Big Idea:

- Designing out the variability in the response from a particular source

Example 3: Strawberry Storage

A study (Smith & Skog, 1992) was conducted in order to investigate the effects of storage method on the firmness of strawberries. As strawberries harvested, they are placed into storage containers called clamshells. Because clamshells have holes in them, air can circulate from outside the clamshell into the clamshell and vice versa, while the clamshell protects the fruit.



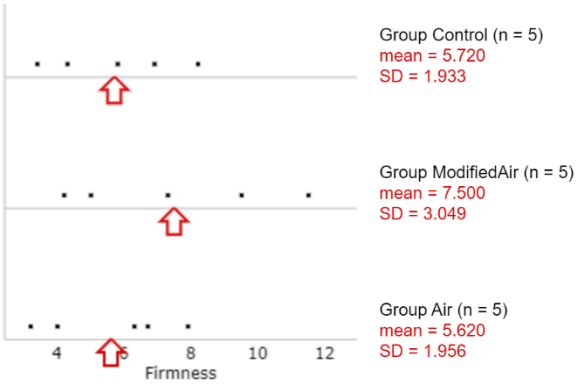
are

To test the potential effect of changing the composition of the air in which strawberries are stored, researchers obtained 15 clamshells filled with strawberries. The strawberries came from 5 different varieties: Allstar, Bounty, Kent, Selva and Vesper. (Some varieties are naturally very hardy, others are more fragile.) (The berries in a clamshell were all from the same variety.)

The treatments of interest were: regular air (approximately 21% oxygen and 0.04% carbon dioxide), modified air (18% oxygen and 15% carbon dioxide) and a control condition. Air and modified air clamshells were measured after 42 hours. The control conditional clamshells were measured immediately after packing. The response of interest was the firmness (Newtons) of each clamshell. (The firmness of each berry was measured and then averaged to obtain 'clamshell firmness'.)

1. Sources of variation diagram:

Observed Variation in:	Sources of explained variation	Sources of unexplained variation
Clamshell firmness (Newtons)	• Storage method (Air, Control, Modified Air)	• Variety of the berries (5 different varieties used) • Slight variations due to size, color, etc. • Slight variations due to packing, weather, etc. • Measurement process • unknown
Inclusion criteria • *Strawberries in same area of California; these 5 varieties* *Design* • Time at which the berries were picked, size and color all controlled		



Source	df	Sum Sq	Mean Sq	F	p-value
Treatments	2	11.19	5.59	1.00	0.3981
Error	12	67.44	5.62		
Total	14	78.62			

2. Why is the difference in means not statistically significant?

3. How could the researchers design their study to 'take into account' the variety-to-variety variation in clamshell firmness?

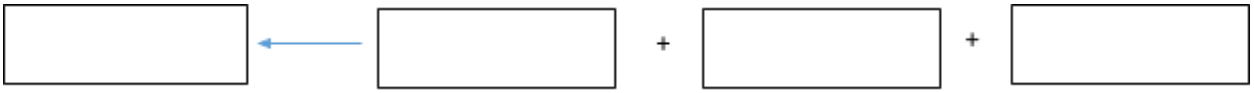
Analysis needs to match the design:

Account for the variety-to-variety variation in clamshell firmness within the analysis

Method 1: Quantify how much variety-to-variety variation there is in firmness, then move this variation from the unexplained column into the explained sources of variation column.

Observed Variation in:	Sources of explained variation	Sources of unexplained variation
Avg firmness of clamshell	• Storage method (Air, Control, Modified Air) • Variety (Allstar, Bounty, Kent, Selva, Vesper)	• ~~Variety of the berries (5 different varieties used)~~ • Slight variations due to size, color, etc. • Slight variations due to packing, weather, etc. • The mechanism used to measure firmness • unknown
Inclusion criteria • *Strawberries in same area of California; these 5 varieties* *Design* • Time at which the berries were picked, size and color all controlled		

Word Model:



4. Determine the effect of each variety:

effect of Allstar = group mean – overall mean = 7.7 – 6.28 = 1.42 N
effect of Bounty = -1.85
effect of Kent = 0.19
effect of Selva = 2.92
effect of Vesper = -2.68

	Variety	Storage	Firmness	
1	Allstar	Air	6.7	
2	Allstar	ModifiedAir	9.5	7.7
3	Allstar	Control	6.9	
4	Bounty	Air	4	
5	Bounty	ModifiedAir	5	4.43
6	Bounty	Control	4.3	
7	Kent	Air	6.3	
8	Kent	ModifiedAir	7.3	6.47
9	Kent	Control	5.8	
10	Selva	Air	7.9	
11	Selva	ModifiedAir	11.5	9.2
12	Selva	Control	8.2	
13	Vesper	Air	3.2	
14	Vesper	ModifiedAir	4.2	3.6
15	Vesper	Control	3.4	

