

**Pre-Clinic**  
**American Society for Quality**  
**Section 0904 - East Central Indiana**

**Overview of**  
**Design of Experiments Principals**

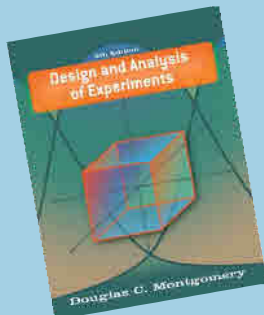
**Dr Rebecca Pierce**

Associate Professor of Mathematical Sciences



# Introduction to Experimental Design

Adapted from  
*Introduction to Design and Analysis of Experiments*  
by  
*George W. Cobb*



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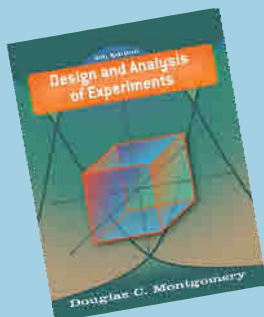
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# Planning a Good Experiment

- Senior Honors Project
  - Biology Major at Mount Holyoke College
  - What happens when animals hibernate?
  - How changes in the animal's environment cause the animal to start hibernating?
- Gather information efficiently



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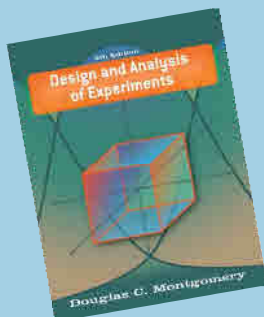
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# The Content of an Experiment: Three Decisions

- In planning almost any experiment, you have to decide
  - What measurement to make **(the response)**
  - What conditions to study **(the treatments)**
  - What experimental material to use **(the units)**



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# Three Sources of Variability

1. Due to the conditions of interest
2. Due to the measurement process
3. Due to the experimental material & process



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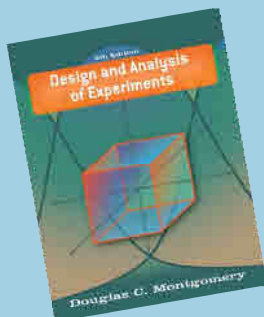
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# Three Sources of Variability

1. Due to the conditions of interest
2. Due to the measurement process
3. Due to the experimental material & process

**A good design will let you estimate the amount of variability due to each source.**



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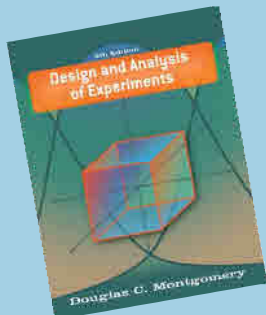
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# Three Kinds of Variability

1. Planned systematic variability
2. Chance-like variability
3. Unplanned systematic variability



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# Three Kinds of Variability

1. Planned systematic variability
2. Chance-like variability
3. **Unplanned systematic variability**



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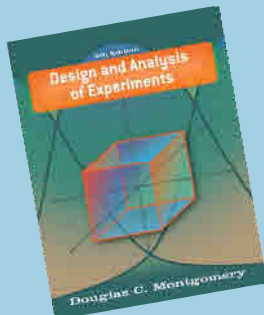
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# Design in a Nutshell

- Isolate the Effects of Interest
- Control What You Can
- Randomize the Rest



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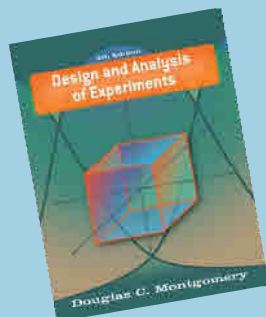
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# Five Questions

- Long versus Short Days
- Heart versus Brains
- Interaction
- Hamsters
- Measurement Error



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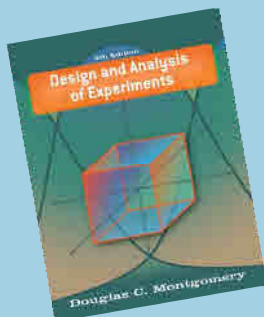
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# Three Basic Principals

- Random Assignment
- Blocking
- Factorial Crossing



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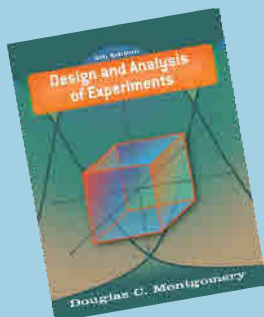
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# Four Experimental Designs

- One-way Randomized Basic Factorial
- One-way Complete Block
- Factorial Crossing & Two-way Basic Factorial
- Split Plot/Repeated Measures



