GLM with two fixed explanatory var	iables 3 examples	Factor * Factor Factor * Covariate Covariate * Covariate	
Format for writing a model with two expressions $e = \beta_0^+ \beta_{V1} V 1 + \beta_{V2} V 2 + \beta_{V2} V 2 + \beta_{V2} V 2 + \beta_{V3} V 2 + \beta_{V4} V 2$	$r_{\times V2}V1 \times V2 + \varepsilon_{Normal}$ product of two componenthe response variable. M, calculate df, fill of	onent variables $\beta_{VI \times V2} VI \times V2$ le depends on V2	
4. Does oxygen consumption <i>VO</i> <sub>2</sub> dependence (Acmea digitalis and A. scabra)? Eight report Data from Sokal and Rohlf (1995).			
Response variable with symbol			
Explanatory variable Symbol	Categorical or Ratio scale		
Model	An opening and the standard and department opening and the standard ope		G

Interpret the interactive effect (state this in words)

df

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch13\_1.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/Limpets.csv

Source	df
	42

## GLM with two fixed explanatory variables 3 examples

Factor \* Factor

Factor \* Covariate

Covariate \* Covariate

Format for writing a model with two explanatory variables

Response = 
$$\beta_o + \beta_{V1}V1 + \beta_{V2}V2 + \beta_{V1\times V2}V1\times V2 + \varepsilon_{Normal}$$

The interactive term is written as the product of two component variables  $\beta_{VI \times V2} VI \times V2$ 

Verbal statement: The effect of V1 on the response variable depends on V2

Write the Fixed factor × Fixed factor GLM, calculate df, fill out the Source df table

 $df V1 \times V2 = df(V1) \times df(V2)$ df total = ntot-1

4. Does oxygen consumption  $VO_2$  depend on salinity (100% 75% and 50% seawater) in two species of limpet (Acmea digitalis and A. scabra)? Eight measurements at 3 different salinities in each of two species ntot = 48. 2 (8×3) = 48 Data from Sokal and Rohlf (1995).

Explanatory variable Symbol Categorical or Ratio scale

df

Interpret the interactive effect (state this in words)

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch13 1.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/Limpets.csv

Source	df
Sal	2
Sp	l
SalrSp	2
Ervor	42
total	47

# Factor \* Factor 2nd example -> Factor \* Covariate (aka ANCOVA) Covariate \* Covariate

5. Does inversion heterozygosity ( <i>Hzyg</i> ) change with elevation above sea level ( <i>Hsl</i> ), in 2
species of Drosophila (SP = D. persimilis or D. pseudoobscura). Data are from Dobzhansky
(1948) as reported in Brussard (1984). One measurement in each species at 7 different
elevations.

Property and the second
10

	State of the Control	
10		
ar		

Complete the Source df table.

Interpret the interactive effect (state it in words)

Model

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch14\_1.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/Brussard.csv

# Factor \* Factor 2nd example -> Factor \* Covariate (aka ANCOVA) Covariate \* Covariate

5. Does inversion heterozygosity ( <i>Hzyg</i> ) change with elevation above sea level ( <i>Hsl</i> ), in 2
species of Drosophila (SP = D. persimilis or D. pseudoobscura). Data are from Dobzhansky
(1948) as reported in Brussard (1984). One measurement in each species at 7 different
elevations.

Source	df
	10

Model	
	wee
df	

Complete the Source df table.

Interpret the interactive effect (state it in words)

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch14 1.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/Brussard.csv

Factor \* Factor

Factor \* Covariate

3rd example -> Covariate \* Covariate (aka multiple regression)

6. Data from Snedecor and Cochrane 1980 Table 17.2.1

Does plant available phosphorus content of corn (ppm) from 17 Iowa soils at 20 deg C depend on inorganic and organic phosphorus in the soil?

	Source	df
Model		
df		13

Complete the Source df table.

Interpret the interactive effect (state it in words)

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch12 1.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/PAvailable.csv

Factor \* Factor

Factor \* Covariate

3rd example -> Covariate \* Covariate (aka multiple regression)

6. Data from Snedecor and Cochrane 1980 Table 17.2.1

Does plant available phosphorus content of corn (ppm) from 17 Iowa soils at 20 deg C depend on inorganic and organic phosphorus in the soil?

	Source	df
Model		
df		13

Complete the Source df table.

