Training school: Farm and abattoir interventions in a risk-based meat safety assurance system

RIBMINS WG2/WG3 Virtual Training school (June 20th - 22nd, 2022)

Interventions in the meat chain: The need to integrate causal inference into planning of interventions

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Who am I?

Professor of Veterinary Public Health, Faculty of Veterinary Medicine, Norwegian University of Life Sciences

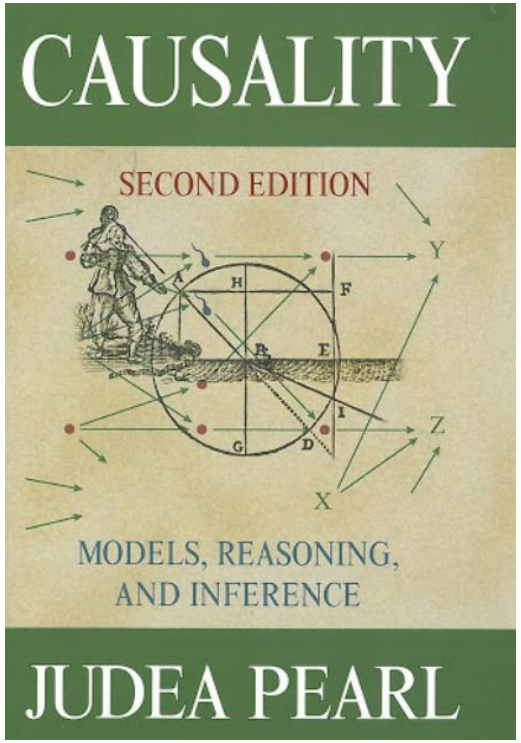
I am a professor in Veterinary Public Health, responsible for coordinating teaching in this field at the faculty. I am a veterinarian by training, with a background is in food safety, the epidemiology of food-borne diseases and veterinary epidemiology. My research has focused on a wide range of zoonotic infections, from "northern" zoonoses to emerging tropical zoonotic infections.

Eystein will give a lecture with the title:

- Interventions in the meat chain: The need to integrate causal inference into planning of interventions

I hope I will be challenging you a bit into thinking about interventions through analyzing causal pathways.

