1. Penicillin example

a) *Here is the ANOVA Table.*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
batch	4	264	66	3.5	0.0407
process	3	70	23.33	1.24	0.3387
Error	12	226	18.83		
Corrected Total	19	560			

The null and alternative hypotheses are:

$$H_o: \mu_1 = \mu_2 = \mu_3 = \mu_4$$

$$H_a: \text{at least one } \mu_i \text{ is different}, i = 1, 2, 3, 4$$

The test statistic is F = 1.24 with p-value =0.3387. Since the p-value is large, we fail to reject the null hypothesis and conclude there is not enough evidence that the yield is different for the four proceses.

b) The output for the analysis of contrasts are given below:

Output of the "contrast" statement:

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
A-B	1	2.50000000	2.50000000	0.13	0.7219
C-(A+B)/2	1	67.50000000	67.50000000	3.58	0.0827
D-(A+B+C)/3	1	0.00000000	0.00000000	0.00	1.0000

Output of the "estimate" statement:

Parameter	Estimate	Standard Error	t Value	Pr > |t|
A-B	-1.00000000	2.74469185	-0.36	0.7219
C-(A+B)/2	4.50000000	2.37697286	1.89	0.0827
D-(A+B+C)/3	-0.00000000	2.24103151	-0.00	1.0000

Based on the results, none of the contrasts are significantly different from zero.

c) The normality assumption is okay by checking all tests of normality (p-values are big for all tests) and the normal probability plot.

d) The output of p-values for all pairwise comparison is given below:

Least Squares Means for effect process
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: yield

i/j	1	2	3	4
1		0.9827	0.3105	0.8838
2	0.9827		0.4905	0.9827
3	0.3105	0.4905		0.7002
4	0.8838	0.9827	0.7002	

Note that the p-values have been adjusted by Tukey's method, and can be directly compared with 0.05 for experiment-wise error rate. Based on the results, there are no differences for all pairwise comparison.

2. LS example

a) The ANOVA table is given below.

Source	DF	SS	MS	F Value	Pr > F
freeway	3	3.015725	1.005242	0.41	0.7497
stream	3	108.960825	36.320275	14.94	0.0034
trt	3	2275.772625	758.590875	311.98	<.0001
Error	6	14.5894	2.431567		
Total	15	2402.338575			

b) The test for the contrast of difference between the management plan of "in situ" versus the other plans is given below

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
uncut - rest	1	2005.443075	2005.443075	824.75	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
uncut - rest	-25.8550000	0.90029008	-28.72	<.0001

With a small p-value, we will reject the null hypothesis and conclude that the management plan of "in situ" has a different mean from the other plans.

c) Compare LS with RCBD with column (freeway) blocks.

$MSE_{LS} = 2.43$
$MSE_{RCBD} = (SS_{Row} + SS_{Error}) / (df_{Row} + df_{Error}) = (108.96 + 14.60) / (6 + 3) = 13.73$
(LS is more precise than the RCBD with only column blocks!)

Relative Efficiency = $MSE_{RCBD} / MSE_{LS} = 13.73 / 2.43 = 5.65$
RCBD requires 5.65 times as many observations to get the same precision as the Latin square design.