Interpret the interactive effect (state it in words)

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch12\_1.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/PAvailable.csv

<b>GLM - Random Effects</b>	The first solution to heterogeneous errors.
-----------------------------	---

The GLM assumes a normal error with fixed (constant) variance =  $\varepsilon_{Normal}$  Grouped data usually violate this assumption.-- > heterogeneous residuals

Examples: Paired data, clustered data, blocked data

Examples: Repeated measures (e.g. 3 samples at one time), longitudinal data (3 samples in sequence) To capture this heterogeneity, we introduce a random effect variable Z with random coefficients  $\tau$  (tau).

$$Y = \mu_o + \tau_Z Z + \varepsilon_{Normal}$$

$$\mu_o$$
 = random intercept  $\tau_z Z$  = random effect

#### **GLM Single Random Factor**

10 The first published ANOVA table was Example 38 in Fisher (1925) *Statistical Methods for Research Workers*. "In an experiment on the accuracy of counting soil bacteria, a soil sample was divided into four parallel samples and from each of these after dilution seven plates were inoculated. The number of colonies on each plate is shown below in example 12 (Table 41). Do the results from the four samples agree within the limits of random sampling? In other words, is the whole set of 28 values homogeneous, or is there any perceptible intraclass correlation?"

in other words, is the	whole set of 28 valu	es nomogeneous	, or is there any	perceptible i	nuacias	ss correlation?
Table 42	Degrees of	Sum of	Mean	F-ratio	$\mathbb{R}^2$	Likelihood Ratio
	Freedom	Squares	Square			
Between Classes (Soi	l sample) 3	1446				
Within Classes (Error	) 24	94.96				
Assign a symbol to th	e response variable	and exp	olanatory variab	le	_	
Using the notation sho	own above, write the	model (use $\mu$ and	d τ)			
Compute both mean s	quares (= SS/df) and	l place them in th	ne ANOVA tabl	e		
Compute the ratio of t	he two means square	es (the F-ratio) a	nd place it in the	e table		
Compute the explaine	d variance $R^2 = Betv$	ween class SS/SS	total =			
Do the 4 samples devi	ate from random sar	npling? To find	out we calculat	e the likeliho	ood ratio	0.
$LR = (1-R^2)^{-n/2} =$						
Likelihood Ratio to	est: Compare the F-r	atio to the 5% p-	value of the F-d	listribution		
The 5% probability	for the F-distribution	on (excel code) is	FINV(0.05)	5,3,24) = 3.0	009	
Do the results from	the four samples ag	gree within the li	mits of random:	sampling?		

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/FisherEx38.csv

						,
GLM - Random Effects. T	The first solution	to heterogeneous	errors.			
The GLM assumes a normal error with fixed (constant) variance $= \varepsilon_{Normal}$ Grouped data usually violate this assumption> heterogeneous residuals Examples: Paired data, clustered data, blocked data Examples: Repeated measures (e.g. 3 samples at one time), longitudinal data (3 samples in sequence) To capture this heterogeneity, we introduce a random effect variable $Z$ with random coefficients $\tau$ (tau). $Y = \mu_o + \tau_z Z + \varepsilon_{Normal} \qquad \qquad \mu_o = \text{random intercept}$ $\tau_Z Z = \text{random effect}$						
<b>GLM Single Random Fact</b>		de transfer and a sure of the transfer properties to the constitution of the transfer and the transfer and the constitution of the transfer and the constitution of th			the Madical Strategy of the process of Australian cond	
Fr	ecuracy of counting dilution seven per 41). Do the resurt set of 28 values egrees of reedom	ing soil bacteria, a blates were inocularles from the four such homogeneous, or Sum of Squares	soil sample wated. The number amples agree	as divided in the light within the light	into founcies on imits of our or	each plate is shown frandom sampling?
Between Classes (Soil samp Within Classes (Error)	ole) 3 24	1446 94.96				

Within Classes (Error)	24	94.96
Assign a symbol to the response	onse variable	e and explanatory variable
Using the notation shown ab	ove, write th	the model (use $\mu$ and $\tau$ )
Compute the ratio of the two Compute the explained varia Do the 4 samples deviate from $LR = (1-R^2)^{-n/2} =$	o means squa ance $R^2 = Be$ om random s	sampling? To find out we calculate the likelihood ratio
Likelihood Ratio test: Co The 5% probability for the Do the results from the fo	ne F-distribu our samples	F-ratio to the 5% p-value of the F-distribution ution (excel code) is: FINV(0.05,3,24) = 3.009 agree within the limits of random sampling?er/b4605/GLMMworkshop/Data/FisherEx38.csv

