

# THE DESIGN AND MIXED-MODEL ANALYSIS OF EXPERIMENTS

## PRACTICAL XII SOLUTIONS

**XII.1** Example XII.3, *Internal parasites in calves*, involved an experiment to compare two methods for the control of intestinal parasites in calves involved 60 calves. At the start of the grazing season the calves were randomly assigned to the two methods so that 30 calves received each method. The weights of each calf were measured at weeks 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 19.

What are the components of the study?

1. Observational unit            a calf in a week
2. Response variable            Weight
3. Unrandomized factors        Calf, Week
4. Randomized factors          Method
5. Type of study                  a repeated measurements study  
    with calves in a CRD

What is the experimental structure for this experiment?

Structure	Formula
unrandomized	60 Calf* 11 Week
randomized	2 Method*Week

What are the terms derived from the experimental structure? Write out the Hasse diagram for each structure formula or use the rule for completely crossed structures.

$$\text{Calf*Week} = \text{Calf} + \text{Week} + \text{Calf.Week}$$

$$\text{Method*Week} = \text{Method} + \text{Week} + \text{Method.Week}$$

*The degrees of freedom can be computed using the rule for completely crossed structures.*

Which factors would you suggested be regarded as fixed and which as random? What are the maximal expectation and variation models?

*Fixed factors: Method and Week*

*Random factor: Calf*

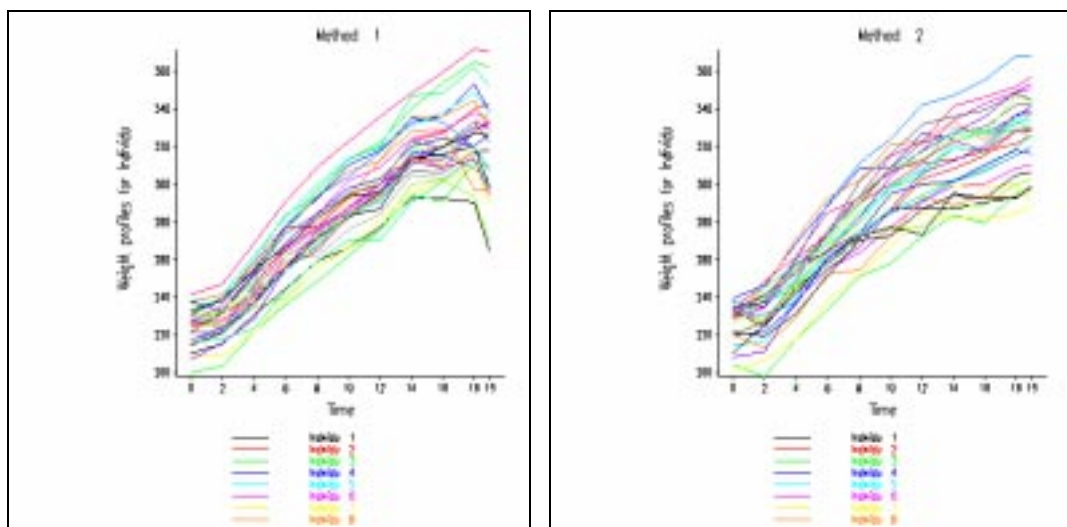
$E[Y] = \text{Method} \cdot \text{Week}$

$\text{Var}[Y] = \text{Calf} + \text{Calf} \cdot \text{Week}$

Write down the analysis of variance table, including the expected mean squares for the lines in it.

Source	df	E[MSq]	
Calf	59		
Method	1	$\sigma_{CW}^2 + 11\sigma_C^2$	$+f_M(\psi)$
Residual	58	$\sigma_{CW}^2 + 11\sigma_C^2$	
Week	10	$\sigma_{CW}^2$	$+f_W(\psi)$
Calf.Week	590		
Method.Week	10	$\sigma_{CW}^2$	$+f_{MW}(\psi)$
Residual	580	$\sigma_{CW}^2$	
Total	569		

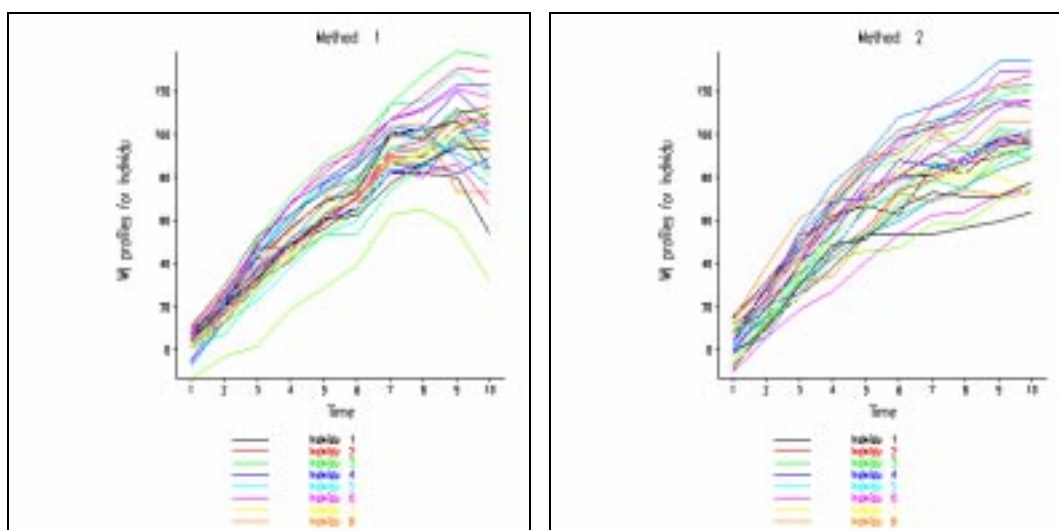
- a) The data are stored in the file *rmecalf.gsh* in the *G:\Disciplina\Genstat* directory. Obtain plots of the individual profiles for the two methods.



- b) Note that the first observation is at week 0 and represents differences between the calves at the time of application of the treatment and not of any treatment effect. Use the following Genstat instructions to subtract the observation at week 0 from all other observations:

```
POINTER Wt; !p(Weight[2,4...18,19])
CALC #Wt=#Wt-Weight[0]
```

- c) Having done that obtain plots of the individual difference profiles for the two methods. What problems do you think there would be in doing a single analysis of variance of all the measurements?



*The variance is clearly increasing over time so that a transformation would have to be found to stabilize the variance.*

- d) The profiles are displaying some curvature so a linear relationship is likely to be inadequate. Fit orthogonal polynomials up to degree 6 to the profile for each calf. Analyse the resulting coefficients. What do you conclude?

*The Genstat output below contains the commands, and associated output, to produce the diagram above and the analysis of the polynomials fitted to the differences from week 0.*

*It will be found that the coefficients of degree 3, 4 and 6 are significantly different between the treatments. It would appear that simple polynomials (up to degree 3) are inadequate in capturing the differences between the treatments.*

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Genstat 5 Procedure Library Release PL11

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```

4  DELETE [redefine=yes] Weeks,Calves,Methods,Weights
5  FACTOR [modify=yes;nvalues=660;levels=!(0,2,4,6,8,10,12,14,16,18,19)] Weeks
6  READ Weeks; frepresentation=ordinal

```

Identifier	Values	Missing	Levels
Weeks	660	0	11

```

26 FACTOR [modify=yes;nvalues=660;levels=60] Calves
27 READ Calves; frepresentation=ordinal

```

Identifier	Values	Missing	Levels
Calves	660	0	60

```

53 FACTOR [modify=yes;nvalues=660;levels=2] Methods
54 READ Methods; frepresentation=ordinal

```

Identifier	Values	Missing	Levels
Methods	660	0	2

```

73 VARIATE [nvalues=660] Weights
74 READ Weights

```

Identifier	Minimum	Mean	Maximum	Values	Missing
Weights	198.0	283.5	372.0	660	0

```

110
111 "
-112 **** separate data for Weeks and Calf profiles
-113 "
114 SUBSET [CONDITION=Weeks==0] OLD=Calves,Methods; \
115                                NEW=Calf,Method
116 FOR i=0,2...18,19
117     SUBSET [CONDITION=Weeks==i] OLD=Weights; NEW=Weight[i]
118 ENDFOR
119 PRINT Calf,Method,Weight[0,2...18,19]; FIELD=9; DEC=0

```

Calf	Method	Weight[0]	Weight[2]	Weight[4]	Weight[6]	Weight[8]	Weight[10]
1	1	210	215	230	244	259	266
2	1	230	240	258	277	277	293
3	1	226	233	248	277	297	313
4	1	233	239	253	277	292	310
5	1	238	241	262	282	300	314
6	1	225	228	237	261	271	288
7	1	224	225	239	257	268	290
8	1	237	241	255	276	293	307
9	1	237	224	234	239	256	266
10	1	233	239	259	283	294	313
11	1	217	222	235	256	267	285
12	1	228	223	246	266	277	287
13	1	241	247	268	290	309	323
14	1	221	221	240	253	273	282
15	1	217	220	235	259	262	276
16	1	214	221	237	256	271	283
17	1	224	231	241	256	265	283
18	1	200	203	221	236	248	262
19	1	238	232	252	268	285	298
20	1	230	222	243	253	268	284
21	1	217	224	242	265	284	302
22	1	209	209	221	238	256	267
23	1	224	227	245	267	279	294
24	1	230	231	244	261	272	283
25	1	216	218	223	243	259	270
26	1	231	239	254	276	294	304
27	1	207	216	228	255	275	285
28	1	227	236	251	264	276	287
29	1	221	232	251	274	284	295
30	1	233	238	254	266	282	294
31	2	233	224	245	258	271	287
32	2	231	238	260	273	290	300
33	2	232	237	245	265	285	298
34	2	239	246	268	288	308	309
35	2	215	216	239	264	282	299

36	2	236	226	242	255	263	277
37	2	219	229	246	265	279	292
38	2	231	245	270	292	302	321
39	2	230	228	243	255	272	276
40	2	232	240	247	263	275	286
41	2	234	237	259	289	311	324
42	2	237	235	258	263	282	304
43	2	229	234	254	276	294	315
44	2	220	227	248	273	290	308
45	2	232	241	255	276	293	309
46	2	210	225	242	260	272	277
47	2	229	241	252	265	274	285
48	2	204	198	217	233	251	258
49	2	220	221	236	260	274	295
50	2	233	234	250	268	280	298
51	2	234	234	254	274	294	306
52	2	200	207	217	238	252	267
53	2	220	213	229	252	254	273
54	2	225	239	254	269	289	308
55	2	236	245	257	271	294	307
56	2	231	231	237	261	274	285
57	2	208	211	238	254	267	287
58	2	232	248	261	285	292	307
59	2	233	241	252	273	301	316
60	2	221	219	231	251	270	272

Weight[12] Weight[14] Weight[16] Weight[18] Weight[19]

277	292	292	290	264
300	323	327	340	343
322	340	354	365	362
318	333	336	353	338
319	331	338	348	338
300	316	319	333	330
304	313	310	318	318
312	336	336	344	328
276	300	302	293	269
320	347	348	362	352
295	317	315	308	301
300	312	308	328	333
336	348	359	372	370
292	307	306	317	318
284	305	303	315	317
287	314	316	320	298
295	314	313	328	334
276	294	291	311	310
303	320	324	320	327
290	316	314	330	330
309	324	328	338	334
281	295	301	309	289
312	328	329	297	297
294	318	320	333	338
270	290	301	314	297
317	335	333	319	307
296	314	319	330	330
297	315	309	313	294
300	323	319	333	322
295	310	320	327	326
287	287	290	293	297
311	313	317	321	326
304	319	317	334	329
327	324	327	336	341
307	321	328	332	337
290	299	300	308	310
299	299	298	300	290
322	334	323	337	337
277	289	289	300	303
294	302	308	319	326
342	347	355	368	368
318	327	336	349	353
323	341	346	352	357
322	326	330	342	343

310	330	326	329	330
273	295	292	305	306
303	308	315	328	328
272	283	279	295	298
300	301	310	318	316
308	319	318	336	333
318	334	343	349	350
284	282	282	284	288
293	289	294	292	298
313	324	327	347	344
317	327	328	328	325
291	301	307	315	320
306	312	320	337	338
312	323	318	328	329
332	336	339	348	345
287	294	292	292	299