The session

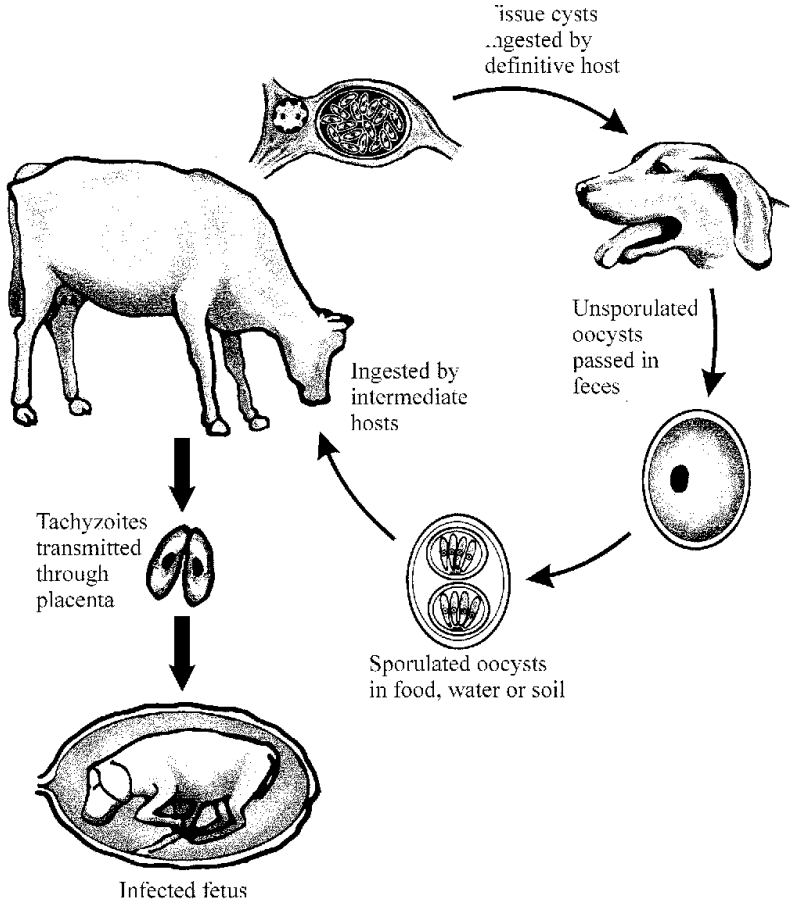


1. How to think about and work with causality
2. An example of causality: Links between dogs, straydogs, Neospora and abortion in cattle.
3. Lessons for pre-harvest interventions in the meat chain based upon causal thinking
4. FAO, Definition of Epidemiology. **Epidemiology is concerned with disease. prevention and "succession of events which. result in the exposure of specific types of. individual to specific type of environment"**
5. Epidemiology is a science of intervention, based upon statistical analyses of statistical databases.

The biology

Neospora also known as Neospora caninum is **single celled parasitic organism that can affect cattle, particularly pregnant cattle, where it can result in abortion**. The disease affects cattle worldwide, and once infected, cattle remain infected for life, making the disease very difficult to eradicate. 4. nov. 2020

Neospora is not zoonotic, but Neospora affects zoonoses as it is linked to pre-harvest management and contact between cattle and dogs



The herd dataset (n=197) (Adis Softic)

An epidemiological study focusing on reproductive failure in cattle and potential infectious agents
Focus on *Neospora* as a cause of abortions in cattle.

Variable	Obs	Unique	Mean	Min	Max	Label
abortion	197	2	.4619289	0	1	Abortion
Neo	197	2	.4060914	0	1	Neospora
dogs	196	2	.5714286	0	1	Dogs in the farm
straydogs	197	2	.5431472	0	1	Straydogs in/around farm

The **four variables** of interest:

- Abortion observed in herd
- Neospora infection in herd
- Pet dog observed at farm
- Straydog observed at or near farm

The aim of the study was to **i*dentify farm level variables associated with abortion in cattle***

Standard univariable analyses

abortion	Odds ratio	Std. err.	z	P>|z|	[95% conf.	interval]
dogs						
Yes	**4.098813**	**1.278573**	**4.52**	**0.000**	**2.22401**	**7.554046**
_cons	**.3770493**	**.092259**	**-3.99**	**0.000**	**.2334104**	**.6090823**

abortion	Odds ratio	Std. err.	z	P>|z|	[95% conf.	interval]
straydogs						
Yes	**2.42965**	**.7172633**	**3.01**	**0.003**	**1.362255**	**4.333404**
_cons	**.5254237**	**.1165532**	**-2.90**	**0.004**	**.3401654**	**.8115759**

abortion	Odds ratio	Std. err.	z	P>|z|	[95% conf.	interval]
Neo						
Yes	**4.95**	**1.552007**	**5.10**	**0.000**	**2.677455**	**9.151412**
_cons	**.4444445**	**.089026**	**-4.05**	**0.000**	**.3001336**	**.6581431**

