1)

Contingency Table for Hodgkin’s Disease Data

| **Table of htype by response** | | | | |
| --- | --- | --- | --- | --- |
| **htype** | **response** | | | |
| **Frequency Expected** | **none** | **partial** | **positive** | **Total** |
| **ld** | 44 16.862 | 10 13.115 | 18 42.022 | 72 |
| **lp** | 12 24.357 | 18 18.944 | 74 60.699 | 104 |
| **mc** | 58 62.297 | 54 48.454 | 154 155.25 | 266 |
| **ns** | 12 22.483 | 16 17.487 | 68 56.03 | 96 |
| **Total** | 126 | 98 | 314 | 538 |

a) Based on this contingency table, it appears the positive responses for lymphocyte depletion are less than expected, while the negative responses are greater than expected. It seems the positive responses for lymphocyte predominance and nodular sclerosis are greater than expected, while the negative responses for these two histological types are less than expected. The results for mixed cellularity are very similar to the expected counts. Based on the deviations from expected responses for three of the four histological types, it appears there may be some significant associations.

Tests of Association for Hodgkin’s Disease Data

| **Statistic** | **DF** | **Value** | **Prob** |
| --- | --- | --- | --- |
| **Chi-Square** | 6 | 75.8901 | <.0001 |
| **Likelihood Ratio Chi-Square** | 6 | 68.2955 | <.0001 |
| **Mantel-Haenszel Chi-Square** | 1 | 31.6676 | <.0001 |
| **Phi Coefficient** |  | 0.3756 |  |
| **Contingency Coefficient** |  | 0.3516 |  |
| **Cramer's V** |  | 0.2656 |  |

Although the responses are ordinal, the histological types are not ordinal. This indicates the Mantel-Haenzel test will not be useful since it tests for linear trends across the rows and columns of the contingency table. Since we have a sufficiently large amount of data in every cell, the approximate chi-square tests for association are appropriate to use. Therefore, we do not have to rely on Fisher’s exact test for association, which would be very computationally expensive and time consuming for this 4x3 table.

Based on the very low p-values for the Pearson and Likelihood Ratio Chi-Square tests, we conclude there is significant association between the histological type and response to treatment after 3 months at any reasonable level of significance.

Contingency table for lymphocyte predominance and lymphocyte depletion

| **Statistic** | **DF** | **Value** | **Prob** |
| --- | --- | --- | --- |
| **Chi-Square** | 2 | 50.5100 | <.0001 |
| **Likelihood Ratio Chi-Square** | 2 | 52.4917 | <.0001 |
| **Mantel-Haenszel Chi-Square** | 1 | 48.5130 | <.0001 |
| **Phi Coefficient** |  | 0.5357 |  |
| **Contingency Coefficient** |  | 0.4722 |  |
| **Cramer's V** |  | 0.5357 |  |

| **Table of htype by response** | | | | |
| --- | --- | --- | --- | --- |
| **htype** | **response** | | | |
| **Frequency Expected** | **none** | **partial** | **positive** | **Total** |
| **ld** | 44 22.909 | 10 11.455 | 18 37.636 | 72 |
| **lp** | 12 33.091 | 18 16.545 | 74 54.364 | 104 |
| **Total** | 56 | 28 | 92 | 176 |

b) Similar to the results from part a, it appears lymphocyte depletion has less than expected positive responses and more than expected negative responses, while lymphocyte predominance has greater than expected positive responses and less than expected negative responses. Based on this contingency table, it appears there is significant association.

Tests of Association for lymphocyte predominance and lymphocyte depletion

Analogous to part a, the Mantel-Haenszel test for linear trends is not appropriate for this data. The counts in each cell are sufficiently large, indicating we can rely on the approximate chi-square tests of association rather than Fisher’s exact test. Based on the very low p-values for the Pearson and Likelihood Ratio Chi-Square test, we conclude there is significant association at any reasonable level of significance between the response to treatment after 3 months and whether the histological type is lymphocyte depletion or lymphocyte predominance.

Risk difference in response type between lymphocyte predominance and lymphocyte depletion

| **Table of htype by response** | | | |
| --- | --- | --- | --- |
| **htype** | **response** | | |
| **Frequency Row Pct** | **none** | **positive** | **Total** |
| **ld** | 44 70.97 | 18 29.03 | 62 |
| **lp** | 12 13.95 | 74 86.05 | 86 |
| **Total** | 56 | 92 | 148 |