```

120 FACTOR [LEV=30] Individuals
121 CALC Individuals=NEWLEVELS(Calf; !v((1...30)2))
122 DREPMEASURES [GROUPS=Method,Individuals] DATA=Weight

```

```

***** Warning (Code HG 20). Statement 130 in Procedure DREPMEAS
Command: DGRAPH [WINDOW= window; KEYWINDOW= keywindow; TITLE= Title_] GroupMns
Key window full

```

```

***** Warning (Code HG 20). Statement 130 in Procedure DREPMEAS
Command: DGRAPH [WINDOW= window; KEYWINDOW= keywindow; TITLE= Title_] GroupMns
Key window full

```

```

123 DREPMEASURES [GROUPS=Method] DATA=Weight
124 "
-125 **** analyse differences from week 0 polynomial coefficients to degree 6
-126 "
127 POINTER Wt; !p(Weight[2,4...18,19])
128 CALC #Wt=#Wt-Weight[0]
129 DREPMEASURES [GROUPS=Method,Individuals] DATA=Wt

```

```

***** Warning (Code HG 20). Statement 130 in Procedure DREPMEAS
Command: DGRAPH [WINDOW= window; KEYWINDOW= keywindow; TITLE= Title_] GroupMns
Key window full

```

```

***** Warning (Code HG 20). Statement 130 in Procedure DREPMEAS
Command: DGRAPH [WINDOW= window; KEYWINDOW= keywindow; TITLE= Title_] GroupMns
Key window full

```

```

130 DREPMEASURES [GROUPS=Method] DATA=Wt
131 VORTHPOL [MAXDEGREE=6] Wt; CONTRAST=pol
132 BLOCK Calf
133 TREAT Method
134 FOR k=0...6
135 ANOVA [FPROB=Y; PSE=LSD] pol[k]
136 APLOT METHOD=fit,normal
137 ENDFOR

```

```

137.....

```

```

***** Analysis of variance *****

```

```

Variate: pol[0]

```

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Calf stratum					
Method	1	0.1	0.1	0.00	0.982
Residual	58	7743.5	133.5		
Total	59	7743.6			

