Multiple Comparisons and Contrasts on the Tubes data

Beginning of `tubes.data`

```
id mcg r day AML   AMS  AMld   PML  PMS   PMld   AMslp PMslp SWeight
  1 198 1  1   0.6    .    .    0.8    .      .     .     .
  2 198 1  2   1.8    .    .    2.8    .      .     .     .
  3 198 1  3   4.7    1    .    6.1    1      .     .     .
  4 198 1  4   7.8    4  2.0    8.7    5    2.1     .     .
  5 198 1  5  11.2    6  1.8   12.1    7    2.0     .     .
  6 198 1  6  14.3   12  1.9   15.0   11    1.4     .     .
  7 198 1  7  17.5   12  2.1   18.5   13    1.6     .     .
  8 198 1  8  20.9   19  1.1   21.9   19    1.7     .     .
  9 198 1  9  24.0   22  1.6   25.2   22    1.3     .     .
 10 198 1 10  27.2   26  2.1   28.4   26    1.2     .     .
 11 198 1 11  30.7   28  1.4   32.3   28    1.5     .     .
 12 198 1 12     .   31    .      .   31      .     .     .
 13 198 1 13     .   37    .      .   36      .     .     .
 14 198 1 14     .   37    .      .   38      .  3.11  3.18  0.5996
 15 198 2  1   0.5    .    .    0.6    .      .     .     .
 16 198 2  2   1.4    .    .    2.3    .      .     .     .
 17 198 2  3   4.15   1    .    5.6    1      .     .     .
 18 198 2  4   7.4    2  2.0    8.7    4    2.1     .     .
 19 198 2  5  10.8    5  2.2   12.0    8    2.0     .     .
 20 198 2  6  14.2   10  1.7   15.3   13    1.6     .     .
 21 198 2  7  17.1   13  2.2   18.1   16    1.7     .     .
 22 198 2  8  21.3   18  1.1   22.2   18    1.4     .     .
 23 198 2  9  24.4   27  1.4   25.6   24    1.2     .     .
 24 198 2 10  27.6   26  2.1   28.8   28    1.2     .     .
 25 198 2 11  31.2   29  1.9   32.5   29    1.3     .     .
 26 198 2 12     .   33    .      .   36      .     .     .
 27 198 2 13     .   38    .      .   41      .     .     .
 28 198 2 14     .   42    .      .   42      .  3.21  3.26  0.6040
 29 198 3  1   0.5    .    .    0.65   .      .     .     .
 30 198 3  2   1.6    .    .    2.5    .      .     .     .
 31 198 3  3   4.2    .    .    5.6    .      .     .     .
 32 198 3  4   7.4    4  2.1    8.7    5    1.4     .     .
 33 198 3  5  10.9    8  2.0   11.9   12    1.8     .     .
 34 198 3  6  14.1   15  1.6   14.8   14    1.1     .     .
 35 198 3  7  17.2   16  2.1   18.4   17    1.8     .     .
 36 198 3  8  20.8   25  1.1   21.8   25    1.5     .     .
 37 198 3  9  23.9   21  1.6   25.0   27    1.2     .     .
 38 198 3 10  27.1   28  1.8   28.1   28    1.5     .     .
 39 198 3 11  30.7   33  1.6   32.0   32    1.3     .     .
 40 198 3 12     .   31    .      .   35      .     .     .
 41 198 3 13     .   37    .      .   39      .     .     .
 42 198 3 14     .   37    .      .   38      .  3.14  3.18  0.6172
```