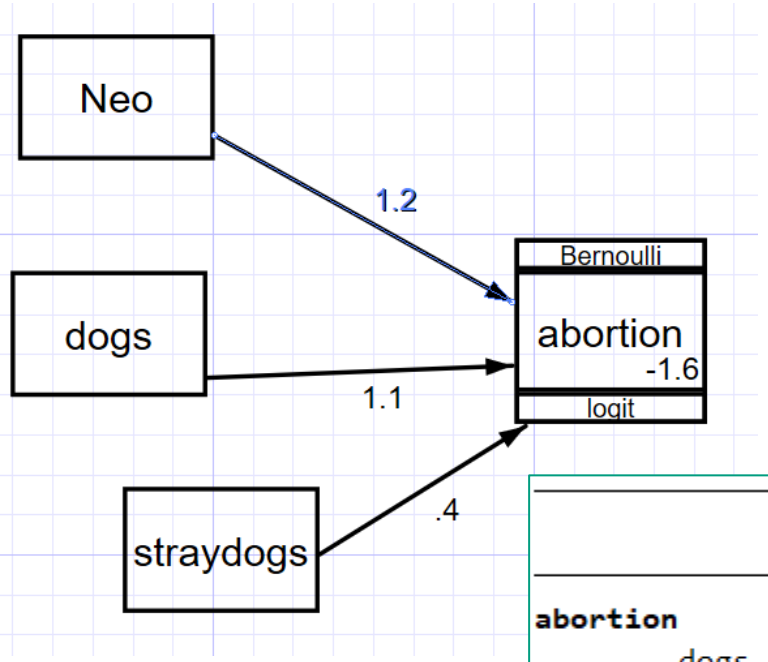
Multivariable model

abortion	Odds ratio	Std. err.	z	P>|z|	[95% conf.	interval]
Neo						
Yes	**3.478744**	**1.180713**	**3.67**	**0.000**	**1.788619**	**6.765923**
dogs						
Yes	**3.117508**	**1.03241**	**3.43**	**0.001**	**1.628994**	**5.966174**
straydogs						
Yes	**1.488411**	**.5017584**	**1.18**	**0.238**	**.7687303**	**2.881851**
_cons	**.2108874**	**.0678147**	**-4.84**	**0.000**	**.1122875**	**.3960683**

abortion	Odds ratio	Std. err.	z	P>|z|	[95% conf.	interval]
Neo						
Yes	**3.920306**	**1.279329**	**4.19**	**0.000**	**2.067969**	**7.431832**
dogs						
Yes	**3.160098**	**1.040007**	**3.50**	**0.000**	**1.657926**	**6.023321**
_cons	**.2500922**	**.0697165**	**-4.97**	**0.000**	**.144816**	**.4319006**

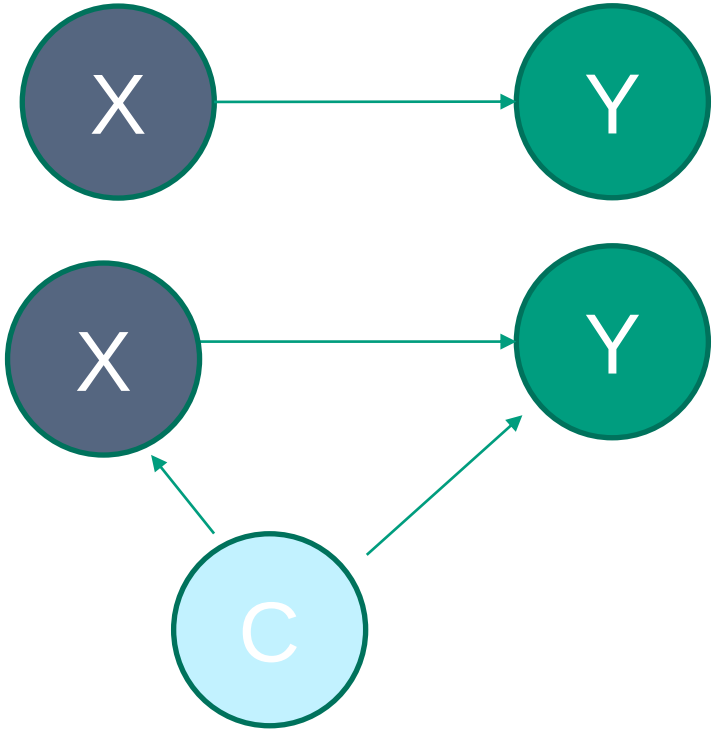
- All variables with a p<0.20 included in the next step – the multivariable modelling.
- No strong collinearity between variables
- Backward selection strategy!
  - Straydog deleted
  - Final model with *Neospora* and Dogs at farm

Sorry – the causal model was wrong



	exp(b)	Std. err.	z	P>|z|	[95% conf.	interval]
abortion						
dogs	3.117509	1.03241	3.43	0.001	1.628994	5.966175
straydogs	1.488411	.5017585	1.18	0.238	.7687304	2.881851
Neo	3.478744	1.180714	3.67	0.000	1.788619	6.765924
_cons	.2108874	.0678147	-4.84	0.000	.1122874	.3960682