```

* MESSAGE: the following units have large residuals.

```

Calf 9                    -34.9    s.e. 11.4

\*\*\*\*\* Tables of means \*\*\*\*\*

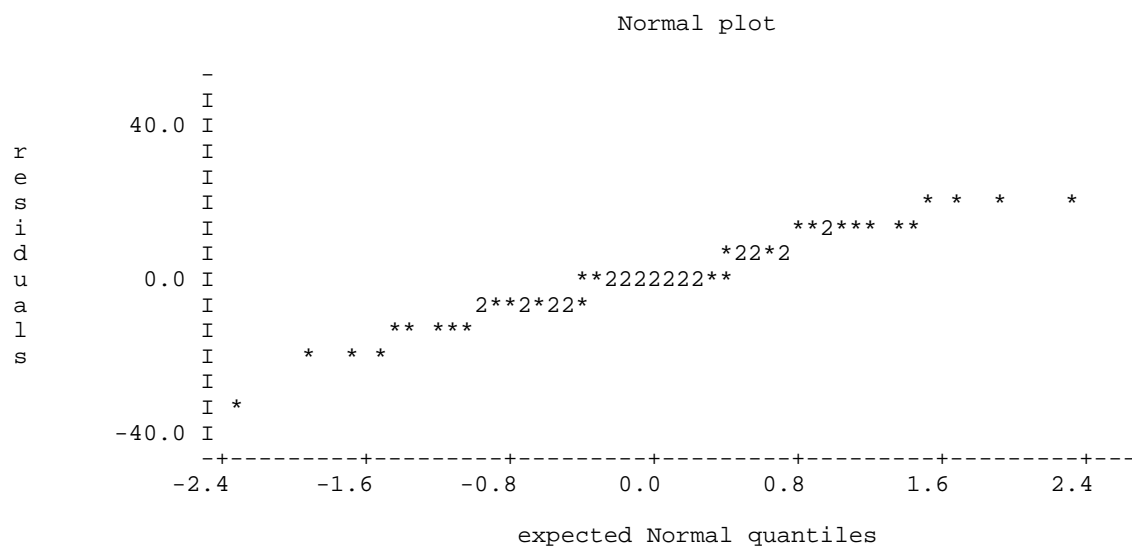
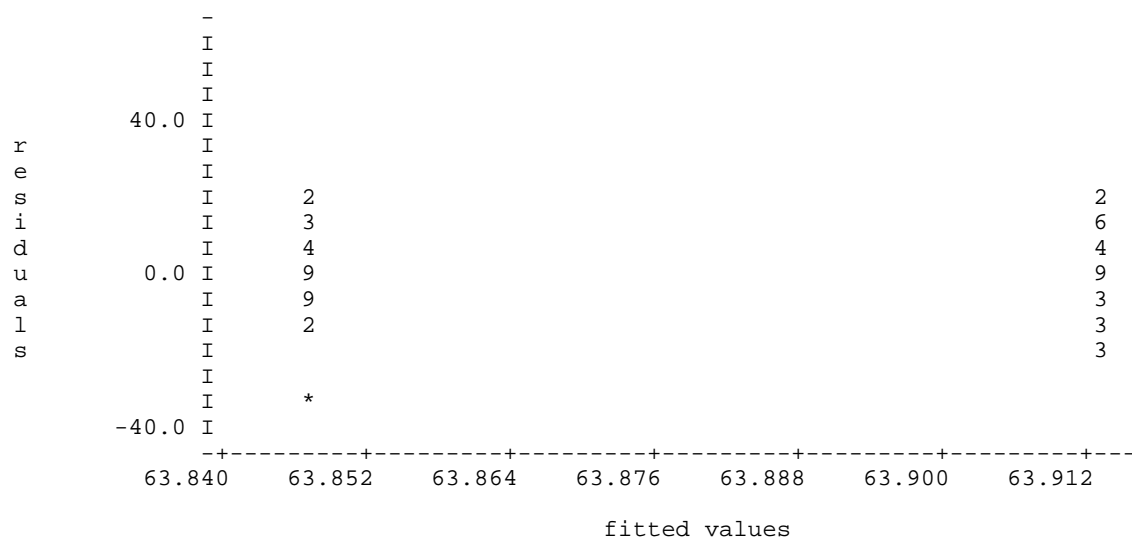
Variate: pol[0]

Grand mean 63.9

Method	1	2
	63.8	63.9

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Method
rep.	30
d.f.	58
l.s.d.	5.97



137.....

\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[1]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Calf stratum					
Method	1	4.119	4.119	1.09	0.302
Residual	58	220.182	3.796		
Total	59	224.302			

\*\*\*\*\* Tables of means \*\*\*\*\*

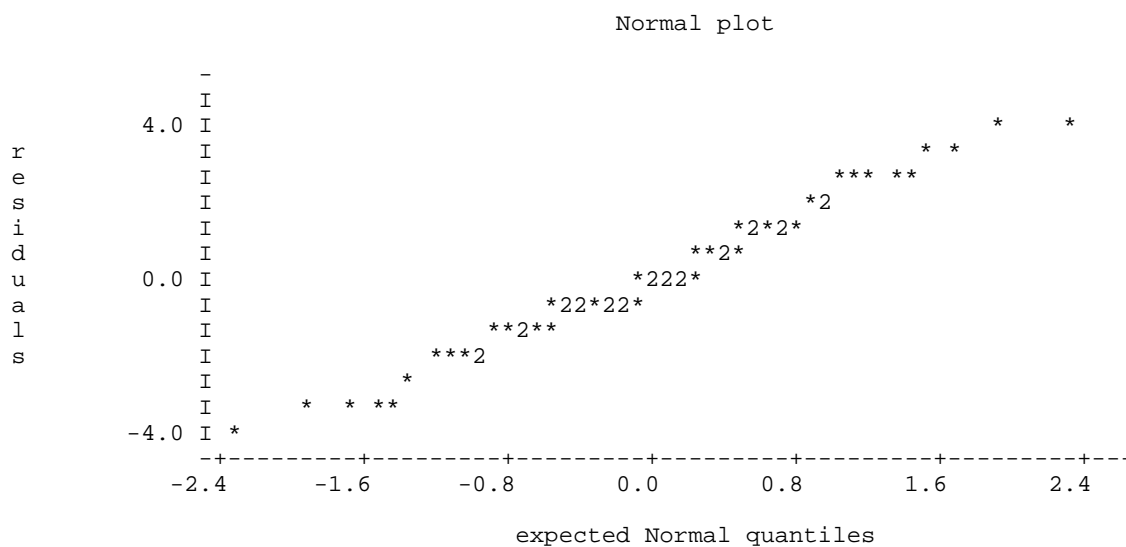
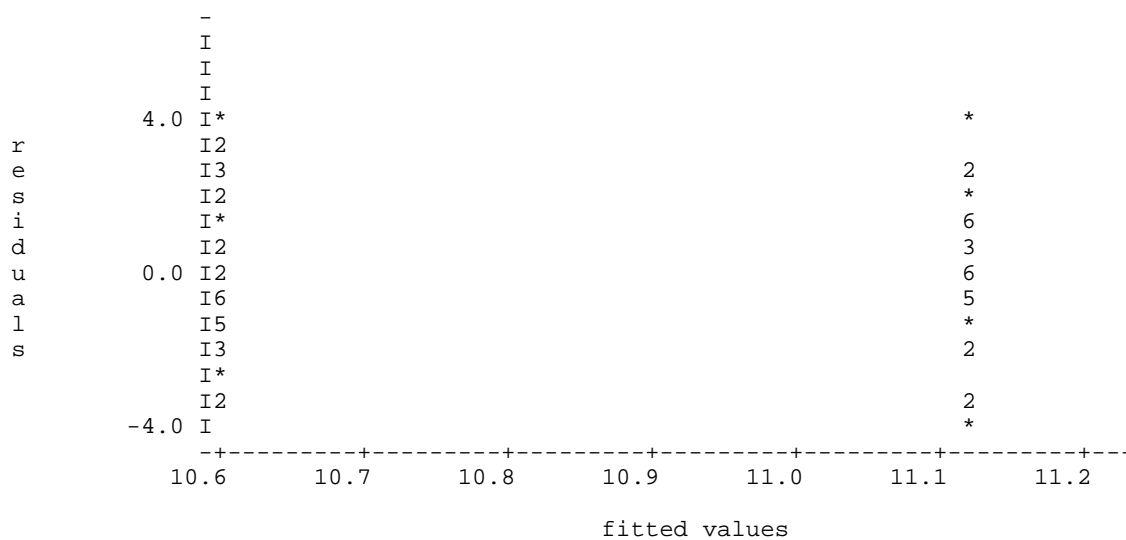
Variate: pol[1]

Grand mean 10.86

Method	1	2
	11.12	10.60

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Method
rep.	30
d.f.	58
l.s.d.	1.007





137.....

\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[2]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Calf stratum					
Method	1	0.0083	0.0083	0.05	0.829
Residual	58	10.2117	0.1761		
Total	59	10.2199			

\* MESSAGE: the following units have large residuals.

Calf 23	-1.220	s.e. 0.413
Calf 26	-1.012	s.e. 0.413

\*\*\*\*\* Tables of means \*\*\*\*\*

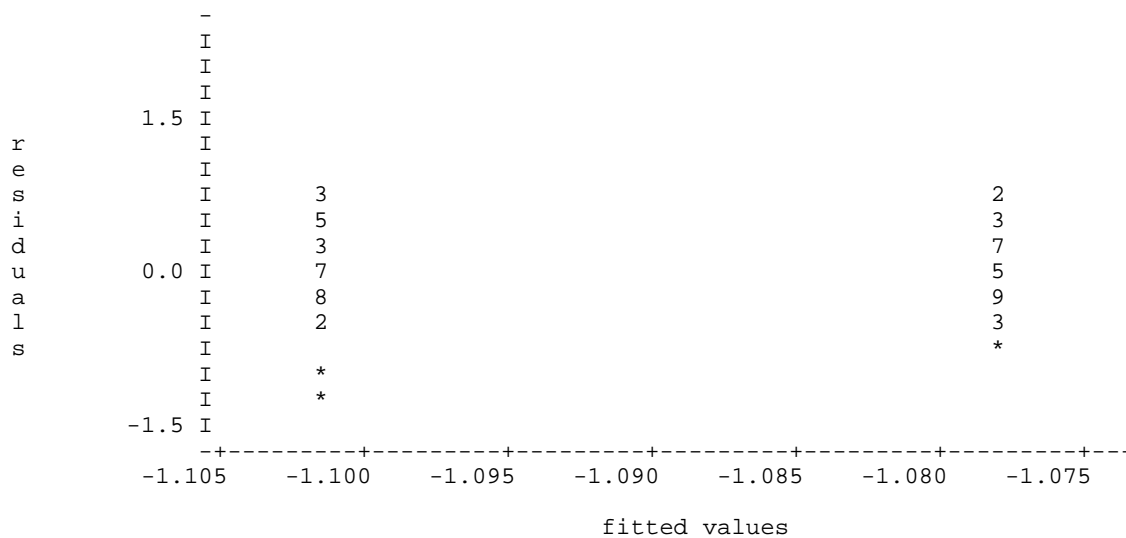
Variate: pol[2]

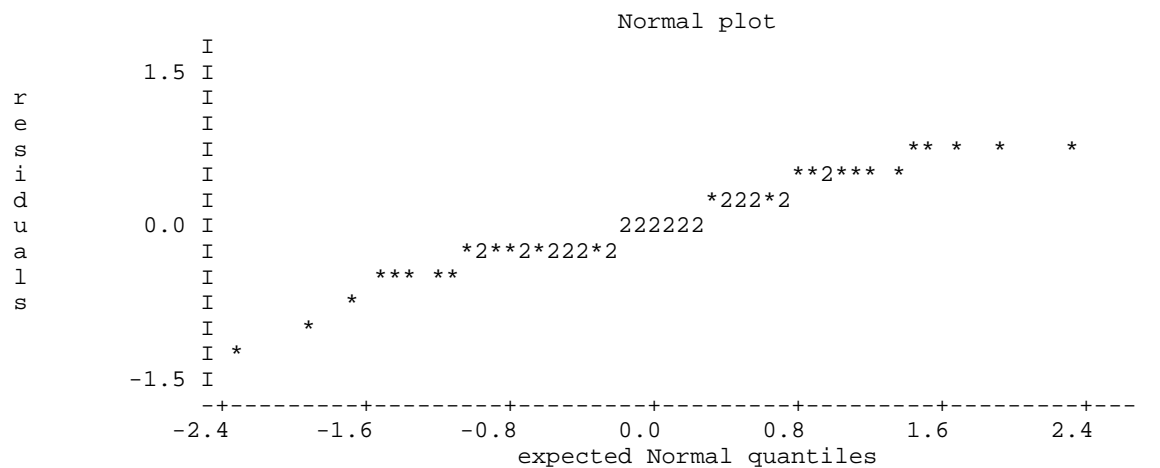
Grand mean -1.090

Method	1	2
	-1.102	-1.078

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Method
rep.	30
d.f.	58
l.s.d.	0.2169





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\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[3]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Calf stratum					
Method	1	0.31775	0.31775	24.60	<.001
Residual	58	0.74931	0.01292		
Total	59	1.06706			

\* MESSAGE: the following units have large residuals.

Calf 9	-0.380	s.e. 0.112
Calf 12	0.278	s.e. 0.112

\*\*\*\*\* Tables of means \*\*\*\*\*

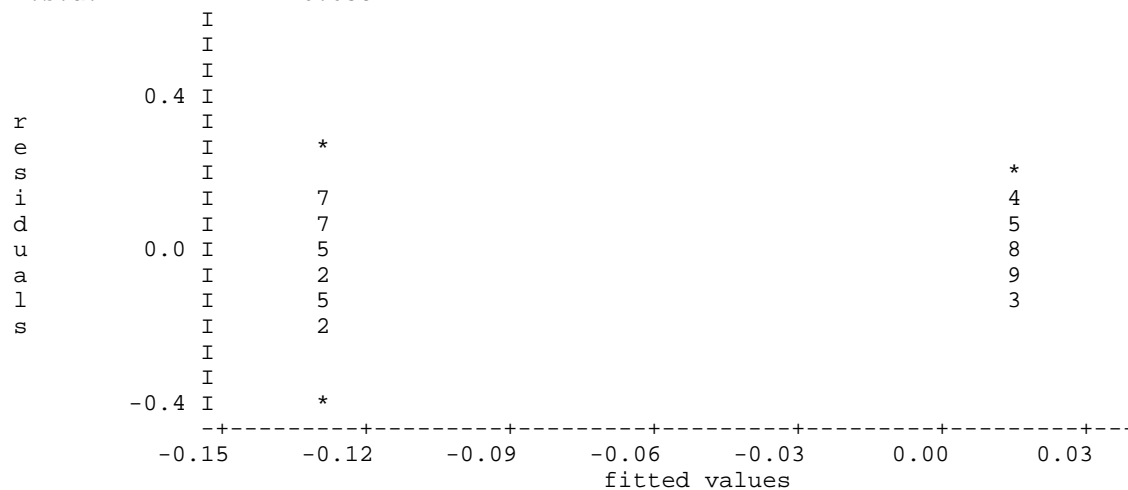
Variate: pol[3]

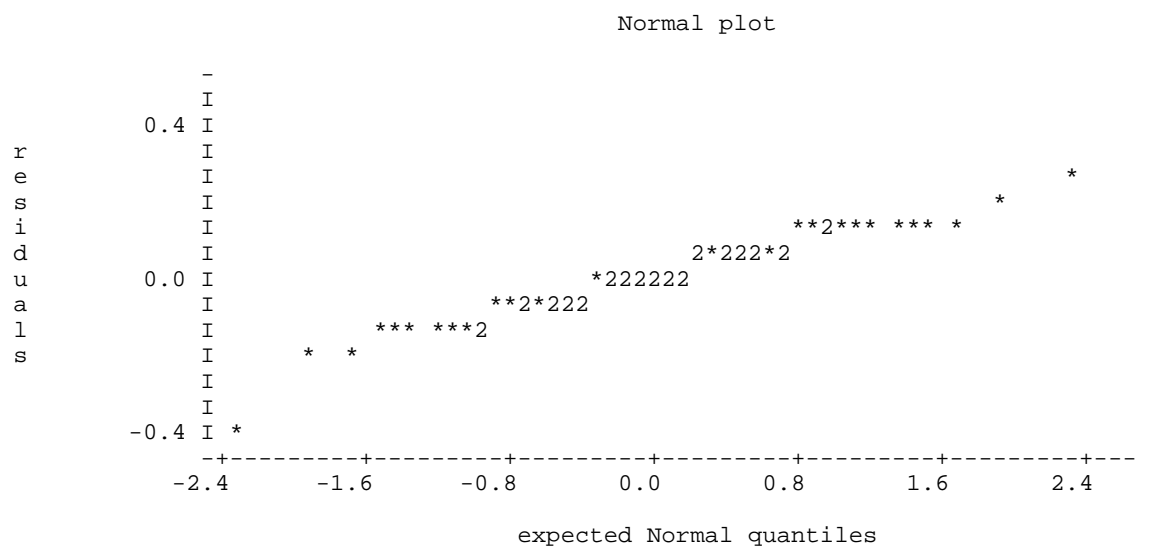
Grand mean -0.057

Method	1	2
	-0.130	0.016

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Method
rep.	30
d.f.	58
l.s.d.	0.0587





137.....

\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[4]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Calf stratum					
Method	1	0.0349516	0.0349516	42.58	<.001
Residual	58	0.0476056	0.0008208		
Total	59	0.0825572			

\* MESSAGE: the following units have large residuals.

Calf 7            0.0731    s.e. 0.0282

\*\*\*\*\* Tables of means \*\*\*\*\*

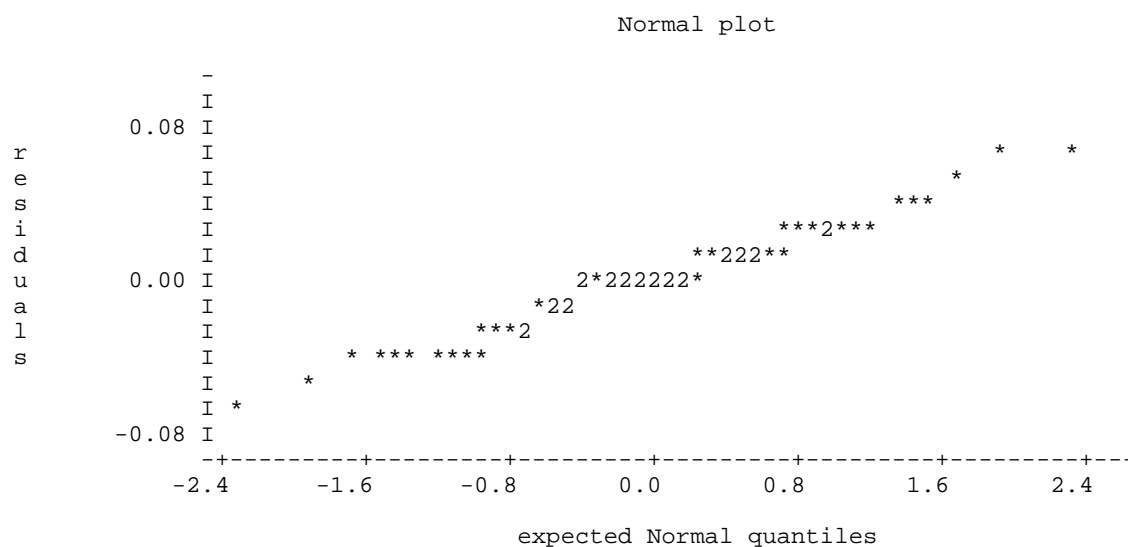
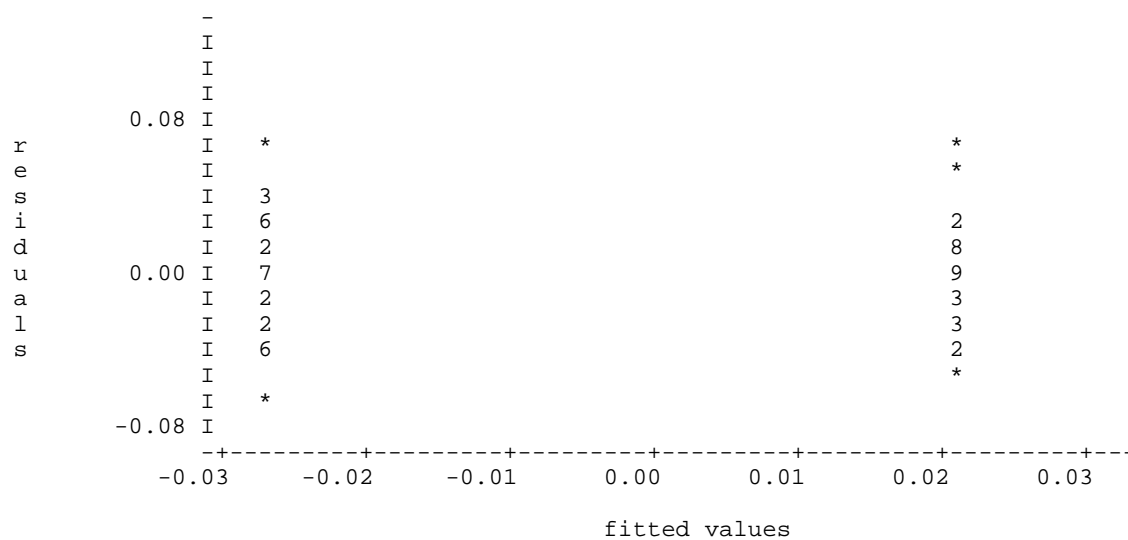
Variate: pol[4]

Grand mean   -0.0029

Method	1	2
	-0.0270	0.0212

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Method
rep.	30
d.f.	58
l.s.d.	0.01481



137.....

\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[5]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Calf stratum					
Method	1	0.0000081	0.0000081	0.03	0.863
Residual	58	0.0155930	0.0002688		
Total	59	0.0156011			

\* MESSAGE: the following units have large residuals.

Calf 23	0.0574	s.e. 0.0161
Calf 25	-0.0454	s.e. 0.0161

\*\*\*\*\* Tables of means \*\*\*\*\*

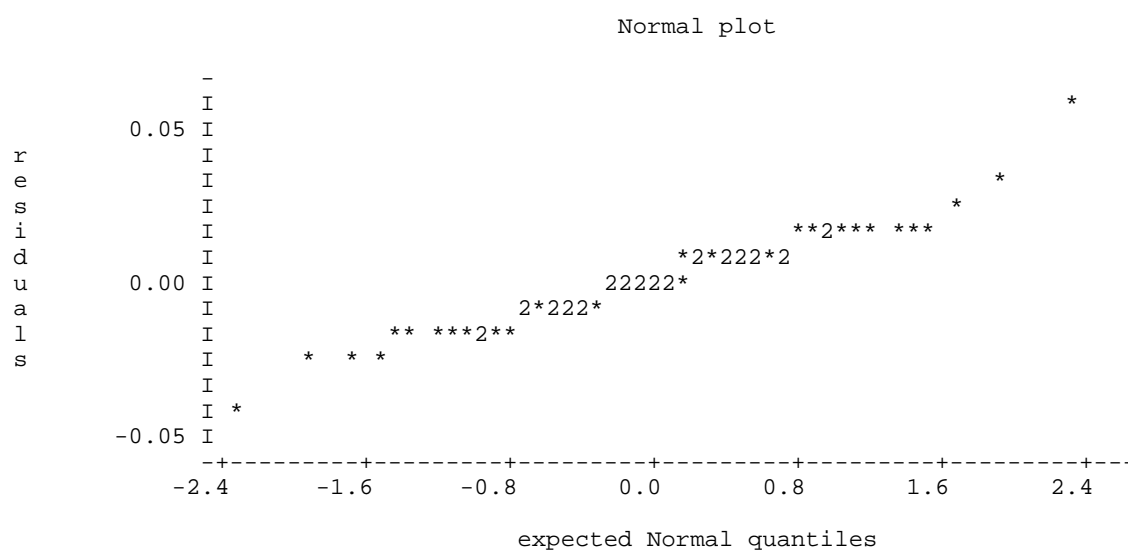
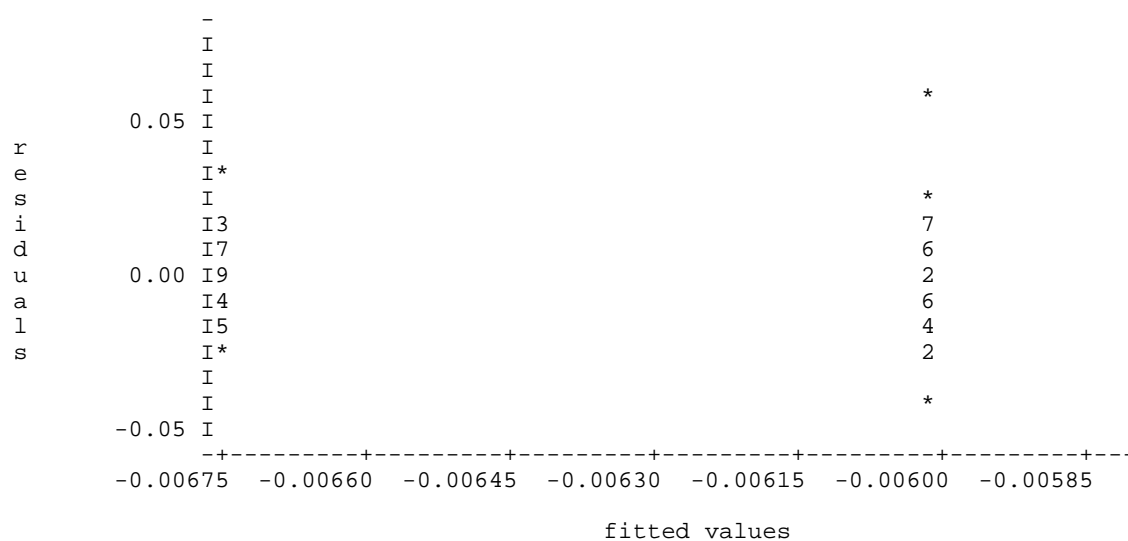
```
Variate: pol[5]
```

Grand mean -0.0064

Method	1	2
	-0.0060	-0.0067

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Method
rep.	30
d.f.	58
l.s.d.	0.00847



137.....

\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[6]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Calf stratum					
Method	1	0.00045260	0.00045260	9.82	0.003
Residual	58	0.00267195	0.00004607		
Total	59	0.00312455			

\* MESSAGE: the following units have large residuals.

Calf 23            0.02241    s.e. 0.00667

\*\*\*\*\* Tables of means \*\*\*\*\*