GLM with two random factors 2 examples

Nested - Random within Random Crossed - Random × Random

$$Y = \mu_o + \Sigma \tau_Z Z + \varepsilon_{Normal}$$
 
$$\Sigma \tau_Z Z = \text{sum of random effects of random variable } Z$$

11. Winglength of 12 mosquitos (3 cages, 4 flies per cage). The left wing of each fly was measured twice.

Source Cage FlycCage	10	SS 665.68 1720.68 15.62	MS 332.84 191.19 1.3017	F 1.74 147.07	10 M (10 To )	p 0.23 <0.0001	
<u>Error</u> Total	$\frac{12}{23}$	2401.97	1,5017				

ANOVA table Table 10.1 in Sokal and Rohlf (1995).

Write the model from the Source and df columns in the ANOVA table

Show how each df was calculated: 2 = \_\_\_\_\_ 9 = \_\_\_\_\_ 23 = 12 =

Note that the Cage F-ratio was not calculated with respect to the MS error. The Cage F-ratio was calculated from a random factor, Fly(Cage). Why? Stay tuned.

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch13\_6.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/FisherEx38.csv

Nested - Random within Random Crossed - Random × Random

$$Y = \mu_o + \Sigma \tau_z Z + \varepsilon_{Normal}$$
 
$$\Sigma \tau_z Z = \text{sum of random effects of random variable } Z$$

11. Winglength of 12 mosquitos (3 cages, 4 flies per cage). The left wing of each fly was measured twice.

Source	df	SS	MS	F	>	p .
Cage	2	665.68	332.84	1.74		0.23
Fly⊂Cage	9	1720.68	191.19	147.07		< 0.0001
Error	_12	15.62	1.3017			
Total	23	2401.97				

ANOVA table Table 10.1 in Sokal and Rohlf (1995).

Write the model from the Source and df columns in the ANOVA table

Show how each df was calculated: 
$$2 = 3 - 1$$
  $9 = 3(4 - 1)$   $23 = 24 - 1$   $12 = 23 - 2 - 9$ 

Note that the Cage F-ratio was not calculated with respect to the MS error. The Cage F-ratio was calculated from a random factor, Fly(Cage). Why? Stay tuned.

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch13\_6.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/FisherEx38.csv

#### GLM with two random factors

2nd example -->

Nested - Random within Random Crossed - Random × Random

12. Fisher's Table 42 (Example 38) shows a nested design.

It ignores the fact that each plate was inoculated with subsamples from each of the four initial samples (Classes). Consequently, we can treat class (*i.e.* sample) as a random factor with 4 levels and cross it with another random factor, plate.

Assign symbols to both explanatory variables and write a two way random effects GLM with an interaction term.

Plate			Sam	ple	
		1	- 11	III	IV
	1	72	74	78	69
	2	69	72	74	67
	3	63	70	70	66
	4	59	69	58	64
	5	59	66	58	62
	6	53	58	56	58
	7	51	52	56	54
Total		426	461	450	440
Mean		60.86	65.86	64.29	62.86

Symbols	Process & the filter of the Organization in Special Engineers and Artistics			
Model				
Model	-			

Complete the Source and df columns of the ANOVA table for this model. The correct model is a saturated model, the error term will have zero degrees of freedom. We'll use this in the next session.

#### GLM with two random factors

2nd example -->

Nested - Random within Random Crossed - Random × Random

12. Fisher's Table 42 (Example 38) shows a nested design.

It ignores the fact that each plate was inoculated with subsamples from each of the four initial samples (Classes). Consequently, we can treat class (*i.e.* sample) as a random factor with 4 levels and cross it with another random factor, plate.

Assign symbols to both explanatory variables and write a two way random effects GLM with an interaction term.

Plate			Samp	ole	
			11	III	I۷
	1	72	74	78	69
	2	69	72	74	67
	3	63	70	70	66
	4	59	69	58	64
	5	59	66	58	62
	6	53	58	56	58
	7	51	52	56	54
Total		426	461	450	440
Mean		60.86	65.86	64.29	62.86

Symbols	
Model	

Complete the Source and df columns of the ANOVA table for this model. The correct model is a saturated model, the error term will have zero degrees of freedom. We'll use this in the next session.