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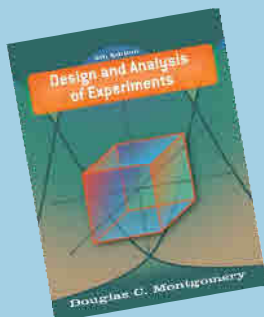
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# One-way Randomized Basic Factorial

- Simplest Design
- Randomly Assign a Day Length to each Hamster
- For balance, make sure half get one & half the other

Long Days		Short Days	
Hamster	Conc. (mg/ml)	Hamster	Conc. (mg/ml)
#4	1.490	#3	1.385
#1	1.525	#8	1.485
#7	1.555	#5	1.255
#2	1.790	#6	1.285
Average	1.590		1.353



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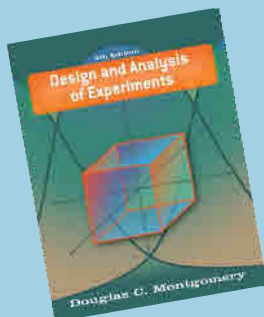
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# Randomized Complete Block

- Treatments: Long versus Short Days
- Experimental Units: Hamsters (8)
- Blocks: Pairs of Similar Hamster (4)
- Randomly assign long days to one hamster in each pair, short days to the other



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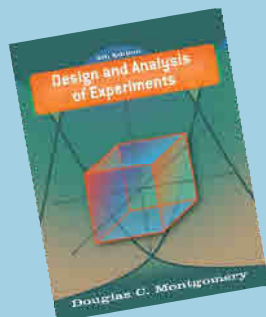
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# Factorial Crossing & Two-way Basic Factorial

Condition			
Day Length/Organ	Hamster	Enzyme Conc. (mg/ml)	Condition Ave.
Long days/heart	#7	1.555	1.673
	#2	1.790	
Long days/brain	#4	6.625	8.500
	#1	10.375	
Short days/heart	#3	1.385	1.320
	#5	1.255	
Short days/brain	#8	11.625	12.425
	#6	13.225	



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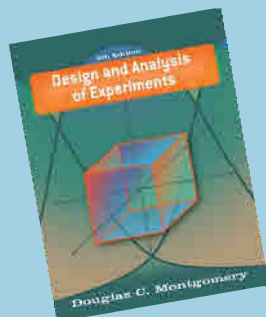
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# Factorial Crossing & Two-way Basic Factorial

		Treatment Conditions	
		Heart	Brain
Long	Long days/ heart	Long days/ heart	Long days/ brain
	Short	Short days/ heart	Short days/ brain

		Data	
		Heart	Brain
Long	1.555	6.625	
	1.790	10.375	
Short	1.385	11.625	
	1.255	13.225	



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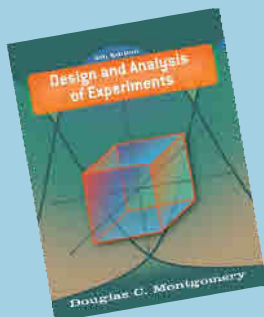
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# Split Plot/Repeated Measures

	Hamster	Heart	Brian
Long Days	#4	1.490	6.625
	#1	1.525	10.375
	#7	1.555	9.900
	#2	1.790	8.800
Short Days	#3	1.385	12.500
	#8	1.485	11.625
	#5	1.255	18.275
	#6	1.285	13.225

# Split Plot/ Repeated Measures

- **Factorial Crossing**
  - All possible combinations of day length & organ
- **Randomization**
  - Long & short days are assigned to hamsters completely at random
- **Blocking**
  - Chunks of hamsters associated with hearts & brains come (pre)sorted into blocks, two chunks per hamster



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# Factor Structure

- Every experimental design has its own characteristic set of meaningful averages  
or
- Its own set of meaningful ways to sort the observed values into groups



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# One-way Randomized Basic Factorial

Long

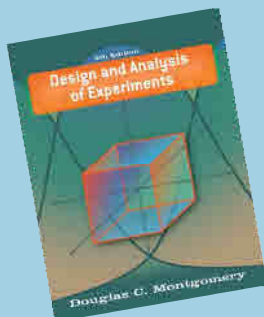
Short

1.490	1.385
1.525	1.485
1.555	1.255
1.790	1.285


Ave.