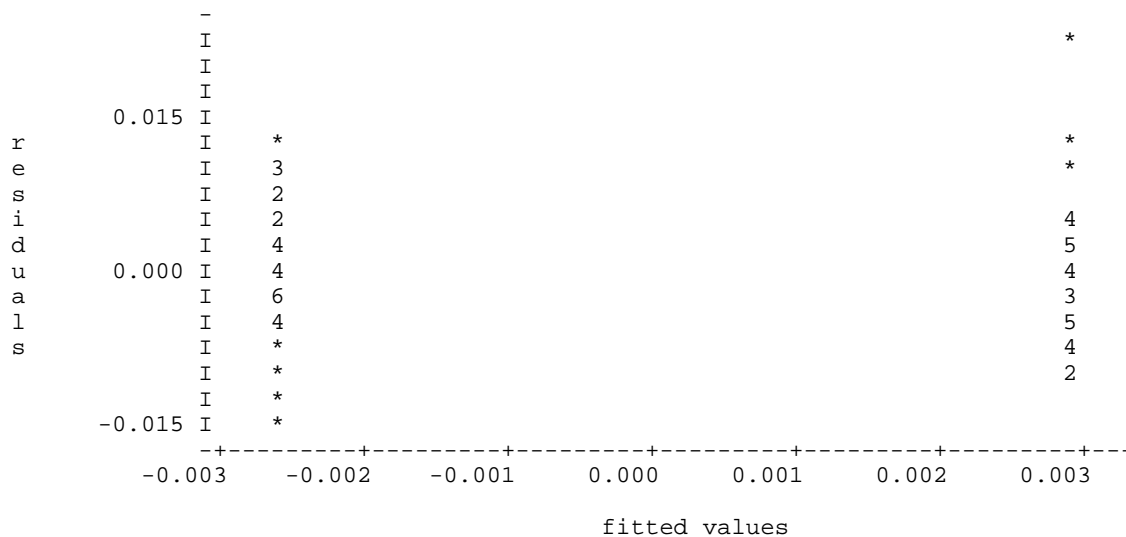
Variate: pol[6]

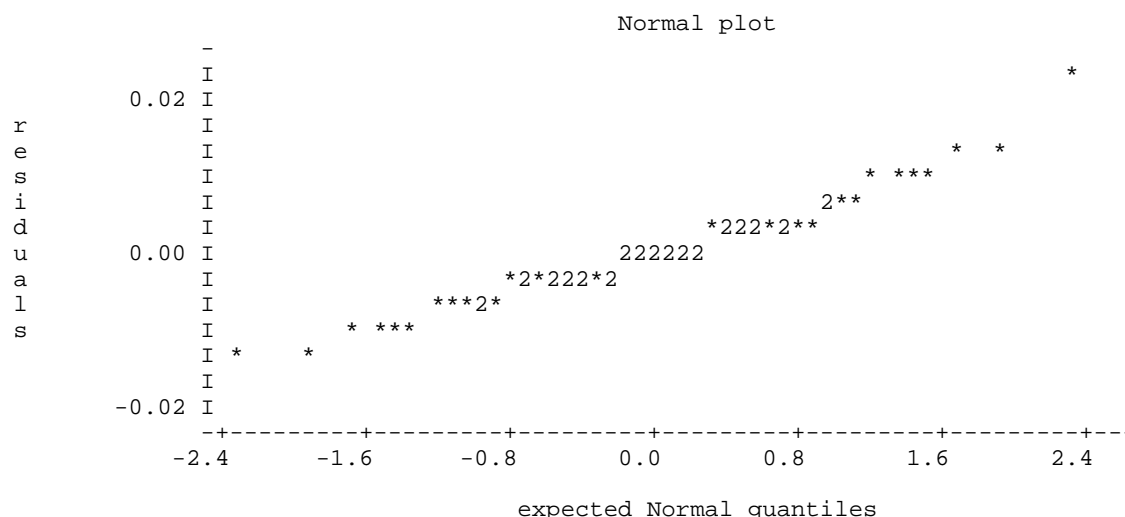
Grand mean 0.00012

Method	1	2
	0.00287	-0.00262

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Method
rep.	30
d.f.	58
l.s.d.	0.003508





**XII.2** In an experiment to study the influence of various strains of the Newcastle Disease virus on the growth of chickens, 200 chicks were divided into 20 groups in such a way as to ensure that the group averages were nearly equal. These 20 groups were then divided into four blocks of five and the five treatments (four strains of virus and an uninfected control) were randomized to the groups within a block. The average weight of the chicks in a group was measured at the start of the experiment and at weekly intervals thereafter.

What are the components of the study?

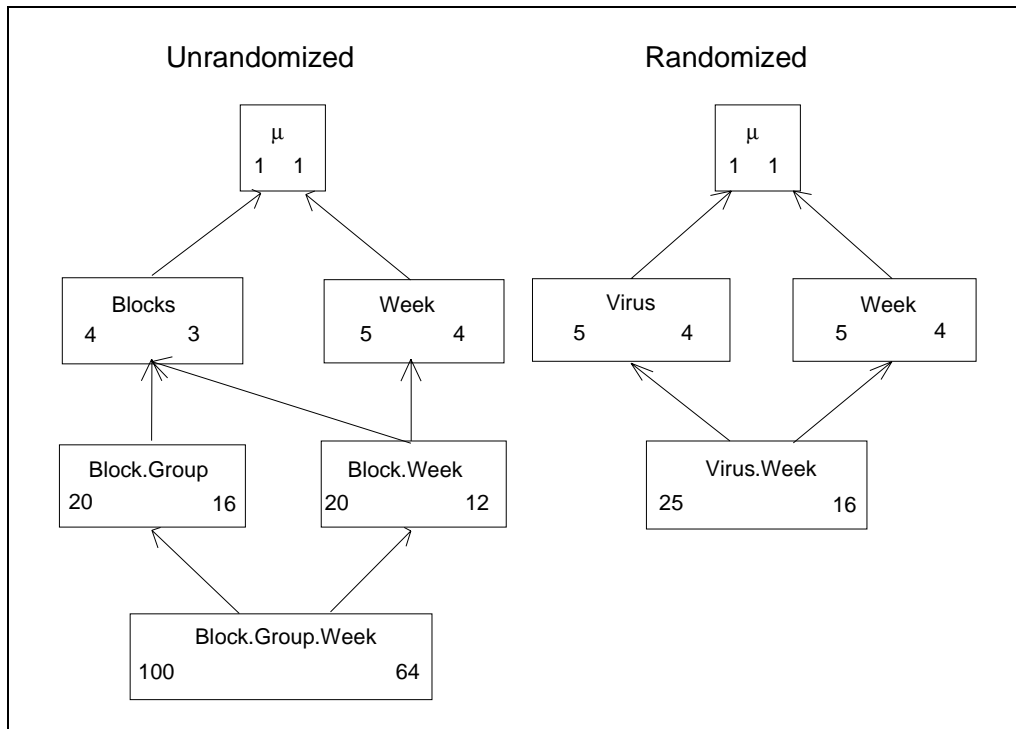
1. Observational unit      a group of chicks
2. Response variable      Weight
3. Unrandomized factors    Block, Group, Week
4. Randomized factors      Virus
5. Type of study            a repeated measures experiment  
with groups in an RCBD

What is the experimental structure for this experiment?

Structure	Formula
unrandomized	$(4 \text{ Block}/5 \text{ Group}) * 5 \text{ Week}$
randomized	$5 \text{ Virus} * \text{Week}$

What are the terms derived from the experimental structure? Write out the Hasse diagram for each structure formula or use the rule for completely crossed structures.

$$\begin{aligned}
 (\text{Block}/\text{Group}) * \text{Week} &= (\text{Block} + \text{Block}.\text{Group}) * \text{Week} \\
 &= \text{Block} + \text{Block}.\text{Group} + \text{Block}.\text{Week} \\
 &\quad + \text{Block}.\text{Group}.\text{Week} \\
 \text{Virus} * \text{Week} &= \text{Virus} + \text{Week} + \text{Virus}.\text{Week}
 \end{aligned}$$



Which factors would you suggested be regarded as fixed and which as random? What are the maximal expectation and variation models?

*Fixed factors:* Week and Virus

*Random factors:* Block and Group

$E[Y] = \text{Virus.Week}$

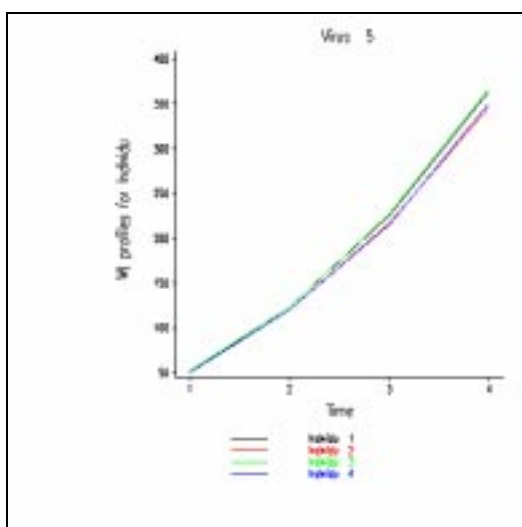
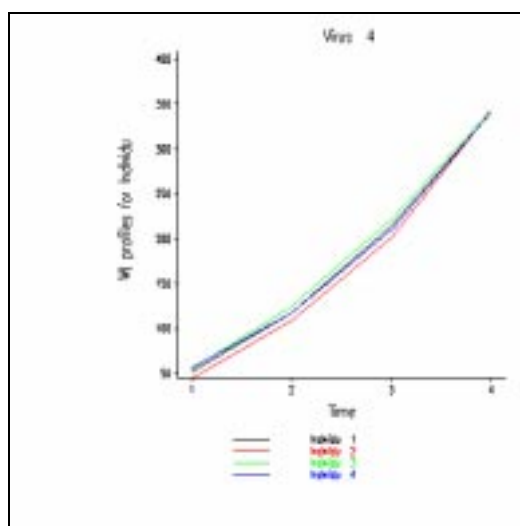
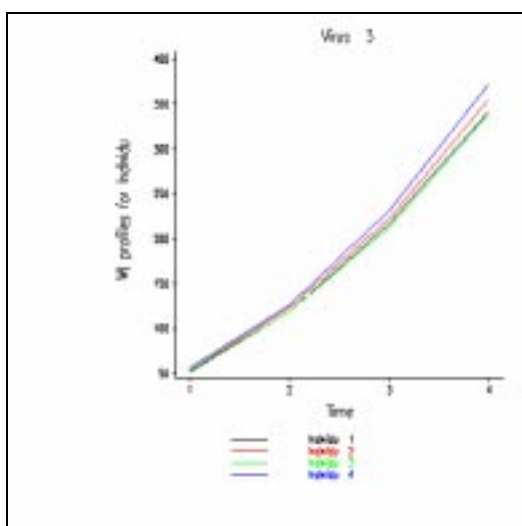
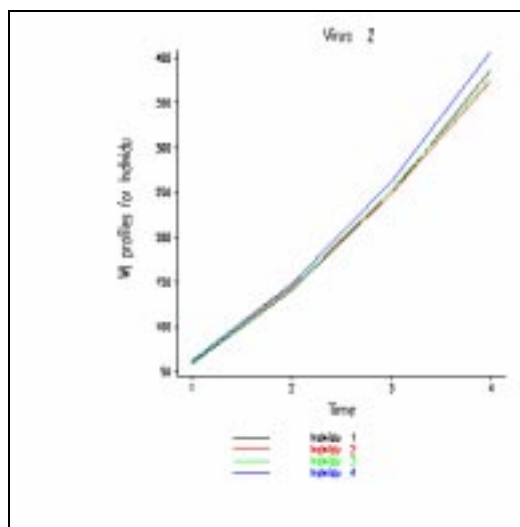
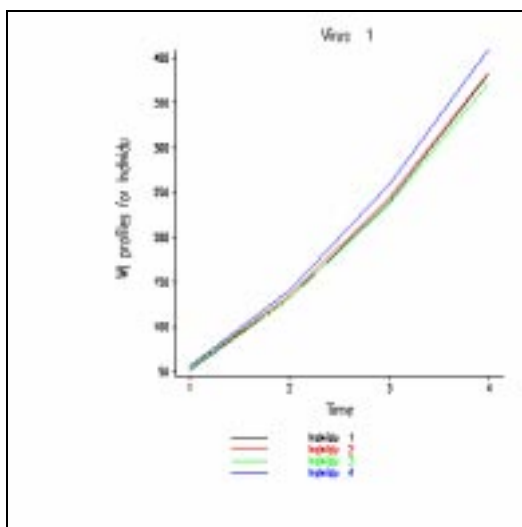
$\text{Var}[Y] = \text{Block} + \text{Block.Group} + \text{Block.Week} + \text{Block.Group.Week}$

Write down the ANOVA table, including the  $E[\text{MSq}]$ s for the lines in it.

Source	df	$E[\text{MSq}]$
Block	3	$\sigma_{\text{BGW}}^2 + 5\sigma_{\text{BG}}^2 + 5\sigma_{\text{BW}}^2 + 25\sigma_{\text{B}}^2$
Block.Group	16	
Virus	4	$\sigma_{\text{BGW}}^2 + 5\sigma_{\text{BG}}^2 + f_V(\psi)$
Residual	12	$\sigma_{\text{BGW}}^2 + 5\sigma_{\text{Bg}}^2$
Week	4	$\sigma_{\text{BGW}}^2 + 5\sigma_{\text{BW}}^2 + f_W(\psi)$
Block.Week	12	$\sigma_{\text{BGW}}^2 + 5\sigma_{\text{BW}}^2$
Block.Group.Week	64	
Virus.Week	16	$\sigma_{\text{BGW}}^2 + f_{\text{VW}}(\psi)$
Residual	48	$\sigma_{\text{BGW}}^2$
Total	99	



- a) The differences from the initial reading are stored in the file *RMEChickVirusDiffs.gsh* in the *G:\Disciplina\Genstat* directory. Obtain plots of the individual difference profiles for the five treatments.



*The following is the Genstat output for producing these.*

Genstat 5 Release 4.1 (PC/Windows NT) 03 May 2000 11:50:48  
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Genstat 5 Fourth Edition - (for Windows)  
Genstat 5 Procedure Library Release PL11

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```
3  "Data taken from File:
D:/ANALYSES/LM/REPEATMEASURE/RMECHICKVIRUSDIFFS.GSH"
4  DELETE [redefine=yes] Weeks,Blocks,Groups,Viruses,Weights
5  FACTOR [modify=yes;nvalues=80;levels=4] Weeks
6  READ Weeks; frepresentation=ordinal
```