Random or Fixed? The definition of fixed versus random differs among text books.

Definition from Quinn and Keough (2002)

There are two types of categorical predictor variables in linear models. The most common type is a <u>fixed factor</u>, where all the levels of the factor (*i.e.* all the groups or treatments) that are of interest are included in the analysis. We cannot extrapolate our statistical conclusions beyond these specific levels to other groups or treatments not in the study. If we repeated the study, we would usually use the same levels of the fixed factor again. Linear models based on fixed categorical predictor variables (fixed factors) are termed fixed effects models (or Model 1 ANOVAs). Fixed effect models are analogous to linear regression models where X is assumed to be fixed. The other type of factor is a <u>random factor</u>, where we are only using a random selection of all the possible levels (or groups) of the factor and we usually wish to make inferences about all the possible groups from our sample of groups. If we repeated the study, we would usually take another sample of groups from the population of possible groups.

Drawing a branching tree diagram is not a reliable way to distinguish crossed from nested designs.

Why? Because a crossed design can be drawn as a branching tree.

The reliable way to distinguish crossed and nested designs is to write all of the two way tables and fill in the sample size in each cell of each table. If all (or most) of the cells have at least one sample then the two variables are crossed. If not the two factors are nested. For three factors there are three pairs and so three two-way tables.

# GLMM with two explanatory variables 2 examples Fixed + Random Fixed × Random

The GLM assumes a normal error with fixed (constant) variance =  $\varepsilon_{Normal}$  Grouped data often violate this assumption.-- > heterogeneous residuals

Paired data, clustered data, blocked data

Repeated measures (e.g. 3 samples at once), longitudinal data (3 sequential samples)

To capture this heterogeneity, we write a General Linear Mixed Model, which has both fixed and random effects.

