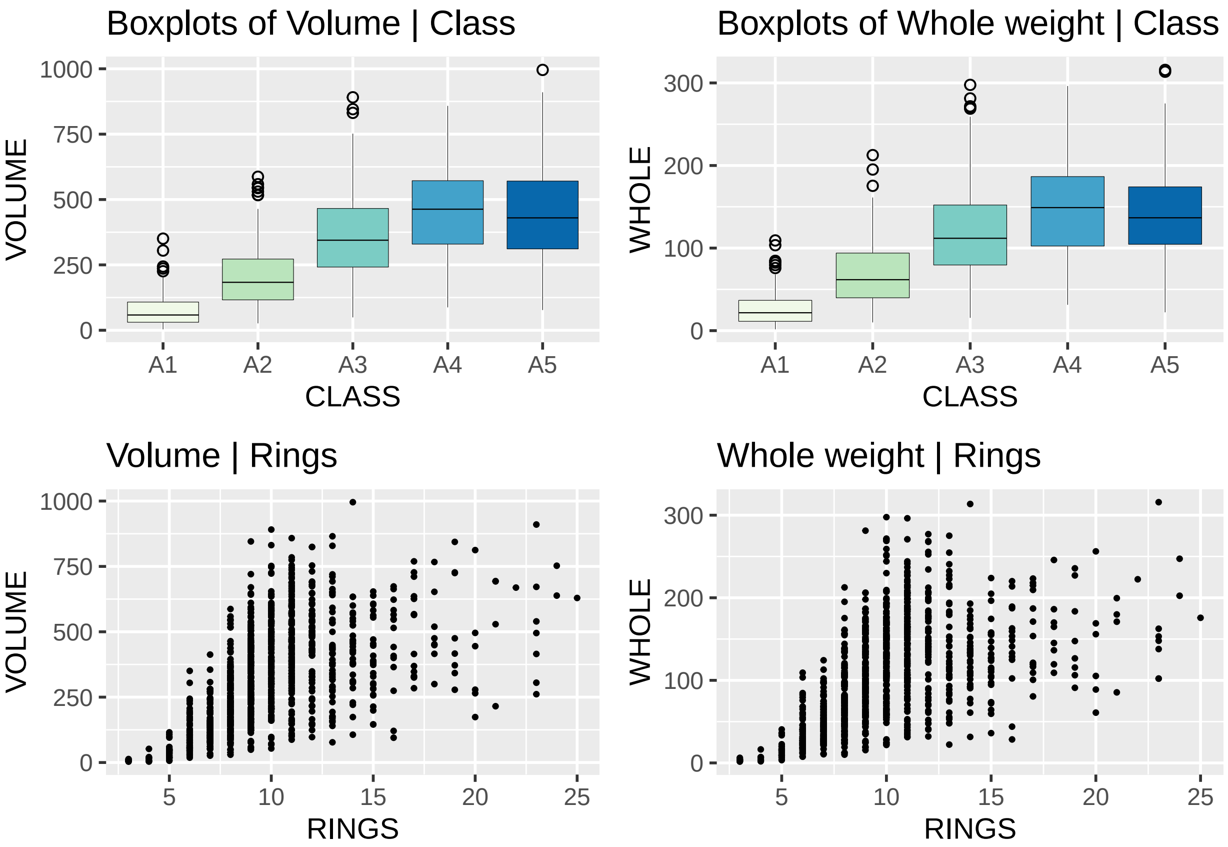
	SEX	LENGTH	DIAM	HEIGHT	WHOLE	SHUCK	RINGS	CLASS	VOLUME	RATIO
3	I	10.080	7.350	2.205	79.37500	44.00000	6	A1	163.364040	0.2693371
37	I	4.305	3.255	0.945	6.18750	2.93750	3	A1	13.242072	0.2218308
42	I	2.835	2.730	0.840	3.62500	1.56250	4	A1	6.501222	0.2403394
58	I	6.720	4.305	1.680	22.62500	11.00000	5	A1	48.601728	0.2263294
67	I	5.040	3.675	0.945	9.65625	3.93750	5	A1	17.503290	0.2249577
89	I	3.360	2.310	0.525	2.43750	0.93750	4	A1	4.074840	0.2300704
105	I	6.930	4.725	1.575	23.37500	11.81250	7	A2	51.572194	0.2290478
200	I	9.135	6.300	2.520	74.56250	32.37500	8	A2	145.027260	0.2232339
350	F	7.980	6.720	2.415	80.93750	40.37500	7	A2	129.505824	0.3117620
379	F	15.330	11.970	3.465	252.06250	134.89812	10	A3	635.827846	0.2121614
420	F	11.550	7.980	3.465	150.62500	68.55375	10	A3	319.365585	0.2146560
421	F	13.125	10.290	2.310	142.00000	66.47062	9	A3	311.979938	0.2130606
458	F	11.445	8.085	3.150	139.81250	68.49062	9	A3	291.478399	0.2349767
586	F	12.180	9.450	4.935	133.87500	38.25000	14	A5	568.023435	0.0673388
746	M	13.440	10.815	1.680	130.25000	63.73125	10	A3	244.194048	0.2609861
754	M	10.500	7.770	3.150	132.68750	61.13250	9	A3	256.992750	0.2378764
803	M	10.710	8.610	3.255	160.31250	70.41375	9	A3	300.153640	0.2345924
810	M	12.285	9.870	3.465	176.12500	99.00000	10	A3	420.141472	0.2356349
852	M	11.550	8.820	3.360	167.56250	78.27187	10	A3	342.286560	0.2286735