Identifier	Values	Missing	Levels
Weeks	80	0	4

```
10 FACTOR [modify=yes;nvalues=80;levels=4] Blocks
11 READ Blocks; frepresentation=ordinal
```

Identifier	Values	Missing	Levels
Blocks	80	0	4

```
15 FACTOR [modify=yes;nvalues=80;levels=5] Groups
16 READ Groups; frepresentation=ordinal
```

Identifier	Values	Missing	Levels
Groups	80	0	5

```
20 FACTOR [modify=yes;nvalues=80;levels=5] Viruses
21 READ Viruses; frepresentation=ordinal
```

Identifier	Values	Missing	Levels
Viruses	80	0	5

```
25 VARIATE [nvalues=80] Weights
26 READ Weights
```

Identifier	Minimum	Mean	Maximum	Values	Missing
Weights	45.1	194.3	410.6	80	0

```
34
35  "
-36 **** separate data for Weeks and Group profiles
-37  "
38  SUBSET [CONDITION=Weeks==1] OLD=Blocks,Groups,Viruses; \
39      NEW=Block,Group,Virus
40  FOR i=1...4
41      SUBSET [CONDITION=Weeks==i] OLD=Weights; NEW=Weight[i]
42  ENDFOR
43  PRINT Block,Group,Virus,Weight[1...4]; FIELD=9; DEC=2
```

Block	Group	Virus	Weight[1]	Weight[2]	Weight[3]	Weight[4]
1	1	1	52.00	130.85	240.15	382.55
1	2	2	59.30	140.60	249.40	387.10
1	3	3	52.05	118.35	217.15	341.75
1	4	4	51.50	116.55	213.55	340.15
1	5	5	50.35	122.60	225.80	364.20
2	1	1	54.30	134.55	245.15	383.65
2	2	2	60.65	144.55	248.35	373.45
2	3	3	53.40	122.15	223.15	355.65
2	4	4	45.10	108.50	201.50	342.40
2	5	5	50.00	119.85	217.15	346.65
3	1	1	54.45	132.15	237.35	372.45
3	2	2	59.85	143.35	253.05	378.05
3	3	3	52.50	118.00	212.10	338.70
3	4	4	54.80	124.15	221.15	343.05
3	5	5	51.55	122.95	227.35	366.35

4	1	1	56.75	140.75	259.85	410.65
4	2	2	61.80	147.95	261.95	407.75
4	3	3	55.55	126.20	231.70	372.40
4	4	4	55.40	116.70	209.70	340.70
4	5	5	50.90	119.65	216.25	351.25

```

44  DUPLICATE OLD=Block; NEW=Individuals
45  DREPMEASURES [GROUPS=Virus,Individuals] DATA=Weight
46  DREPMEASURES [GROUPS=Virus] DATA=Weight

```

- b) Perform a repeated measurements ANOVA on the measurements from all 4 times. Perform diagnostic checking and, if necessary, identify a suitable transformation and analyse the transformed data.

*The following output gives the repeated measurements ANOVA.*

```

47  "
-48  **** perform repeated measurements ANOVA
-49  "
50  DUPLICATE OLD=Weeks; NEW=Week
51  BLOCK  (Blocks/Groups)*Weeks
52  TREAT  Viruses*POL(Week;2)
53  ANOVA  [FPROB=Y; PSE=LSD] Weights

53.....
..

***** Analysis of variance *****

Variate: Weights

Source of variation      d.f.      s.s.      m.s.      v.r.  F pr.

Blocks stratum           3      808.34      269.45

Weeks stratum
Week                     3 1090989.69  363663.23
  Lin                    1 1072415.58 1072415.58
  Quad                   1  18571.47  18571.47
  Deviations             1     2.64      2.64

Blocks.Groups stratum
Viruses                  4   11203.85   2800.96   22.36  <.001
Residual                12    1503.10    125.26    4.41

Blocks.Weeks stratum     9     439.20     48.80    1.72

Blocks.Groups.Weeks stratum
Viruses.Week            12    3191.90    265.99    9.37  <.001
  Viruses.Lin            4    3016.34    754.08   26.57  <.001
  Viruses.Quad           4    167.51     41.88    1.48  0.230
  Deviations             4      8.06      2.01    0.07  0.990
Residual                36    1021.55     28.38

Total                   79 1109157.63

* MESSAGE: the following units have large residuals.

Blocks 4    Weeks 4           6.20    s.e. 2.34

Blocks 2    Groups 4    Weeks 4           8.56    s.e. 3.57
Blocks 3    Groups 5    Weeks 4           8.97    s.e. 3.57
Blocks 4    Groups 5    Weeks 4          -8.90    s.e. 3.57

```

\*\*\*\*\* Tables of means \*\*\*\*\*

Variate: Weights

Grand mean 194.29

Viruses	1	2	3	4	5
	205.47	211.07	186.92	180.31	187.68

Week	1	2	3	4
	54.11	127.52	230.59	364.94

Viruses	Week	1	2	3	4
1		54.37	134.57	245.62	387.32
2		60.40	144.11	253.19	386.59
3		53.37	121.17	221.03	352.12
4		51.70	116.47	211.47	341.57
5		50.70	121.26	221.64	357.11

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Viruses	Week	Viruses
			Week
rep.	16	20	4
l.s.d.	8.621	*	*
d.f.	12	*	*