| **Column 1 Risk Estimates** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Risk** | **ASE** | **(Asymptotic) 95% Confidence Limits** | | **(Exact) 95% Confidence Limits** | |
| **Row 1** | 0.7097 | 0.0576 | 0.5967 | 0.8227 | 0.5805 | 0.8180 |
| **Row 2** | 0.1395 | 0.0374 | 0.0663 | 0.2128 | 0.0742 | 0.2311 |
| **Total** | 0.3784 | 0.0399 | 0.3002 | 0.4565 | 0.3000 | 0.4617 |
|  |  |  |  |  |  |  |
| **Difference** | 0.5701 | 0.0687 | 0.4355 | 0.7048 |  |  |
| **Difference is (Row 1 – Row 2)** | | | | | | |

| **Column 2 Risk Estimates** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Risk** | **ASE** | **(Asymptotic) 95% Confidence Limits** | | **(Exact) 95% Confidence Limits** | |
| **Row 1** | 0.2903 | 0.0576 | 0.1773 | 0.4033 | 0.1820 | 0.4195 |
| **Row 2** | 0.8605 | 0.0374 | 0.7872 | 0.9337 | 0.7689 | 0.9258 |
| **Total** | 0.6216 | 0.0399 | 0.5435 | 0.6998 | 0.5383 | 0.7000 |
|  |  |  |  |  |  |  |
| **Difference** | -0.5701 | 0.0687 | -0.7048 | -0.4355 |  |  |
| **Difference is (Row 1 - Row 2)** | | | | | | |

c) When considering only positive or no response types, lymphocyte depletion had about 71% no response and 29% positive response and lymphocyte predominance had about 14% no response and 86% positive response. Based on the point estimate, lymphocyte predominance responds positively 57% more than lymphocyte depletion. Since the 95% confidence interval of the differences in the two responses between these histological types doesn’t contain 0, the difference is statistically significant. In fact, this difference is very significant since the interval is not close to 0. This indicates lymphocyte predominance is significantly more likely to response positively to treatment than lymphocyte depletion.

2)

Contingency Table for Church Assembly Vote Data

| **Table of group by vote** | | | | |
| --- | --- | --- | --- | --- |
| **group** | **vote** | | | |
| **Frequency Expected** | **abs** | **aye** | **no** | **Total** |
| **bishops** | 8 3.0155 | 1 2.2616 | 8 11.723 | 17 |
| **clergy** | 20 23.06 | 14 17.295 | 96 89.645 | 130 |
| **laity** | 52 53.925 | 45 40.443 | 207 209.63 | 304 |
| **Total** | 80 | 60 | 311 | 451 |

a) Based on the contingency table, there are many more laity and clergy compared to bishops. In fact, the cell counts for bishops are so small it may be inappropriate to use asymptotic results such as the chi-square test of association. Overall, there are slight deviations between expected and actual counts, indicating there may be association in the data.

| **Statistic** | **DF** | **Value** | **Prob** |
| --- | --- | --- | --- |
| **Chi-Square** | 4 | 12.2244 | 0.0158 |
| **Likelihood Ratio Chi-Square** | 4 | 10.0001 | 0.0404 |
| **Mantel-Haenszel Chi-Square** | 1 | 0.7633 | 0.3823 |
| **Phi Coefficient** |  | 0.1646 |  |
| **Contingency Coefficient** |  | 0.1624 |  |
| **Cramer's V** |  | 0.1164 |  |
| **WARNING: 22% of the cells have expected counts less than 5. Chi-Square may not be a valid test.** | | | |

| **Fisher's Exact Test** | |
| --- | --- |
| **Table Probability (P)** | 7.911E-06 |
| **Pr <= P** | 0.0363 |

Tests of Association for Church Assembly Vote Data

Due to the small number of bishops, the results indicate Chi-Square tests may not be valid. Therefore, we should rely on Fisher’s exact test of association. Due to the small p-value, we reject the null hypothesis of independence at a 5% level of significant. We conclude there is association between the groups and how they voted.

| **Table of group by vote** | | | |
| --- | --- | --- | --- |
| **group** | **vote** | | |
| **Frequency Expected** | **aye** | **no** | **Total** |
| **clergy** | 14 17.928 | 96 92.072 | 110 |
| **laity** | 45 41.072 | 207 210.93 | 252 |
| **Total** | 59 | 303 | 362 |

| **Statistic** | **DF** | **Value** | **Prob** |
| --- | --- | --- | --- |
| **Chi-Square** | 1 | 1.4771 | 0.2242 |
| **Likelihood Ratio Chi-Square** | 1 | 1.5346 | 0.2154 |
| **Continuity Adj. Chi-Square** | 1 | 1.1250 | 0.2888 |
| **Mantel-Haenszel Chi-Square** | 1 | 1.4731 | 0.2249 |
| **Phi Coefficient** |  | -0.0639 |  |
| **Contingency Coefficient** |  | 0.0637 |  |
| **Cramer’s V** |  | -0.0639 |  |

Contingency table of clergy and laity vs aye and no votes

b) It is difficult to discern whether there is association in this contingency table, which excludes bishops and abstained votes. Therefore, we must rely on the statistical tests for association shown below. Additionally, the cell counts are now large enough to rely on the Chi-Square tests.