Essay Question (2 points): What are your observations regarding the results in (3)(b)?

Answer: Most shuck/volume ratio outliers come from the infant classification. Further, the large majority of outliers are from the younger classes, A1-A3. Only one outlier is classified as A5. Additionally, the only extreme outliers come from the female and infant classes, but none appear for the male class.

### Section 4: (8 points) Getting insights about possible predictors.

(4)(a) (3 points) With "mydata," display side-by-side boxplots for VOLUME and WHOLE, each differentiated by CLASS There should be five boxes for VOLUME and five for WHOLE. Also, display side-by-side scatterplots: VOLUME and WHOLE versus RINGS. Present these four figures in one graphic: the boxplots in one row and the scatterplots in a second row. Base R or ggplot2 may be used.



Essay Question (5 points) How well do you think these variables would perform as predictors of age? Explain.

Answer: Neither of these variables perform well as predictors of age. Both volume and whole weight are positively correlated to the number of rings – that is, generally, as either weight or volume increases, so does the number of rings. However, this is a very loose correlation. For example, an abalone with 500 cmˆ3 volume could have anywhere between 8 rings and 23 rings. There is a similar range for an abalone with 150g whole weight. The story is similar for the correlation between volume-class and weight-class: generally higher volume or higher weight abalone are classified higher/older, but especially classes A3, A4, and A5 have strikingly similar IQRs for both volume and weight. An abalone of volume 250 cmˆ3 or weight 125g could very likely be in either A3, A4, or A5. This either indicates that volume and weight are poor predictors of exact age (though good predictors of a ballpark age), or that the classification system for age is flawed.

### Section 5: (12 points) Getting insights regarding different groups in the data.

(5)(a) (2 points) Use *aggregate()* with "mydata" to compute the mean values of VOLUME, SHUCK and RATIO for each combination of SEX and CLASS. Then, using *matrix()*, create matrices of the mean values. Using the "dimnames" argument within *matrix()* or the *rownames()* and *colnames()* functions on the matrices, label the rows by SEX and columns by CLASS. Present the three matrices (Kabacoff Section 5.6.2, p. 110-111). The *kable()* function is useful for this purpose. You do not need to be concerned with the number of digits presented.

	A1	A2	A3	A4	A5

Table 2: Volume

	A1	A2	A3	A4	A5
M	255.29938	276.8573	412.6079	498.0489	486.1525
I	66.51618	160.3200	270.7406	316.4129	318.6930
F	103.72320	245.3857	358.1181	442.6155	440.2074