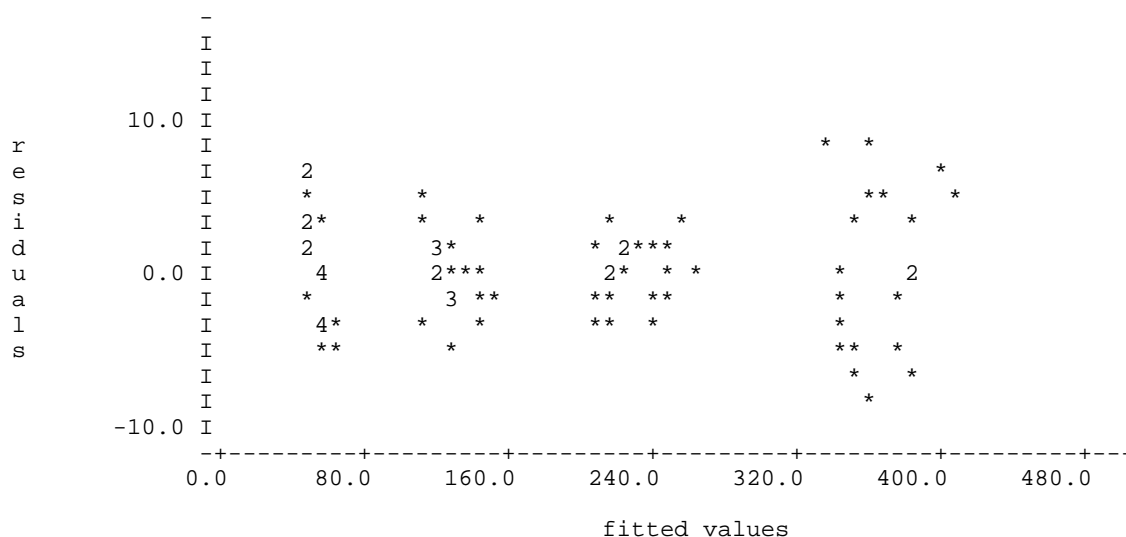
Except when comparing means with the same level(s) of

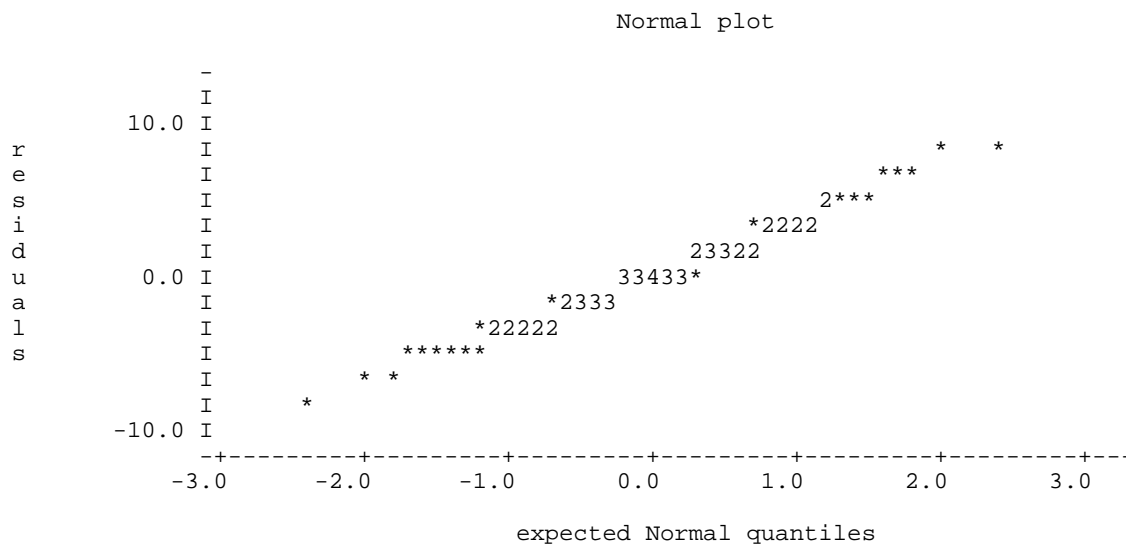
Week	10.483
d.f.	29.34

```
54  CALC  pBG=1-FPROB(125.26/28.38; 12; 36)
55  &     pBW=1-FPROB(48.80/28.38; 9; 36)
56  PRINT pBG,pBW
```

pBG	pBW
0.0002568	0.1203

```
57  APLOT METHOD=fit,normal
```





```

58  "
-59  **** Tukey's one-degree-of-freedom-for-non-additivity.
-60  **** It is the term designated covariate in the following analysis
-61  "
62  TREAT Viruses*Week
63  AKEEP [FIT=Fit]
64  CALC ResSq=Fit*Fit
65  ANOVA [PRINT=*] ResSq; RES=ResSq
66  COVAR ResSq                                "A computational trick"
67  ANOVA [PRINT=A; FPROB=Y] Weights

```

```

***** Warning (Code AN 40). Statement 1 on Line 67
Command: ANOVA [PRINT=A; FPROB=Y] Weights
Stratum variance cannot be estimated
Weeks stratum has zero residual sum of squares or degrees of freedom

```

```

67.....

```

```

**** Analysis of variance (adjusted for covariate) ****

```

```

Variate: Weights
Covariate: ResSq

```

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
Blocks stratum	3	808.34	269.45			
Weeks stratum						
Week	3	1090989.69	363663.23		1.00	
Blocks.Groups stratum						
Viruses	4	11203.85	2800.96	22.36	1.00	<.001
Residual	12	1503.10	125.26	11.49	1.00	
Blocks.Weeks stratum	9	439.20	48.80	4.48		
Blocks.Groups.Weeks stratum						
Viruses.Week	12	3191.90	265.99	24.41	1.00	<.001
Covariate	1	640.09	640.09	58.73		<.001
Residual	35	381.46	10.90		2.60	
Total	79	1109157.63				

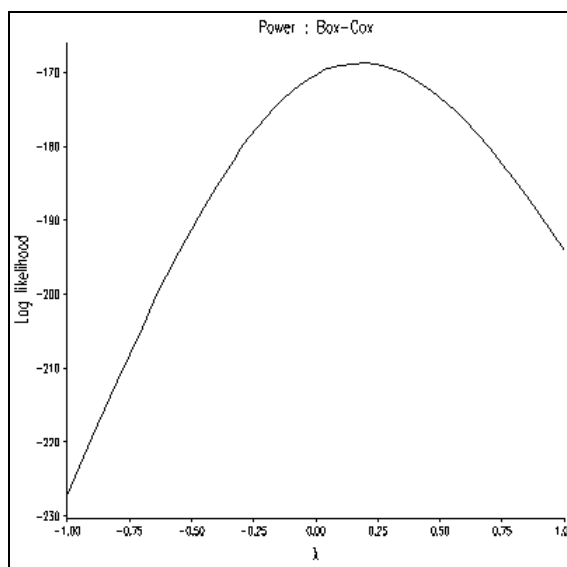
```

68  COVAR

```

The above analysis indicates that the assumptions are not met. In particular, Tukey's test for nonadditivity is significant. In addition, the residual-versus-fitted-values plot indicates that there might be variance heterogeneity.

In the following output, we use the Box-Cox procedure, implemented in YTRANSFORM, to find that the logarithmic transformation may be satisfactory. The analysis of the log-transformed data is also given.



```

69  "
-70  **** search for a transformation and analyse
-71  "
72  YTRANSFORM [LOWER=-1; UPPER=1; TERMS=Viruses*Week] Weights; SAVE=s
73  CALC TWeights=LOG(Weights)
74  BLOCK (Blocks/Groups)*Weeks
75  TREAT Viruses*POL(Week;2)
76  ANOVA [FPROB=Y; PSE=LSD] TWeights

76.....

**** Analysis of variance ****

Variate: TWeights

Source of variation      d.f.      s.s.      m.s.      v.r.      F pr.

Blocks stratum           3      0.0229820  0.0076607

Weeks stratum
Week                     3      40.7739383  13.5913128
  Lin                    1      39.9719058  39.9719058
  Quad                   1      0.7850574   0.7850574
  Deviations             1      0.0169750   0.0169750

Blocks.Groups stratum
Viruses                  4      0.3164797   0.0791199    22.73    <.001
Residual                12      0.0417637   0.0034803     6.97

Blocks.Weeks stratum     9      0.0041444   0.0004605     0.92

Blocks.Groups.Weeks stratum
Viruses.Week            12      0.0302026   0.0025169     5.04    <.001
  Viruses.Lin           4      0.0180220   0.0045055     9.03    <.001
  Viruses.Quad          4      0.0111231   0.0027808     5.57    0.001
  Deviations            4      0.0010575   0.0002644     0.53    0.715
Residual                36      0.0179681   0.0004991

Total                   79      41.2074789

```

\* MESSAGE: the following units have large residuals.

Blocks 2	Groups 4	Weeks 1	-0.0601	s.e. 0.0150
Blocks 2	Groups 4	Weeks 4	0.0589	s.e. 0.0150
Blocks 4	Groups 4	Weeks 1	0.0467	s.e. 0.0150

\*\*\*\*\* Tables of means \*\*\*\*\*

Variate: TWeights

Grand mean 5.0422

Viruses	1	2	3	4	5
	5.0897	5.1405	5.0087	4.9715	5.0006

Week	1	2	3	4
	3.9883	4.8447	5.4378	5.8980

Viruses	Week	1	2	3	4
1		3.9954	4.9017	5.5032	5.9586
2		4.1009	4.9704	5.5339	5.9568
3		3.9770	4.7969	5.3977	5.8633
4		3.9422	4.7565	5.3535	5.8336
5		3.9259	4.7979	5.4008	5.8778

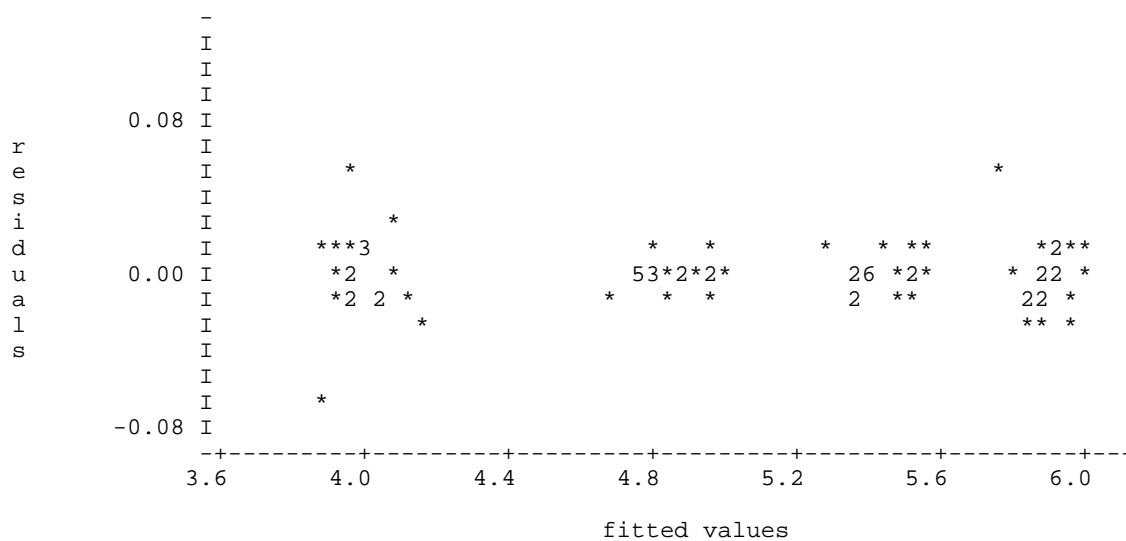
\*\*\* Least significant differences of means (5% level) \*\*\*

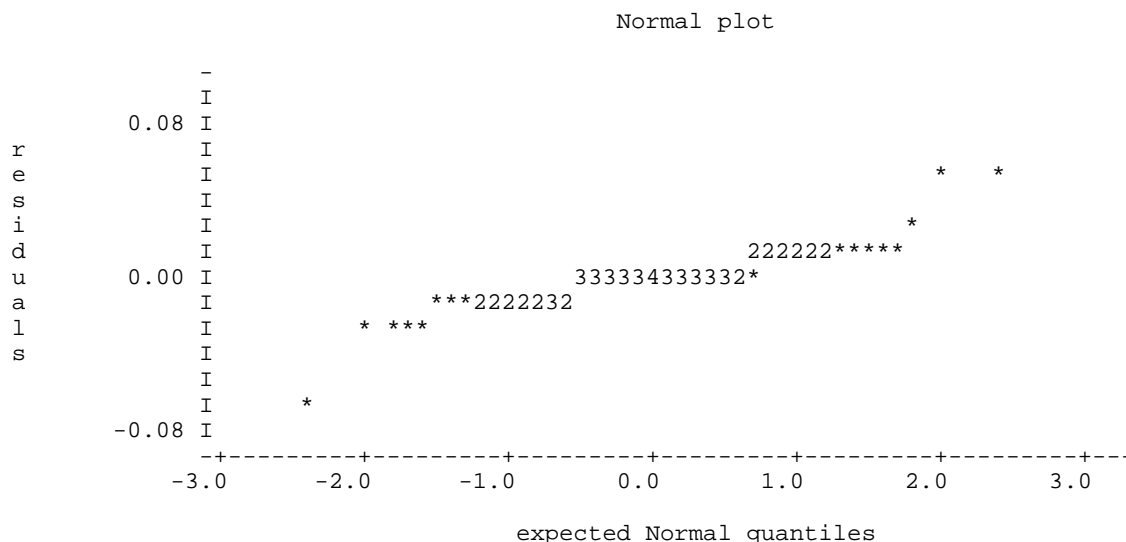
Table	Viruses	Week	Viruses Week
rep.	16	20	4
l.s.d.	0.04544	*	*
d.f.	12	*	*

Except when comparing means with the same level(s) of

Week	0.05159
d.f.	23.12

77 APLOT METHOD=fit,normal





```

78  "
-79  **** Tukey''s one-degree-of-freedom-for-non-additivity.
-80  **** It is the term designated covariate in the following analysis
-81  "
82  TREAT Viruses*Week
83  AKEEP [FIT=Fit]
84  CALC ResSq=Fit*Fit
85  ANOVA [PRINT=*] ResSq; RES=ResSq
86  COVAR ResSq "A computational trick"
87  ANOVA [PRINT=A; FPROB=Y] TWeights

```

```

***** Warning (Code AN 40). Statement 1 on Line 87
Command: ANOVA [PRINT=A; FPROB=Y] TWeights
Stratum variance cannot be estimated
Weeks stratum has zero residual sum of squares or degrees of freedom

```

```

87.....
..