$$Y = \beta_o + \Sigma \beta_X X + \Sigma \tau_Z Z + \varepsilon_{Normal}$$
 
$$\Sigma \beta_X X = \text{sum of fixed effects}$$
 
$$\Sigma \tau_Z Z = \text{sum of heterogeneous random effects}$$
 
$$\varepsilon_{Normal} = \text{homogeneous normal errors}$$

GLMM with two explanatory variables First example	Random(Fixed)	WI	neat Y	ields	
13. Wheat Yields from Cornell (1971)	Treatment	Pot Number	1	Plant nu 2	ımber 3
	None	1	20.6	22.3	19.8
There were against to each treatment	None	2	23.4	21.9	22.8
Three pots were assigned to each treatment.	None	3	21.8	20.6	21.3
The two-way (Pot × Treatment) table now has 12 cells.	Straw	1	13.6 13.7	13.9 14.5	14.2 13.8
	Straw Straw	2	12.9	13.1	13.4
There is 1 sample in each cell.	Straw + PO4		14.8	14.6	14.9
When we do the cross test the design appears to be crossed.	Straw + PO4	2	14.3	13.9	13.5
when we do the cross test the design appears to be crossed.	Straw + PO4	3	14.4	13.8	14.1
However, there were 12 pots in the experiment, not 3.	Straw+PO4+lime	1	14.1	13.8	14.3
	Straw+PO4+lime	2	14.0	13.9	14.2
	Straw+PO4+lime	3	14.4	14.1	13.6
http://www.mun.ca/biology/schneider/b4605/GLMMworksho	p/Data/WheatYield.o	ESV			
Recode the Pot variable to show that there are 12 pots.	Treatment	Pot		Plant nu	ımher
		Number	1	2	3
The two-way (Pot × Treatment) table now has 36 cells.	None	Number 1	20.6	2 22.3	3 19.8
The two-way (Pot × Treatment) table now has 36 cells.	None	Number 1 2	20.6 23.4	2 22.3 21.9	3 19.8 22.8
The two-way (Pot × Treatment) table now has 36 cells. Most of the cells are empty.	None None	Number 1 2 3	20.6 23.4 21.8	2 22.3 21.9 20.6	3 19.8 22.8 21.3
The two-way (Pot × Treatment) table now has 36 cells.  Most of the cells are empty.  We cannot estimate Pot × Treatment.	None None Straw	Number 1 2 3 4	20.6 23.4 21.8 13.6	2 22.3 21.9 20.6 13.9	3 19.8 22.8 21.3 14.2
The two-way (Pot × Treatment) table now has 36 cells. Most of the cells are empty.	None None Straw Straw	Number 1 2 3 4 5	20.6 23.4 21.8 13.6 13.7	2 22.3 21.9 20.6 13.9 14.5	3 19.8 22.8 21.3 14.2 13.8
The two-way (Pot × Treatment) table now has 36 cells.  Most of the cells are empty.  We cannot estimate Pot × Treatment.  Pot is nested within treatment Pot(Treatment)	None None Straw Straw Straw	Number 1 2 3 4 5 6	20.6 23.4 21.8 13.6 13.7 12.9	2 22.3 21.9 20.6 13.9 14.5 13.1	3 19.8 22.8 21.3 14.2 13.8 13.4
The two-way (Pot × Treatment) table now has 36 cells.  Most of the cells are empty.  We cannot estimate Pot × Treatment.	None None Straw Straw Straw Straw + PO4	Number 1 2 3 4 5	20.6 23.4 21.8 13.6 13.7	2 22.3 21.9 20.6 13.9 14.5	3 19.8 22.8 21.3 14.2 13.8
The two-way (Pot × Treatment) table now has 36 cells.  Most of the cells are empty.  We cannot estimate Pot × Treatment.  Pot is nested within treatment Pot(Treatment)  Carry out the cross test for Pot × Plant and Trt × Plant.	None None Straw Straw Straw	Number 1 2 3 4 5 6 7	20.6 23.4 21.8 13.6 13.7 12.9 14.8	2 22.3 21.9 20.6 13.9 14.5 13.1 14.6	3 19.8 22.8 21.3 14.2 13.8 13.4 14.9 13.5 14.1
The two-way (Pot × Treatment) table now has 36 cells.  Most of the cells are empty.  We cannot estimate Pot × Treatment.  Pot is nested within treatment Pot(Treatment)  Carry out the cross test for Pot × Plant and Trt × Plant.  Now many cells?	None None Straw Straw Straw + PO4 Straw + PO4	Number 1 2 3 4 5 6 7 8 9 10	20.6 23.4 21.8 13.6 13.7 12.9 14.8 14.3 14.4	2 22.3 21.9 20.6 13.9 14.5 13.1 14.6 13.9 13.8	3 19.8 22.8 21.3 14.2 13.8 13.4 14.9 13.5 14.1 14.3
The two-way (Pot × Treatment) table now has 36 cells.  Most of the cells are empty.  We cannot estimate Pot × Treatment.  Pot is nested within treatment Pot(Treatment)  Carry out the cross test for Pot × Plant and Trt × Plant.	None None Straw Straw Straw Straw + PO4 Straw + PO4 Straw + PO4 Straw + PO4 Straw+PO4+lime Straw+PO4+lime	Number 1 2 3 4 5 6 7 8 9 10 11	20.6 23.4 21.8 13.6 13.7 12.9 14.8 14.3 14.4 14.1	2 22.3 21.9 20.6 13.9 14.5 13.1 14.6 13.9 13.8 13.8	3 19.8 22.8 21.3 14.2 13.8 13.4 14.9 13.5 14.1 14.3 14.2
The two-way (Pot × Treatment) table now has 36 cells.  Most of the cells are empty.  We cannot estimate Pot × Treatment.  Pot is nested within treatment Pot(Treatment)  Carry out the cross test for Pot × Plant and Trt × Plant.  Now many cells?	None None Straw Straw Straw Straw + PO4	Number 1 2 3 4 5 6 7 8 9 10	20.6 23.4 21.8 13.6 13.7 12.9 14.8 14.3 14.4	2 22.3 21.9 20.6 13.9 14.5 13.1 14.6 13.9 13.8	3 19.8 22.8 21.3 14.2 13.8 13.4 14.9 13.5 14.1 14.3