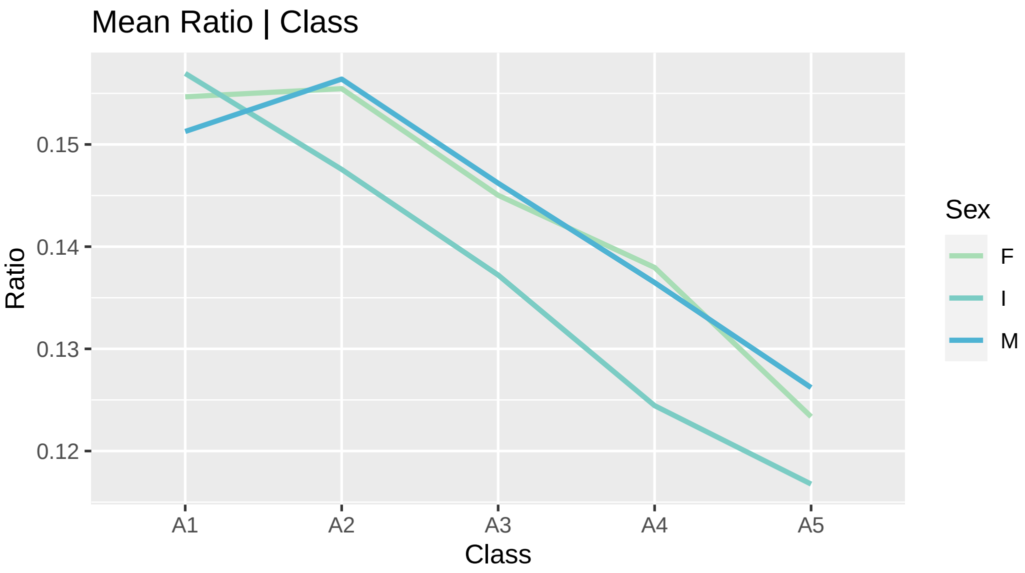
Table 3: Shuck

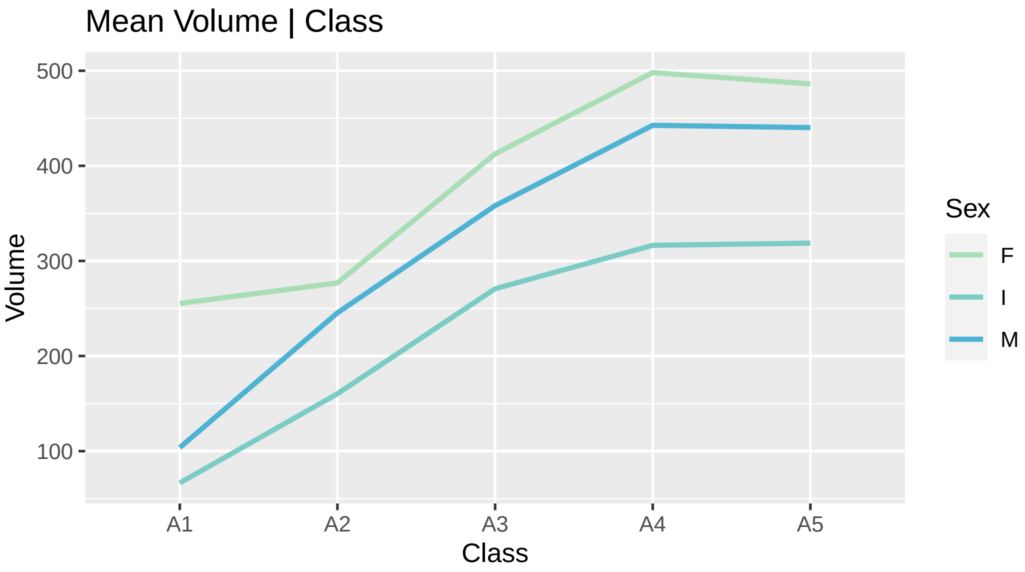
	A1	A2	A3	A4	A5
M	38.90000	42.50305	59.69121	69.05161	59.17076
I	10.11332	23.41024	37.17969	39.85369	36.47047
F	16.39583	38.33855	52.96933	61.42726	55.02762