Tests of Association for clergy and laity vs aye and no votes

The p-values for both Chi-Square tests of association indicate the null hypothesis will not be rejected at any level of significance lower than 20%. Therefore, there is not significant evidence of association between clergy and laity and how they vote aye or no. This result differs from part a, where there was significant evidence of association in the data.

| **Table of group by vote** | | | |
| --- | --- | --- | --- |
| **group** | **vote** | | |
| **Frequency Row Pct** | **aye** | **no** | **Total** |
| **clergy** | 14 12.73 | 96 87.27 | 110 |
| **laity** | 45 17.86 | 207 82.14 | 252 |
| **Total** | 59 | 303 | 362 |

| **Column 1 Risk Estimates** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Risk** | **ASE** | **(Asymptotic) 95% Confidence Limits** | | **(Exact) 95% Confidence Limits** | |
| **Row 1** | 0.1273 | 0.0318 | 0.0650 | 0.1896 | 0.0714 | 0.2043 |
| **Row 2** | 0.1786 | 0.0241 | 0.1313 | 0.2259 | 0.1333 | 0.2315 |
| **Total** | 0.1630 | 0.0194 | 0.1249 | 0.2010 | 0.1264 | 0.2051 |
|  |  |  |  |  |  |  |
| **Difference** | -0.0513 | 0.0399 | -0.1295 | 0.0269 |  |  |
| **Difference is (Row 1 - Row 2)** | | | | | | |

Risk difference in vote aye or no between clergy and laity

| **Column 2 Risk Estimates** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Risk** | **ASE** | **(Asymptotic) 95% Confidence Limits** | | **(Exact) 95% Confidence Limits** | |
| **Row 1** | 0.8727 | 0.0318 | 0.8104 | 0.9350 | 0.7957 | 0.9286 |
| **Row 2** | 0.8214 | 0.0241 | 0.7741 | 0.8687 | 0.7685 | 0.8667 |
| **Total** | 0.8370 | 0.0194 | 0.7990 | 0.8751 | 0.7949 | 0.8736 |
|  |  |  |  |  |  |  |
| **Difference** | 0.0513 | 0.0399 | -0.0269 | 0.1295 |  |  |
| **Difference is (Row 1 - Row 2)** | | | | | | |

c) Since the results from the previous section indicate no significant association between voting responses for clergy and laity, it would be surprising if one was significantly more likely to vote aye than the other. While laity does vote aye slightly more frequently than clergy, the 95% confidence interval of the difference contains 0, indicating the difference is not statistically significant at a 5% level. Therefore, there is not a significant difference in voting aye between laity and clergy.

| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F Value** | **Pr > F** |
| --- | --- | --- | --- | --- | --- |
| **Model** | 2 | 1.75922271 | 0.87961136 | 13.31 | <.0001 |
| **Error** | 175 | 11.56261773 | 0.06607210 |  |  |
| **Corrected Total** | 177 | 13.32184045 |  |  |  |

3)

One-way ANOVA model of alkalinity = alcohol

| **Source** | **DF** | **Anova SS** | **Mean Square** | **F Value** | **Pr > F** |
| --- | --- | --- | --- | --- | --- |
| **Alcohol** | 2 | 1.75922271 | 0.87961136 | 13.31 | <.0001 |

| **R-Square** | **Coeff Var** | **Root MSE** | **Alcalinity Mean** |
| --- | --- | --- | --- |
| 0.132056 | 10.86174 | 0.257045 | 2.366517 |

| **Levene's Test for Homogeneity of Alcalinity Variance ANOVA of Squared Deviations from Group Means** | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F Value** | **Pr > F** |
| **Alcohol** | 2 | 0.1378 | 0.0689 | 5.08 | 0.0072 |
| **Error** | 175 | 2.3734 | 0.0136 |  |  |

| **Welch's ANOVA for Alcalinity** | | | |
| --- | --- | --- | --- |
| **Source** | **DF** | **F Value** | **Pr > F** |
| **Alcohol** | 2.0000 | 11.26 | <.0001 |
| **Error** | 116.5 |  |  |

a) The one-way ANOVA model is statistically significant at any reasonable level. Around 13.2% of the variation in alkalinity values can be explained by alcohol type. However, due to the low p-value of Levene’s test, the assumption of equal variance between group means cannot be trusted. Therefore, we should be cautious when using this ANOVA model for inference. Since the equal variance assumption was not reasonable, a Welch weighted analysis of variance was completed in order to account for the non-constant variance. This ANOVA model was also very statistically significant. Therefore, alcohol type can be used to explain a significant amount of variation in alkalinity values.