GLMM with two explanatory variables First example	Random(Fixed)	W	heat Y	ields	
13. Wheat Yields from Cornell (1971)	Treatment	Pot Number	1	Plant no	umber 3
	None	1	20.6	22.3	19.8
Three pots were assigned to each treatment.	None	2	23.4	21.9	22.8
	None	3	21.8	20.6	21.3
The two-way (Pot $\times$ Treatment) table now has 12 cells.	Straw Straw	1 2	13.6	13.9	14.2
There is 1 sample in each cell.	Straw	3	13.7 12.9	14.5 13.1	13.8 13.4
There is a sample in each cen.	Straw + PO4	1	14.8	14.6	14.9
When we do the cross test the design appears to be crossed.	Straw + PO4	2	14.3	13.9	13.5
	Straw + PO4	3	14.4	13.8	14.1
However, there were 12 pots in the experiment, not 3.	Straw+PO4+lime	1	14.1	13.8	14.3
	Straw+PO4+lime	2	14.0	13.9	14.2
	Straw+PO4+lime	3	14.4	14.1	13.6
http://www.mun.ca/biology/schneider/b4605/GLMMworkshop	o/Data/WheatYield.co	CSV			
Recode the Pot variable to show that there are 12 pots.	Treatment	Pot		Plant nu	ımber
The two-way (Pot × Treatment) table now has 36 cells.	Name	Number	1	2	3
ine two-way (1 of ~ Treatment) table now has 30 cens.	None None	1	20.6	22.3	19.8
Most of the cells are empty.	None	2 3	23.4 21.8	21.9 20.6	22.8 21.3
We cannot estimate Pot × Treatment.	Straw	4	13.6	13.9	14.2
Pot is nested within treatment Pot(Treatment)	Straw	5	13.7	14.5	13.8
	Straw	6	12.9	13.1	13.4
Carry out the cross test for Pot $\times$ Plant and Trt $\times$ Plant.	Straw + PO4	7	14.8	14.6	14.9
Novy many calle?	Straw + PO4	8	14.3	13.9	13.5
Now many cells?	Straw + PO4	9	14.4	13.8	14.1
How many empty cells?	Straw+PO4+lime	10	14.1	13.8	14.3
	Straw+PO4+lime Straw+PO4+lime	11 12	14.0 14.4	13.9 14.1	14.2
Can Pot × Plant be estimated? Y/N	Straw in O4*IIIIle	12	14.4	14.1	13.6
Can Trt × Plant be estimated ? Y/N					

.

## GLMM with two explanatory variables 2nd example Fixed × Random

Subject	Drug A	Drug B
1	0.7	1.9
2	-1.6	0.8
3	-0.2	1.1
4	-1.2	0.1
5	-0.1	-0.1
6	3.4	4.4
7	3.7	5.5
8	0.8	1.6
9	0.0	4.6
10	2.0	3.4

14. Sleep data (Cushny and Peebles), used by Student (W. Gossett) to introduce the *t*-test. Data are: hours of extra sleep with two drugs Hyoscyamine (Drug A) and L Hyoscine (Drug B), each administered to 10 subjects. Values reported are averages. The pairing across subject allows us to remove the effects of individual variation.

Assign a symbol to the response variable	Name and the second of the sec
--	--

For each explanatory variable assign a symbol and state reason for assigning it as Fixed or Random

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch13 3.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/ExtraSleep.csv

Crossed or Nested?

There are only two variables, hence only one interaction term.

We can see right away that this is a crossed design.

# GLMM with two explanatory variables 2nd example Fixed × Random

Subject	Drug A	Drug B
1	0.7	1.9
2	-1.6	0.8
3	-0.2	1.1
4	-1.2	0.1
5	-0.1	-0.1
6	3.4	4.4
7	3.7	5.5
8	0.8	1.6
9	0.0	4.6
10	2.0	3.4

14. Sleep data (Cushny and Peebles), used by Student (W. Gossett) to introduce the *t*-test. Data are: hours of extra sleep with two drugs Hyoscyamine (Drug A) and L Hyoscine (Drug B), each administered to 10 subjects. Values reported are averages. The pairing across subject allows us to remove the effects of individual variation.

Assign a symbol to the response variable

Hr

For each explanatory variable assign a symbol and state reason for assigning it as Fixed or Random

Drug Fixed: Infer only to Drug A + B Subj Random: Infer to other subjects

http://www.mun.ca/biology/schneider/b4605/LNotes/Pt4/Ch13 3.pdf

http://www.mun.ca/biology/schneider/b4605/GLMMworkshop/Data/ExtraSleep.csv

Crossed or Nested?

There are only two variables, hence only one interaction term.

We can see right away that this is a crossed design.