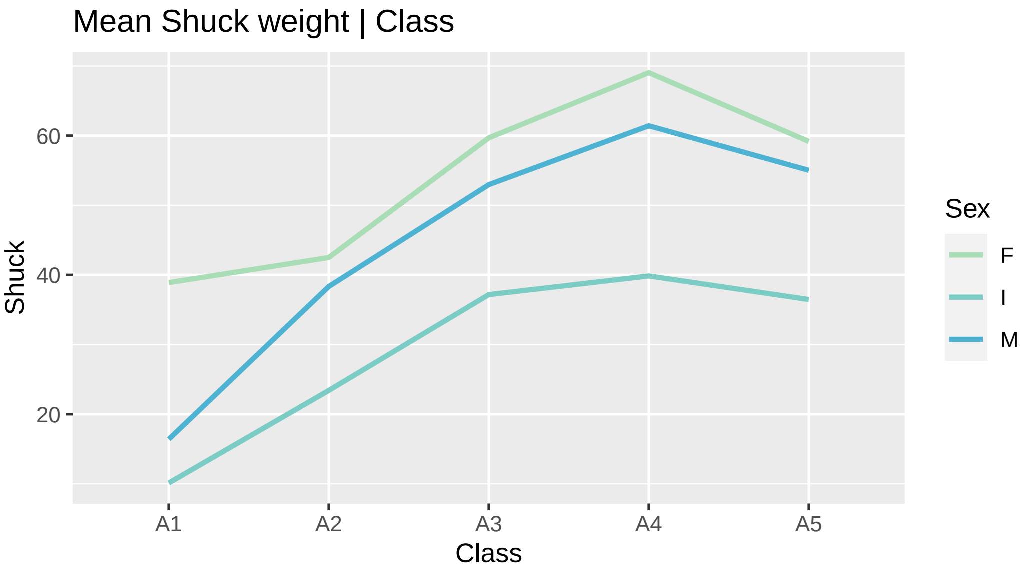
Table 4: Ratio

	A1	A2	A3	A4	A5
M	0.1546644	0.1554605	0.1450304	0.1379609	0.1233605
I	0.1569554	0.1475600	0.1372256	0.1244413	0.1167649
F	0.1512698	0.1564017	0.1462123	0.1364881	0.1262089

(5)(b) (3 points) Present three graphs. Each graph should include three lines, one for each sex. The first should show mean RATIO versus CLASS; the second, mean VOLUME versus CLASS; the third, mean SHUCK versus CLASS. This may be done with the 'base R' *interaction.plot()* function or with ggplot2 using *grid.arrange()*.