| **Comparisons significant at the 0.05 level are indicated by \*\*\*.** | | | | |
| --- | --- | --- | --- | --- |
| **Alcohol Comparison** | **Difference Between Means** | **Simultaneous 95% Confidence Limits** | |  |
| **1 - 3** | 0.01851 | -0.09960 | 0.13662 |  |
| **1 - 2** | 0.21080 | 0.10377 | 0.31784 | \*\*\* |
| **3 - 1** | -0.01851 | -0.13662 | 0.09960 |  |
| **3 - 2** | 0.19229 | 0.07875 | 0.30583 | \*\*\* |
| **2 - 1** | -0.21080 | -0.31784 | -0.10377 | \*\*\* |
| **2 - 3** | -0.19229 | -0.30583 | -0.07875 | \*\*\* |

Tukey’s pairwise comparison test for alkalinity values by alcohol type

b) Since the ANOVA model was statistically significant, it would be surprising if there was not a significant difference in alkalinity group means by alcohol. Tukey’s test may not be exactly correct since the assumption of equal variance between group means is not valid, so we should treat it as an approximation in difference of group means. Based on the significance of the results, it’s safe to assume alkalinity values for alcohol 1 are significantly greater than alcohol 2 and alkalinity values for alcohol 3 are significantly greater than alcohol 2.

4)

One-way ANOVA model of magnesium = alcohol

| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F Value** | **Pr > F** |
| --- | --- | --- | --- | --- | --- |
| **Model** | 2 | 572.833493 | 286.416746 | 35.77 | <.0001 |
| **Error** | 175 | 1401.191957 | 8.006811 |  |  |
| **Corrected Total** | 177 | 1974.025449 |  |  |  |

| **R-Square** | **Coeff Var** | **Root MSE** | **Magnesium Mean** |
| --- | --- | --- | --- |
| 0.290185 | 14.51469 | 2.829631 | 19.49494 |

| **Source** | **DF** | **Anova SS** | **Mean Square** | **F Value** | **Pr > F** |
| --- | --- | --- | --- | --- | --- |
| **Alcohol** | 2 | 572.8334927 | 286.4167464 | 35.77 | <.0001 |

| **Levene's Test for Homogeneity of Magnesium Variance ANOVA of Squared Deviations from Group Means** | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F Value** | **Pr > F** |
| **Alcohol** | 2 | 1253.2 | 626.6 | 3.10 | 0.0477 |
| **Error** | 175 | 35405.9 | 202.3 |  |  |

| **Welch's ANOVA for Magnesium** | | | |
| --- | --- | --- | --- |
| **Source** | **DF** | **F Value** | **Pr > F** |
| **Alcohol** | 2.0000 | 46.34 | <.0001 |
| **Error** | 115.6 |  |  |

a) The one-way ANOVA model is statistically significant at any reasonable level. Around 29.0% of the variation in magnesium values can be explained by alcohol type. Since this is greater than the 13% of variation explained for alkalinity values in problem 3, there is greater variation in magnesium among types of alcohol compared to alkalinity.

Due to the low p-value for Levene’s test, the assumption of equal variances between means for magnesium may not be reasonable. Therefore, a Welch weighted analysis of variance was completed, which also concluded alcohol type can be used to explain a significant amount of the variation in magnesium values.

| **Comparisons significant at the 0.05 level are indicated by \*\*\*.** | | | | |
| --- | --- | --- | --- | --- |
| **Alcohol Comparison** | **Difference Between Means** | **Simultaneous 95% Confidence Limits** | |  |
| **3 - 2** | 1.1786 | -0.0712 | 2.4285 |  |
| **3 - 1** | 4.3794 | 3.0792 | 5.6795 | \*\*\* |
| **2 - 3** | -1.1786 | -2.4285 | 0.0712 |  |
| **2 - 1** | 3.2007 | 2.0224 | 4.3791 | \*\*\* |
| **1 - 3** | -4.3794 | -5.6795 | -3.0792 | \*\*\* |
| **1 - 2** | -3.2007 | -4.3791 | -2.0224 | \*\*\* |

Tukey’s pairwise comparison test for magnesium values by alcohol type

b) Since the one-way ANOVA model was statistically significant, we expect some significant differences in magnesium means by alcohol. Similar to problem 3, Tukey’s test should be treated as an approximation of differences between group means because the assumption of equal variance between group means is not valid. Based on the significance of results, it’s safe to conclude magnesium values for alcohol 3 are significantly greater than alcohol 1 and magnesium values for alcohol 2 are significantly greater than alcohol 1.