Determine the SSvariety:

$$SSVariety = \sum n_j\left(effect_j^2\right) = 3(1.42)^2 + \ldots + 3(-2.68)^2$$

$$SSVariety = 63.51$$

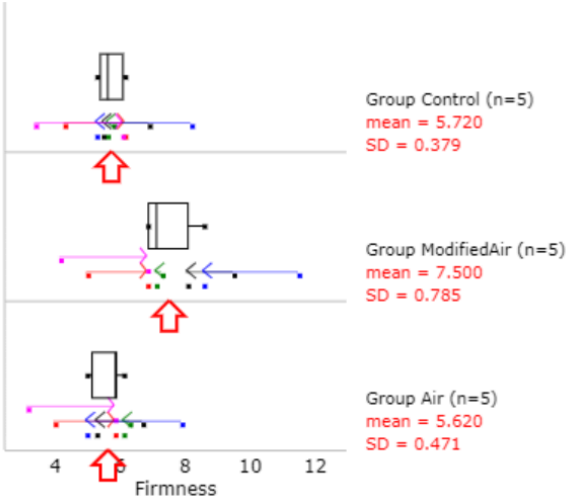
5. Fill in the ANOVA table below accounting for variety. The SS for storage method and total are already filled in to help you out. The following relationships need to hold: SSTotal = SSvariety + SSstorage method + SSError and df Total = df variety + df storage method + df Error.

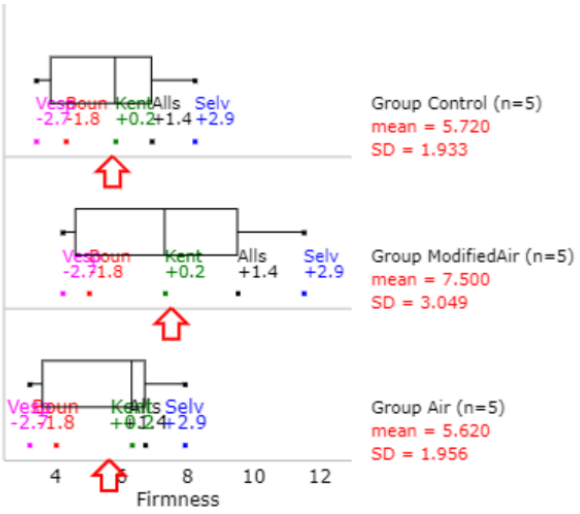
Source	DF	Sum of Squares	Mean Squares	Adjusted F-stat
Variety (= Block)				
Storage Method		11.188		
Error				
Total		78.624		

6. When we remove the effect of each variety from each of the firmness values, what happens to the storage means? What happens to the variation within the storage groups?

Figure 1: **Clamshell Firmness**

Figure 2: **Block-adjusted Firmness**





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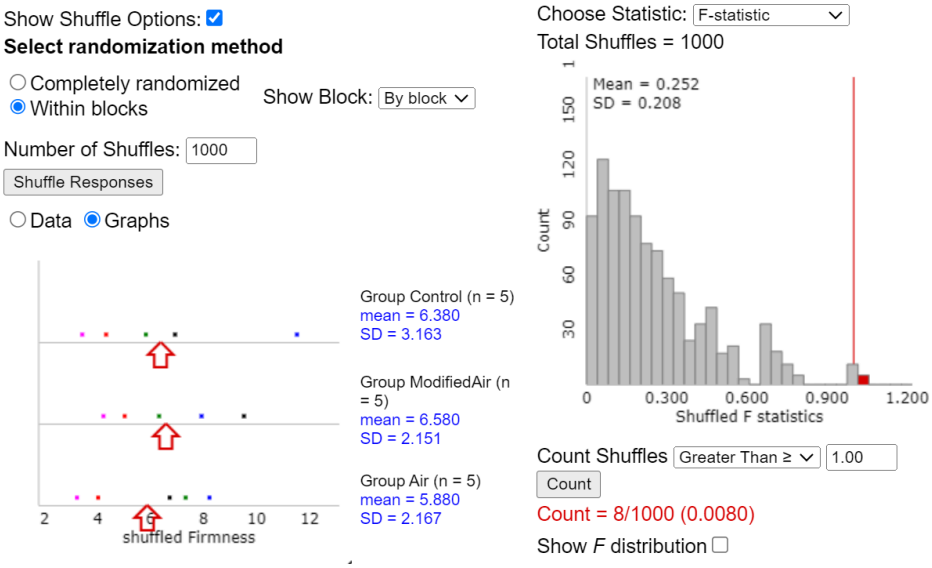
Treatments	2	11.19	5.59	1.00	0.3981
Error	12	67.44	5.62		
Total	14	78.62			

Source	df	Sum Sq	Mean Sq	F	p-value
Treatments	2	11.19	5.59	11.40	0.0046
Blocks	4	63.51	15.88	32.36	0.0000
Error	8	3.93	0.49		
Total	14	78.62			

Method 2: Simulation-based Inference

Adjust the simulation to take into account the variety-to-variety variation

Use the original F-statistic = 1.00 and shuffle within blocks. (Don't want to account for blocks twice.)



Null and alternative hypotheses:

H_o: $\mu_{Air} = \mu_{MA} = \mu_{Control}$, *after accounting for strawberry variety*

H_a: At least one of the μ_i differs, *after accounting for strawberry variety*

OR

H_o: There is not a true or real effect of storage method on strawberry firmness after accounting for strawberry variety

H_a: There is a true or real effect of storage method on strawberry firmness after accounting for strawberry variety