Mean Ratio | Class
Ratio
0.15
0.14
0.13
0.12
A1
A2
A3
A4
A5
Class
Sex
F
I
M

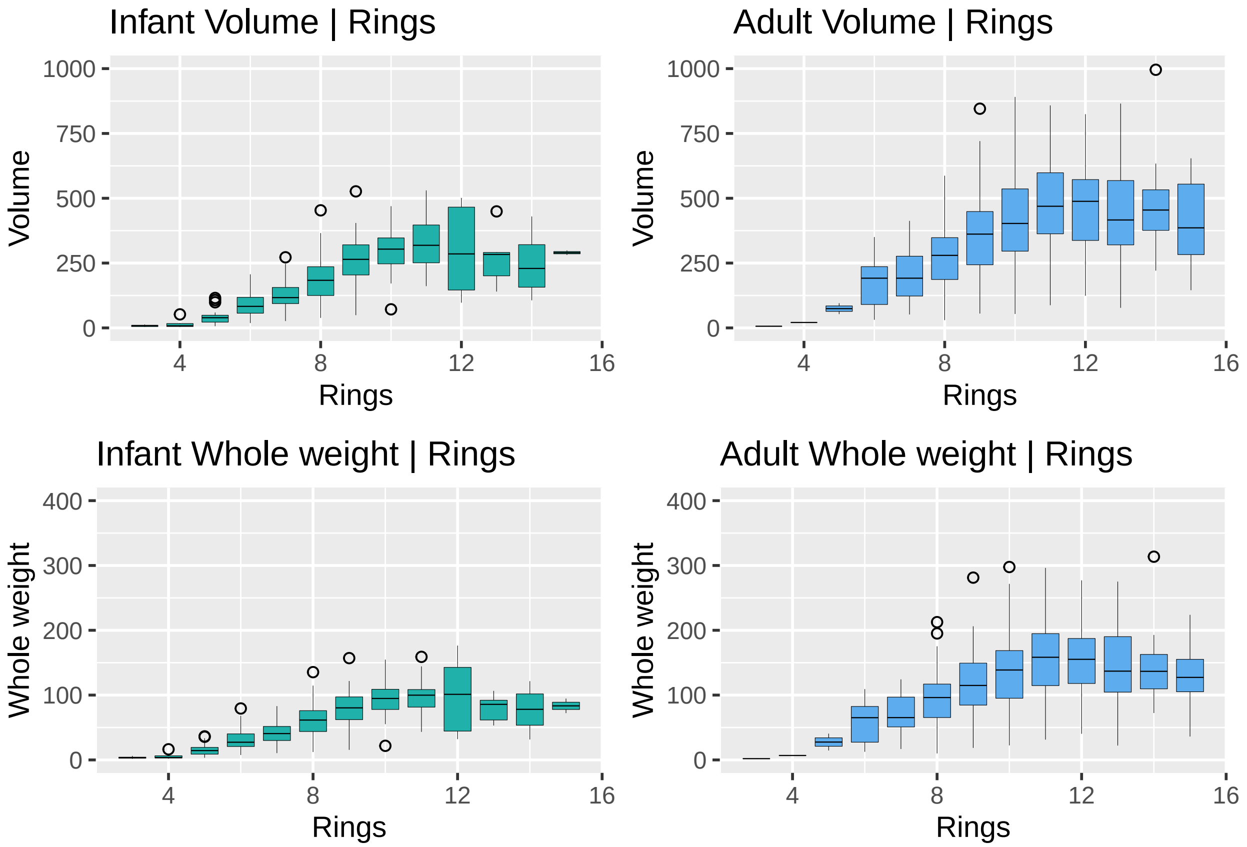

Mean Volume | Class
Volume
500
400
300
200
100
A1
A2
A3
A4
A5
Class
Sex
F
I
M


Mean Shuck weight | Class
Shuck
60
40
20
A1
A2
A3
A4
A5
Class
Sex
F
I
M

Essay Question (2 points): What questions do these plots raise? Consider aging and sex differences.

Answer: These plots raise a number of questions about the variations in shuck/volume ratio, shuck, and volume between the genders. Namely, why do females trend heavier and larger than both males and infants? Further, why do females trend heavier/bigger but their growth as they age is not as great as males and infants? Does the small difference between female A1 and A2 indicate the females develop more slowly? Why are infants consistently both lighter and smaller than the adults, but also have a lower shuck/volume ratio? Is this due to infants truly having a lower shuck/volume ratio, or is just more difficult to identify the sex of an abalone with a lower shuck/volume ratio? Why do both adults and infants tend to get lighter/smaller between A4 and A5?

5(c) (3 points) Present four boxplots using *par(mfrow = c(2, 2)* or *grid.arrange()*. The first line should show VOLUME by RINGS for the infants and, separately, for the adult; factor levels “M” and “F,” combined. The second line should show WHOLE by RINGS for the infants and, separately, for the adults. Since the data are sparse beyond 15 rings, limit the displays to less than 16 rings. One way to accomplish this is to generate a new data set using subset() to select RINGS < 16. Use ylim = c(0, 1100) for VOLUME and ylim = c(0, 400) for WHOLE. If you wish to reorder the displays for presentation purposes or use ggplot2 go ahead.



Essay Question (2 points): What do these displays suggest about abalone growth? Also, compare the infant and adult displays. What differences stand out?

Answer: These displays suggest that most abalone growth occurs in the first half of the abalone life span, from 1 ring to 10-11 rings; the volume and weight weight both increase most rapidly during this period. By contrast, growth appears to level, or even shrink, after reaching 10-11 rings. Additionally, while it makes sense that infants tend to have lower volumes and weights than adults, there is a surprising amount of overlap between the two displays. For example, if classifying on volume/weight alone, an abalone of volume 500 cm^3 or 150g is pretty likely

an adult, but any volume or weight lower than this threshold could easily be either infant or adult. Most abalone classified as "infants" have the same size and weight of some of the smaller/lighter adults. Lastly, the infants tend to be closer to volume/weight to eachother; the infant displays have smaller IQRs and smaller standard deviations as compared to the adults, which are more variable in volume and weight within each ring grouping.

### Section 6: (11 points) Conclusions from the Exploratory Data Analysis (EDA).

Conclusions

Essay Question 1) (5 points) Based solely on these data, what are plausible statistical reasons that explain the failure of the original study? Consider to what extent physical measurements may be used for age prediction.

Answer: (Enter your answer here.)

Essay Question 2) (3 points) Do not refer to the abalone data or study. If you were presented with an overall histogram and summary statistics from a sample of some population or phenomenon and no other information, what questions might you ask before accepting them as representative of the sampled population or phenomenon?

Answer: (Enter your answer here.)

Essay Question 3) (3 points) Do not refer to the abalone data or study. What do you see as difficulties analyzing data derived from observational studies? Can causality be determined? What might be learned from such studies?

Answer: (Enter your answer here.)