Beginning of `tuberead2.sas`

```
/******************** tuberead2.sas ***********************/
options linesize=79 noovp formdlim='_' nodate;
title 'Fungus Tube data with line1=113 eliminated'; /* Data definition file */

data mould;
     infile 'tubes.data' firstobs=2;
     input
```

```
/*************** tubes08s.sas ***************/
/* One-way analysis of tubes data            */
/********************************************/

%include 'tuberead2.sas';
title2 'One-way analysis of tubes data';
title3 ' with multiple comparisons and contrasts';

proc freq;
     tables mcg;

proc glm;
     class mcg;
     model length10 = mcg;
     means mcg;
     means mcg / Tukey Bon Scheffe;
     /* Test custom contrasts, or "planned comparisons" */
     contrast '198vs205'      mcg   1   -1     0   0   0  0;
     contrast '223vs225'      mcg   0    0     0   0   1 -1;
     contrast '223n225vsRest' mcg  -1   -1    -1  -1   2  2;;
     /* Test equality of mcgs excluding 198: a COLLECTION of contrasts */
     contrast 'AllBut198'     mcg   0   1  -1   0   0   0,
                              mcg   0   0   1  -1   0   0,
                              mcg   0   0   0   1  -1   0,
                              mcg   0   0   0   0   1  -1;
     /* Replicate overall F test just to check. */
     contrast 'OverallF=78.34' mcg   1  -1   0   0   0   0,
                               mcg   0   1  -1   0   0   0,
                               mcg   0   0   1  -1   0   0,
                               mcg   0   0   0   1  -1   0,
                               mcg   0   0   0   0   1  -1;
     /* Estimate will print the value of a sample contrast and do a t-test */
     /* F = t-squared */
     estimate '223n225vsRest'  mcg -.25 -.25 -.25 -.25 .5 .5;
     estimate 'AnotherWay'     mcg  -3   -3    -3  -3   6  6 / divisor=12;

proc iml;
     title2 'Table of critical values for all possible Scheffe tests';
     numdf = 5;   /* Numerator degrees of freedom for initial test */
     dendf = 17;  /* Denominator degrees of freedom for initial test */
     alpha = 0.05;
     critval = finv(1-alpha,numdf,dendf);
     zero = {0 0}; S_table = repeat(zero,numdf,1);  /* Make empty matrix */
     /* Label the columns */
     namz = {"Number of Contrasts in followup test"
             "    Scheffe Critical Value"}; mattrib S_table colname=namz;
     do i = 1 to numdf;
        s_table(|i,1|) = i;
        s_table(|i,2|) = numdf/i *  critval;
     end;
     reset noname; /* Makes output look nicer in this case */
     print "Initial test has"  numdf " and " dendf "degrees of freedom."
           "Using significance level alpha = " alpha;
     print s_table;
```

Fungus Tube data with line1=113 eliminated 1
One-way analysis of tubes data
with multiple comparisons and contrasts

The FREQ Procedure

Mycelial Compatibility Group

mcg	Frequency	Percent	Cumulative Frequency	Cumulative Percent
198	4	17.39	4	17.39
205	4	17.39	8	34.78
213	3	13.04	11	47.83
221	4	17.39	15	65.22
223	4	17.39	19	82.61
225	4	17.39	23	100.00

Fungus Tube data with line1=113 eliminated 2
One-way analysis of tubes data
with multiple comparisons and contrasts

The GLM Procedure

Class Level Information

Class	Levels	Values
mcg	6	198 205 213 221 223 225

Number of observations 23

Fungus Tube data with line1=113 eliminated 3
One-way analysis of tubes data
with multiple comparisons and contrasts

The GLM Procedure

Dependent Variable: length10

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	52.94360507	10.58872101	78.34	<.0001
Error	17	2.29791667	0.13517157		
Corrected Total	22	55.24152174			

R-Square	Coeff Var	Root MSE	length10 Mean
0.958402	1.479116	0.367657	24.85652

Source	DF	Type I SS	Mean Square	F Value	Pr > F
mcg	5	52.94360507	10.58872101	78.34	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
mcg	5	52.94360507	10.58872101	78.34	<.0001