The problem in Statistics;
Y=Outcome, X=explanatory, C=confounder



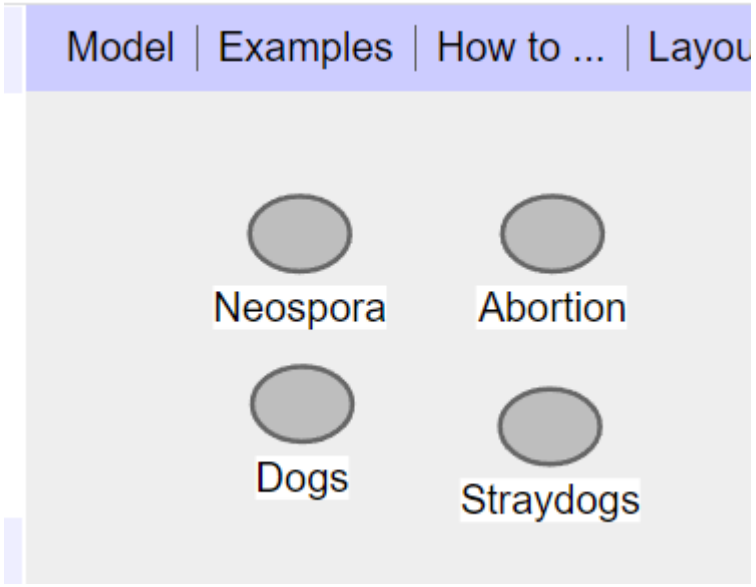
$$Y = aX + \varepsilon$$

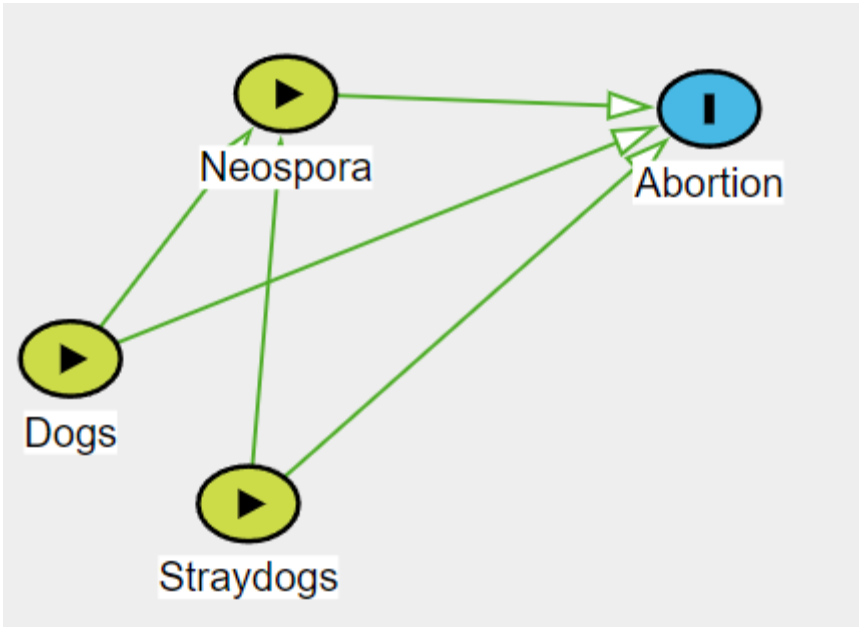
$$Y = aX + bC + \varepsilon$$

Here lies the devil of traditional statistics. We lack structures!!!