```

```

**** Analysis of variance (adjusted for covariate) ****

```

```

Variate: TWeights
Covariate: ResSq

```

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
Blocks stratum	3	0.0229820	0.0076607			
Weeks stratum						
Week	3	40.7739383	13.5913128		1.00	
Blocks.Groups stratum						
Viruses	4	0.3164797	0.0791199	22.73	1.00	<.001
Residual	12	0.0417637	0.0034803	7.03	1.00	
Blocks.Weeks stratum	9	0.0041444	0.0004605	0.93		
Blocks.Groups.Weeks stratum						
Viruses.Week	12	0.0302026	0.0025169	5.08	1.00	<.001
Covariate	1	0.0006352	0.0006352	1.28		0.265
Residual	35	0.0173330	0.0004952		1.01	
Total	79	41.2074789				

```

88  COVAR

```

*It would appear that the assumptions underlying the log-transformed data are met, except for the presence of 3 outliers. The residual-versus-fitted-*



*values plots indicates that the variance is homogeneous and the normal probability plot is displaying a straight line trend (except for the outliers) indicating that the data are approximately normally distributed. Tukey's test for nonadditivity is nonsignificant.*

*In the repeated measures ANOVA the Deviations for Viruses.Weeks is not significant ( $p = 0.715$ ) and the Viruses.Quad ( $p = 0.001$ ) is significant. This indicates that the time trends are adequately described by a quadratic equation but that these differ between the Virus treatments.*

- c) The profiles are displaying some curvature so a linear relationship is likely to be inadequate. Fit orthogonal polynomials up to degree 3 to the profile for each group. Analyse the resulting coefficients. What do you conclude?

*The Genstat output below contains the commands, and associated output, to produce the diagram above and the analysis of the polynomials fitted to the differences from week 0.*

*The assumptions underlying the analysis are not met for the linear coefficient as Tukey's test for nonadditivity is significant and the residual-versus-fitted-values plot is displaying curvature. The mean of the observations over time is also displaying some evidence of curvature, although Tukey's test for non-additivity is not significant in this case.*

*An analysis that corrects this problem is required. I have found that a quadratic regression of the logarithms of the weights on the logarithms of the times provides a satisfactory analysis in that the assumptions are met and 3<sup>rd</sup> and 4<sup>th</sup> degree coefficients are not significant. However, this curve does not have a particularly practical interpretation. Any other ideas for the analysis of this data set?*

```

89  "
-90  **** analyse differences from week 0 polynomial coefficients to degree 3
-91  "
92  VORTHPOL [MAXDEGREE=3] Weight; CONTRAST=pol
93  DELETE [REDEF=y] Fit,ResSq
94  BLOCK Block/Group
95  TREAT Virus
96  FOR k=0...3
97    ANOVA [FPROB=Y; PSE=LSD] pol[k]
98    APLOT METHOD=fit,normal
99    AKEEP [FIT=Fit]
100   CALC ResSq=Fit*Fit
101   ANOVA [PRINT=*] ResSq; RES=ResSq
102   COVAR ResSq
103   ANOVA [PRINT=A; FPROB=Y] pol[k]
104   COVAR
105  ENDFOR

```

"A computational trick"

105.....

\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[0]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	202.08	67.36	2.15	
Block.Group stratum					
Virus	4	2800.96	700.24	22.36	<.001
Residual	12	375.78	31.31		
Total	19	3378.82			

\*\*\*\*\* Tables of means \*\*\*\*\*

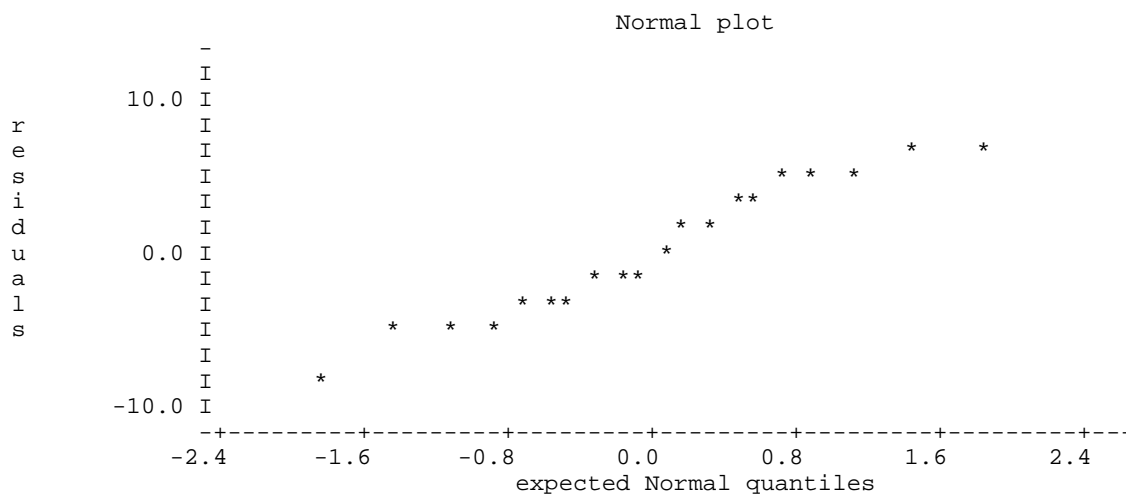
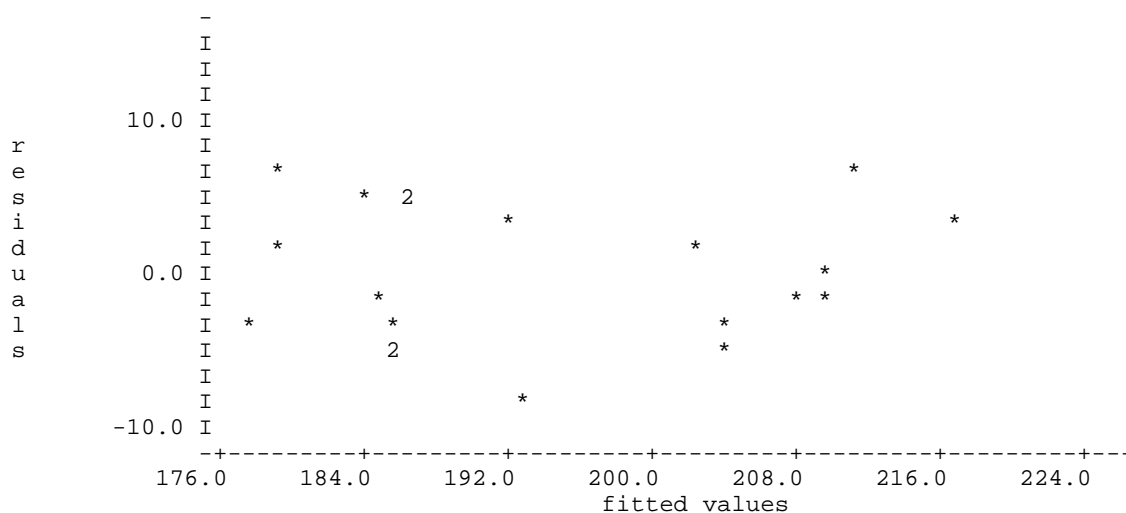
Variate: pol[0]

Grand mean 194.3

Virus	1	2	3	4	5
	205.5	211.1	186.9	180.3	187.7

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Virus
rep.	4
d.f.	12
l.s.d.	8.62



105.....

\*\*\*\*\* Analysis of variance (adjusted for covariate) \*\*\*\*\*

Variate: pol[0]

Covariate: ResSq

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
Block stratum	3	202.08	67.36	2.46		
Block.Group stratum						
Virus	4	2800.96	700.24	25.58	1.00	<.001
Covariate	1	74.63	74.63	2.73		0.127
Residual	11	301.14	27.38		1.14	
Total	19	3378.82				

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\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[1]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	72.83	24.28	1.68	
Block.Group stratum					
Virus	4	603.27	150.82	10.42	<.001
Residual	12	173.65	14.47		
Total	19	849.75			

\*\*\*\*\* Tables of means \*\*\*\*\*

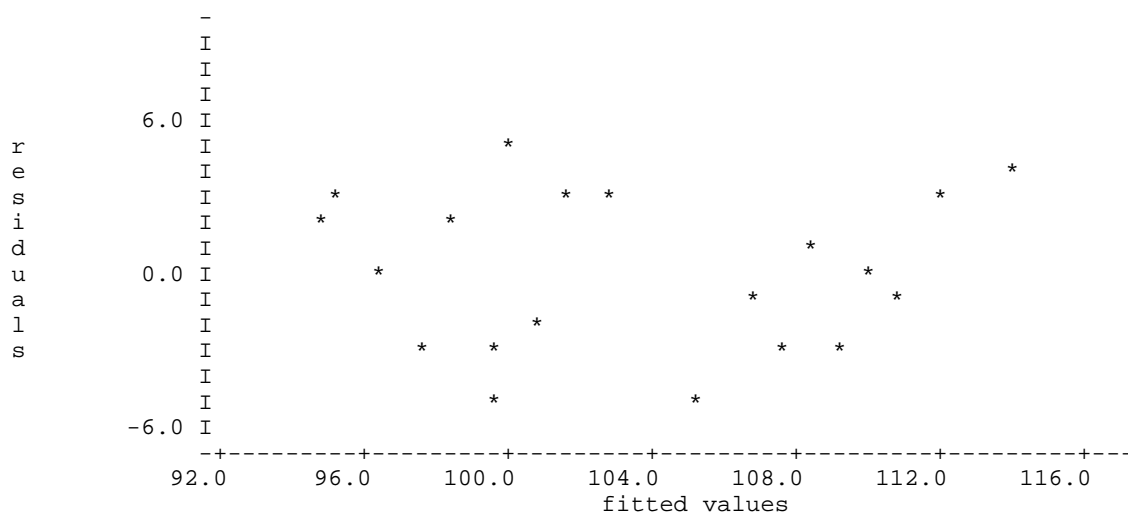
Variate: pol[1]