One-way analysis of tubes data
with multiple comparisons and contrasts

The GLM Procedure

Level of mcg	N	length10 Mean	length10 Std Dev
198	4	27.7750000	0.30956959
205	4	25.3375000	0.30923292
213	3	24.4666667	0.20207259
221	4	22.9500000	0.45643546
223	4	24.3500000	0.18708287
225	4	24.1625000	0.55132416

Rearranged in order of the means, with gaps corresponding to the results of the Tukey tests (next page)

Level of mcg	N	length10 Mean	length10 Std Dev
221	4	22.9500000	0.45643546
225	4	24.1625000	0.55132416
223	4	24.3500000	0.18708287
213	3	24.4666667	0.20207259
205	4	25.3375000	0.30923292
198	4	27.7750000	0.30956959

The GLM Procedure

Tukey's Studentized Range (HSD) Test for length10

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	17
Error Mean Square	0.135172
Critical Value of Studentized Range	4.52365

Comparisons significant at the 0.05 level are indicated by ***.

mcg Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
198 - 205	2.4375	1.6059	3.2691	***
198 - 213	3.3083	2.4101	4.2065	***
198 - 223	3.4250	2.5934	4.2566	***
198 - 225	3.6125	2.7809	4.4441	***
198 - 221	4.8250	3.9934	5.6566	***
205 - 198	-2.4375	-3.2691	-1.6059	***
205 - 213	0.8708	-0.0274	1.7690	
205 - 223	0.9875	0.1559	1.8191	***
205 - 225	1.1750	0.3434	2.0066	***
205 - 221	2.3875	1.5559	3.2191	***
213 - 198	-3.3083	-4.2065	-2.4101	***
213 - 205	-0.8708	-1.7690	0.0274	
213 - 223	0.1167	-0.7815	1.0149	
213 - 225	0.3042	-0.5940	1.2024	
213 - 221	1.5167	0.6185	2.4149	***
223 - 198	-3.4250	-4.2566	-2.5934	***
223 - 205	-0.9875	-1.8191	-0.1559	***
223 - 213	-0.1167	-1.0149	0.7815	
223 - 225	0.1875	-0.6441	1.0191	
223 - 221	1.4000	0.5684	2.2316	***
225 - 198	-3.6125	-4.4441	-2.7809	***
225 - 205	-1.1750	-2.0066	-0.3434	***
225 - 213	-0.3042	-1.2024	0.5940	
225 - 223	-0.1875	-1.0191	0.6441	
225 - 221	1.2125	0.3809	2.0441	***
221 - 198	-4.8250	-5.6566	-3.9934	***
221 - 205	-2.3875	-3.2191	-1.5559	***
221 - 213	-1.5167	-2.4149	-0.6185	***
221 - 223	-1.4000	-2.2316	-0.5684	***
221 - 225	-1.2125	-2.0441	-0.3809	***

One-way analysis of tubes data
with multiple comparisons and contrasts

The GLM Procedure

Bonferroni (Dunn) t Tests for length10

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	17
Error Mean Square	0.135172
Critical Value of t	3.41020

Comparisons significant at the 0.05 level are indicated by ***.

mcg Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
198 - 205	2.4375	1.5509	3.3241	***
198 - 213	3.3083	2.3507	4.2659	***
198 - 223	3.4250	2.5384	4.3116	***
198 - 225	3.6125	2.7259	4.4991	***
198 - 221	4.8250	3.9384	5.7116	***
205 - 198	-2.4375	-3.3241	-1.5509	***
205 - 213	0.8708	-0.0868	1.8284	
205 - 223	0.9875	0.1009	1.8741	***
205 - 225	1.1750	0.2884	2.0616	***
205 - 221	2.3875	1.5009	3.2741	***
213 - 198	-3.3083	-4.2659	-2.3507	***
213 - 205	-0.8708	-1.8284	0.0868	
213 - 223	0.1167	-0.8409	1.0743	
213 - 225	0.3042	-0.6534	1.2618	
213 - 221	1.5167	0.5591	2.4743	***
223 - 198	-3.4250	-4.3116	-2.5384	***
223 - 205	-0.9875	-1.8741	-0.1009	***
223 - 213	-0.1167	-1.0743	0.8409	
223 - 225	0.1875	-0.6991	1.0741	
223 - 221	1.4000	0.5134	2.2866	***
225 - 198	-3.6125	-4.4991	-2.7259	***
225 - 205	-1.1750	-2.0616	-0.2884	***
225 - 213	-0.3042	-1.2618	0.6534	
225 - 223	-0.1875	-1.0741	0.6991	
225 - 221	1.2125	0.3259	2.0991	***
221 - 198	-4.8250	-5.7116	-3.9384	***
221 - 205	-2.3875	-3.2741	-1.5009	***
221 - 213	-1.5167	-2.4743	-0.5591	***
221 - 223	-1.4000	-2.2866	-0.5134	***
221 - 225	-1.2125	-2.0991	-0.3259	***

