Multiple Comparison Procedures, procedures to separate means, use *a posteriori* tests (performed after the fact). Contrast analysis is more powerful and utilizes an *a priori* (before the fact) approach with *1 df comparisons*, which must be specified *prior* to the analysis.

Example 1 of contrast analysis:
4 cultivars A, B, C, and D are compared for disease resistance. The dependent variable is SCORE, a continuous variable in this case. A and D are old cultivars, B and C are modern cultivars.
The null hypothesis is: H0: $\mu A = \mu B = \mu C = \mu D$.

There are 5 reps.
ANOVA table:

Source of variation	df
Cultivar	3
Residual	16
Total	19

Contrast comparisons: 1) old versus new cvs; H02: $(\mu A+\mu D) = (\mu B+\mu C)$
2) cv A vs D; H03: $\mu A = \mu D$
3) cv B vs C; H04: $\mu B = \mu C$

Each null hypothesis is a linear combination of the treatment means. A set of linear combinations of this type is called a set of *orthogonal contrasts*. A set of linear combinations must satisfy two mathematical properties in order to be orthogonal contrasts:
1) The sum of the coefficients in each linear contrast must be zero, and
2) The sum of the products of the corresponding coefficients in any two contrasts must equal zero.

The orthogonal contrasts can be rewritten as:

H02: $(½)\mu A - (½)\mu B - (½)\mu C + (½)\mu D = 0$
H03: $(1)\mu A + (0)\mu B + (0)\mu C - (1)\mu D = 0$
H04: $(0)\mu A + (1)\mu B - (1)\mu C + (0)\mu D = 0$

When a treatment is equality or is not being considered it has a coefficient of zero. When the treatment is part of the comparison, it takes a coefficient value in proportion to the number of comparisons involved.

Property #1: Coefficients sum to zero.

H02: (½) - (½) - (½) + (½) = 0
H03: (1) + (0) + (0) - (1) = 0
H04: (0) + (1) - (1) + (0) = 0

Property #2: Sum of the products of the coefficients in pairwise comparisons = 0.
Contrast 2 vs 3: (½)(1) + (-½)(0) + (-½)(0) + (½)(-1) = 0
Contrast 2 vs. 4: (½)(0) + (-½)(1) + (-½)(-1) + (½)(0) = 0
Contrast 3 vs. 4: (1)(0) + (0)(1) + (0)(-1) + (-1)(0) = 0

In SAS, after the model statement, you write:
ESTIMATE ‘old versus new cvs’ SCORE 1 -1 -1 1/divisor=2;
ESTIMATE ‘A vs D’ SCORE 1 0 0 -1;
ESTIMATE ‘B vs C’ SCORE 0 +1 -1 0;

Example 2 of contrast analysis:
Four fungicides are compared to a control. Two fungicides are strobilurins, and two are carbamates. There are 5 replications.

Treatments:
A control
B strob1
C strob2
D carb1
E carb 2.

Write a basic ANOVA table with degrees of freedom in groups of 3 people.
Design a set of orthogonal contrasts in groups of 3 people.