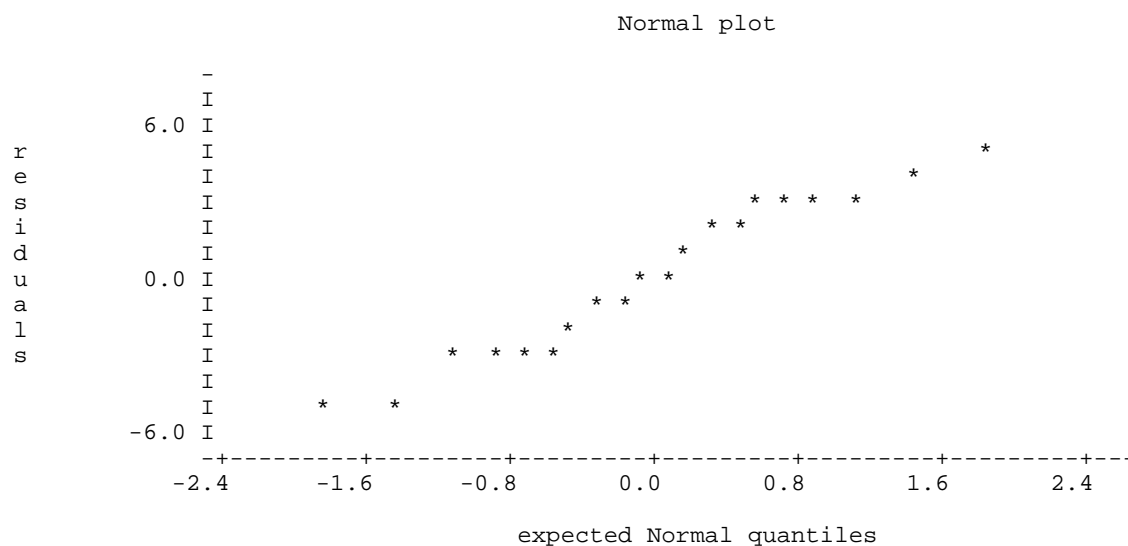
Grand mean 103.56

Virus	1	2	3	4	5
	110.99	108.76	99.61	96.46	101.96

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Virus
rep.	4
d.f.	12
l.s.d.	5.861





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\*\*\*\*\* Analysis of variance (adjusted for covariate) \*\*\*\*\*

Variate: pol[1]  
Covariate: ResSq

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
Block stratum	3	72.83	24.28	2.32		
Block.Group stratum						
Virus	4	603.27	150.82	14.42	1.00	<.001
Covariate	1	58.58	58.58	5.60		0.037
Residual	11	115.07	10.46		1.38	
Total	19	849.75				

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\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[2]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	17.416	5.805	2.13	
Block.Group stratum					
Virus	4	41.878	10.469	3.84	0.031
Residual	12	32.691	2.724		
Total	19	91.985			

\* MESSAGE: the following units have large residuals.

Block 2      Group 4                      3.26      s.e. 1.28

\*\*\*\*\* Tables of means \*\*\*\*\*

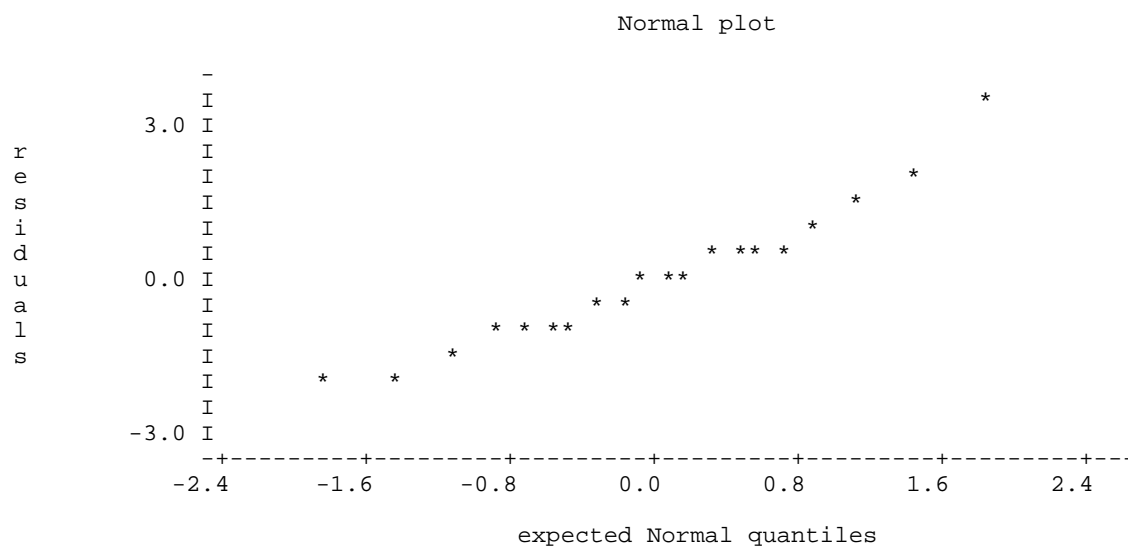
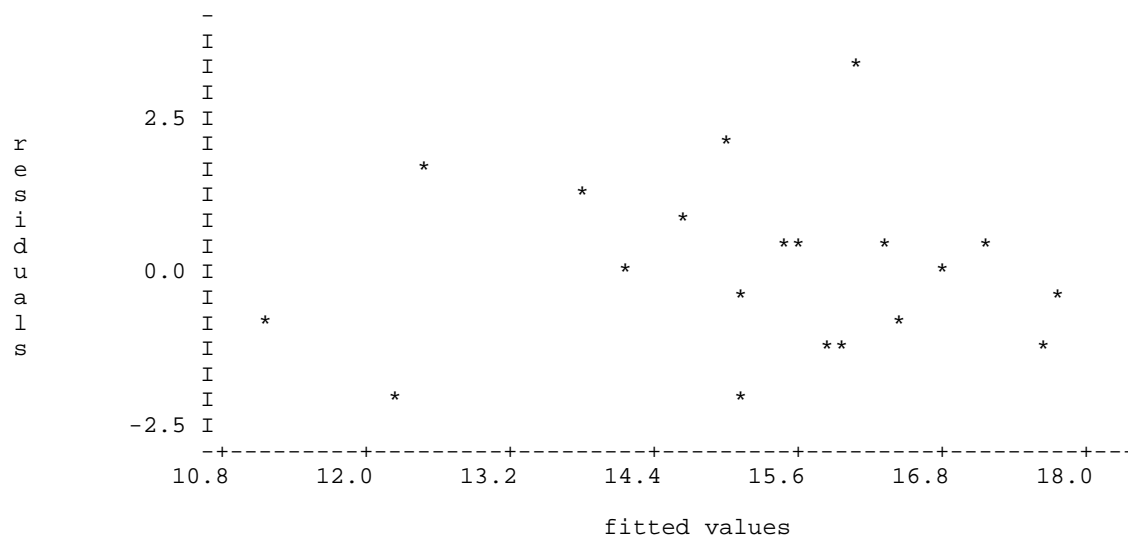
Variate: pol[2]

Grand mean 15.24

Virus	1	2	3	4	5
	15.37	12.42	15.82	16.33	16.23

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Virus
rep.	4
d.f.	12
l.s.d.	2.543



105.....

\*\*\*\*\* Analysis of variance (adjusted for covariate) \*\*\*\*\*

Variate: pol[2]

Covariate: ResSq

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
Block stratum	3	17.416	5.805	2.18		
Block.Group stratum						
Virus	4	41.878	10.469	3.93	1.00	0.032
Covariate	1	3.383	3.383	1.27		0.284
Residual	11	29.309	2.664		1.02	
Total	19	91.985				

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\*\*\*\*\* Analysis of variance \*\*\*\*\*

Variate: pol[3]

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	2.979	0.993	0.95	
Block.Group stratum					
Virus	4	4.475	1.119	1.07	0.412
Residual	12	12.513	1.043		
Total	19	19.967			

\* MESSAGE: the following units have large residuals.

Block 2    Group 4            1.80    s.e. 0.79

\*\*\*\*\* Tables of means \*\*\*\*\*

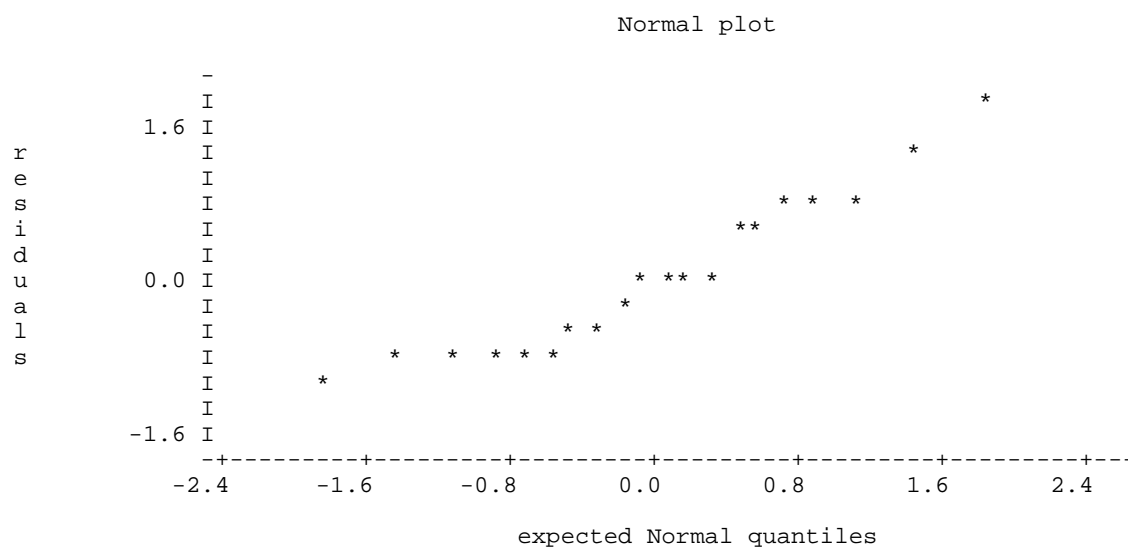
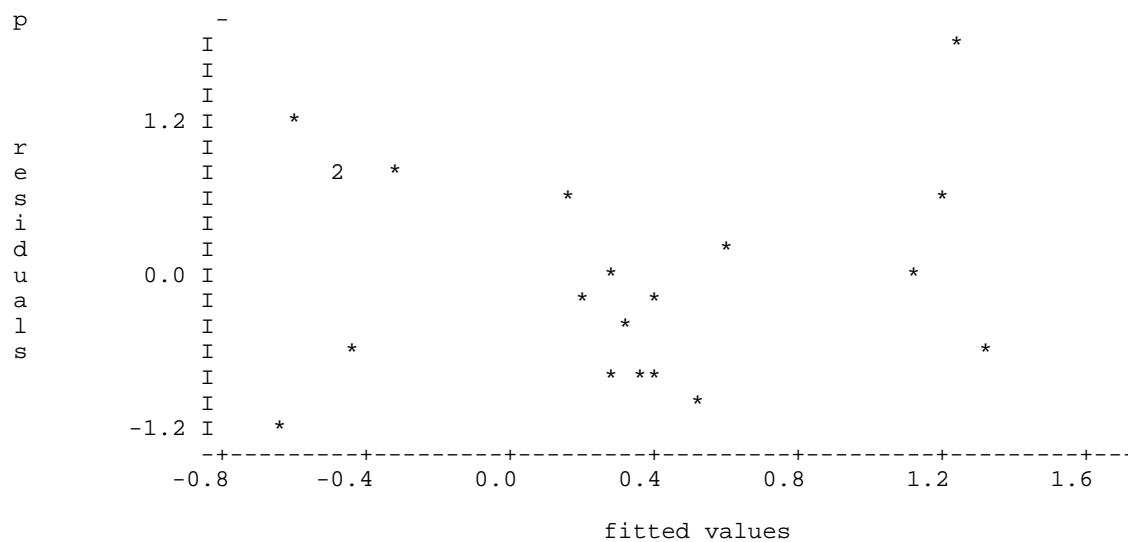
Variate: pol[3]

Grand mean   0.27

Virus	1	2	3	4	5
	-0.03	-0.17	-0.13	0.81	0.88

\*\*\* Least significant differences of means (5% level) \*\*\*

Table	Virus
rep.	4
d.f.	12
l.s.d.	1.573



105.....

\*\*\*\*\* Analysis of variance (adjusted for covariate) \*\*\*\*\*

Variate: pol[3]

Covariate: ResSq

Source of variation	d.f.	s.s.	m.s.	v.r.	cov.ef.	F pr.
Block stratum	3	2.9788	0.9929	1.04		
Block.Group stratum						
Virus	4	4.4752	1.1188	1.17	1.00	0.375
Covariate	1	2.0270	2.0270	2.13		0.173
Residual	11	10.4857	0.9532		1.09	
Total	19	19.9667				