One-way analysis of tubes data
with multiple comparisons and contrasts

The GLM Procedure

Scheffe's Test for length10

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than Tukey's for all pairwise comparisons.

Alpha	0.05
Error Degrees of Freedom	17
Error Mean Square	0.135172
Critical Value of F	2.81000

Comparisons significant at the 0.05 level are indicated by ***.

mcg Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
198 - 205	2.4375	1.4630	3.4120	***
198 - 213	3.3083	2.2558	4.3609	***
198 - 223	3.4250	2.4505	4.3995	***
198 - 225	3.6125	2.6380	4.5870	***
198 - 221	4.8250	3.8505	5.7995	***
205 - 198	-2.4375	-3.4120	-1.4630	***
205 - 213	0.8708	-0.1817	1.9234	
205 - 223	0.9875	0.0130	1.9620	***
205 - 225	1.1750	0.2005	2.1495	***
205 - 221	2.3875	1.4130	3.3620	***
213 - 198	-3.3083	-4.3609	-2.2558	***
213 - 205	-0.8708	-1.9234	0.1817	
213 - 223	0.1167	-0.9359	1.1692	
213 - 225	0.3042	-0.7484	1.3567	
213 - 221	1.5167	0.4641	2.5692	***
223 - 198	-3.4250	-4.3995	-2.4505	***
223 - 205	-0.9875	-1.9620	-0.0130	***
223 - 213	-0.1167	-1.1692	0.9359	
223 - 225	0.1875	-0.7870	1.1620	
223 - 221	1.4000	0.4255	2.3745	***
225 - 198	-3.6125	-4.5870	-2.6380	***
225 - 205	-1.1750	-2.1495	-0.2005	***
225 - 213	-0.3042	-1.3567	0.7484	
225 - 223	-0.1875	-1.1620	0.7870	
225 - 221	1.2125	0.2380	2.1870	***
221 - 198	-4.8250	-5.7995	-3.8505	***
221 - 205	-2.3875	-3.3620	-1.4130	***
221 - 213	-1.5167	-2.5692	-0.4641	***
221 - 223	-1.4000	-2.3745	-0.4255	***
221 - 225	-1.2125	-2.1870	-0.2380	***

The GLM Procedure

Dependent Variable: length10

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
198vs205	1	11.88281250	11.88281250	87.91	<.0001
223vs225	1	0.07031250	0.07031250	0.52	0.4806
223n225vsRest	1	3.98243806	3.98243806	29.46	<.0001
AllBut198	4	11.70089912	2.92522478	21.64	<.0001
OverallF=78.34	5	52.94360507	10.58872101	78.34	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
223n225vsRest	-0.87604167	0.16139606	-5.43	<.0001
AnotherWay	-0.87604167	0.16139606	-5.43	<.0001

Table of critical values for all possible Scheffe tests

Initial test has 5 and 17 degrees of freedom.
Using significance level alpha = 0.05

Number of Contrasts in followup test	Scheffe Critical Value
1	14.049981
2	7.0249904
3	4.683327
4	3.5124952
5	2.8099962