1.590

1.353



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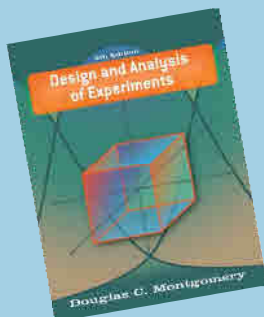
# Randomized Complete Block

Organ

Heart	Brain
1.490	6.625
1.525	10.375
1.555	9.900
1.790	8.800

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Hamster

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# Factorial Crossing & Two-way Basic Factorial

	Heart	Brain
Long	1.555 1.790	6.625 10.375
Short	1.385 1.255	11.625 13.225

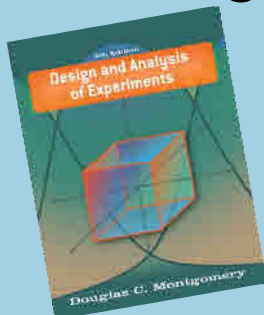
Day Length

Organ

Interaction

# Additional Factors - Every Design

- Grand Average
  - Benchmark
  - Only One Level
- Residual Error
  - Differences between individual observations
  - Differences due
    - Measurement Error
    - Variability in Material
    - Other Sources



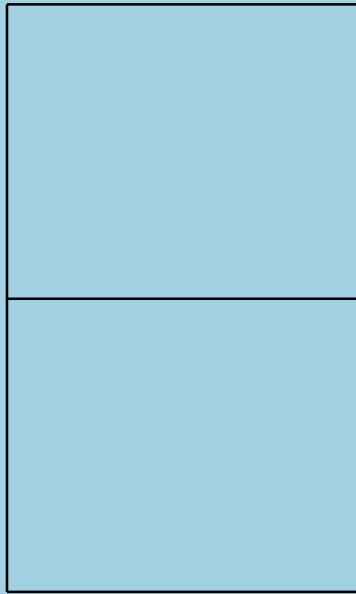
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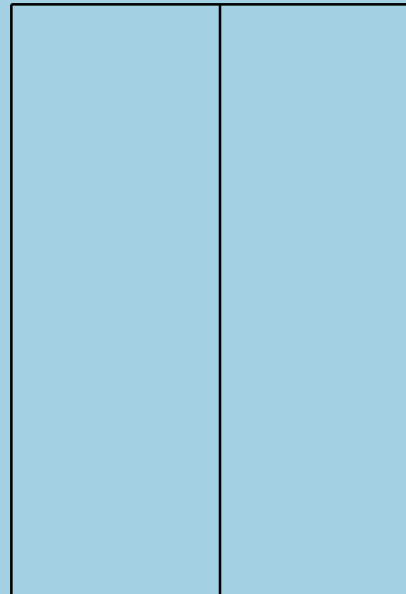
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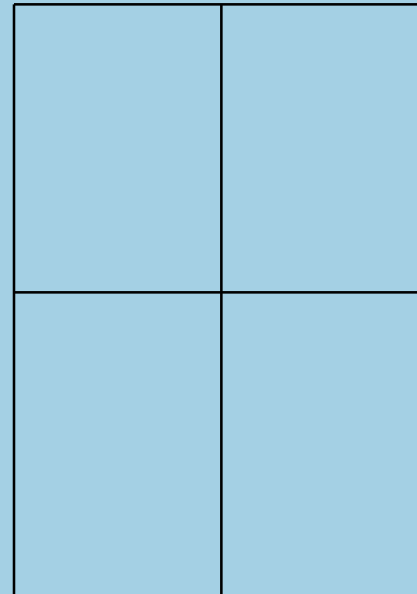
# Split Plot/Repeated Measures



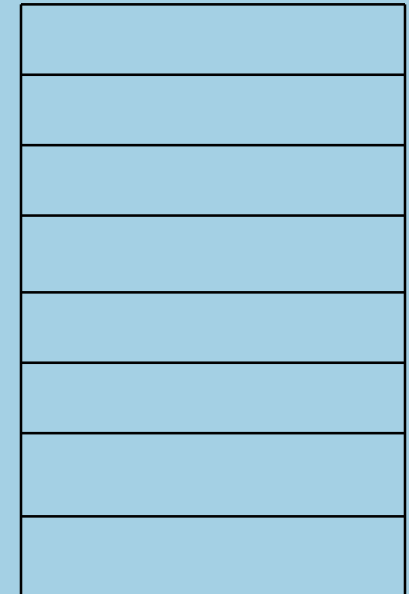
Day  
Length



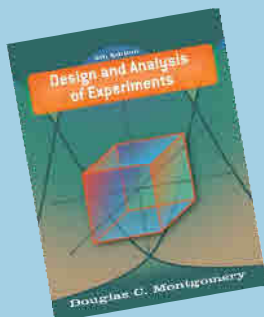
Organs



Interaction



Hamsters



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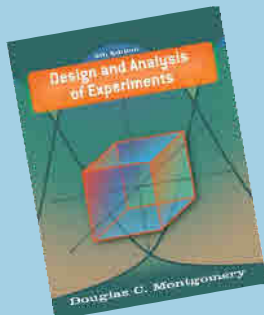


# Other Ways to Guard Against Bias

- Living Organism
- Human Judgments
- Placebos
- “Blind” Subjects
- Control Groups

## Guarding Against Unplanned, Systematic Variation in the Response

### Blind Evaluators



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"It didn't cure their allergies, but the treatment group did have 18% fewer cavities than the group taking the sugar pill."