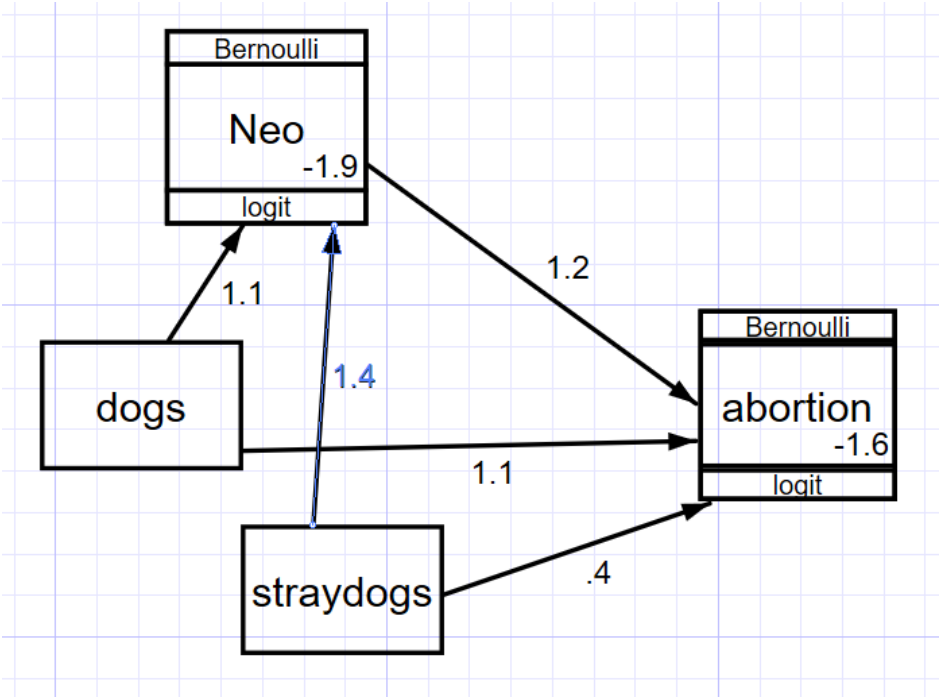
$$Y = aX_2 + \varepsilon$$

The causal model – in Dagitty.net





A Structural Equation Model (SEM) in Stata



	exp(b)	Std. err.	z	P>|z|	[95% conf.	interval]
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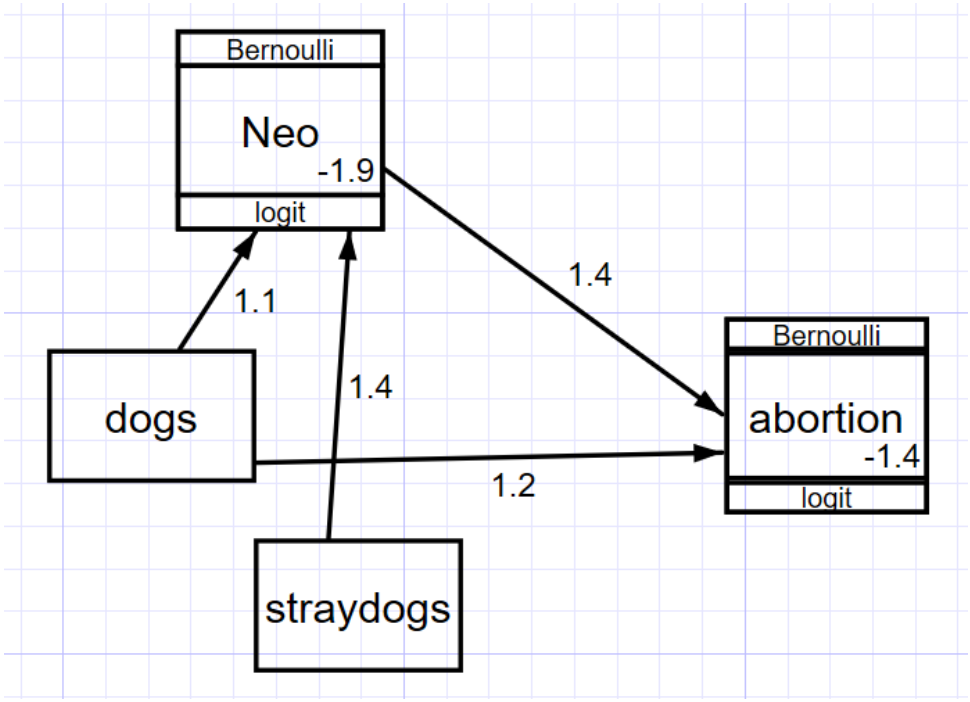
. estat eform Neo

	exp(b)	Std. err.	z	P>|z|	[95% conf.	interval]
Neo						
dogs	**2.998159**	**.991887**	**3.32**	**0.001**	**1.567653**	**5.734023**
straydogs	**4.046348**	**1.332452**	**4.24**	**0.000**	**2.122095**	**7.715458**
_cons	**.1569527**	**.0524875**	**-5.54**	**0.000**	**.0814916**	**.3022904**

Revised SEM

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. estat eform
```

	exp(b)	Std. err.	z	P>|z|	[95% conf.	interval]
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dogs	3.160098	1.040007	3.50	0.000	1.657926	6.023321
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What did we learn?

Learning is discussing in teams keeping biology in mind

- The naïve model was not including our knowledge on the biology of abortions
- Do dogs cause abortions?
  - Dogs and straydogs spread Neospora
  - *Neospora* causes abortions
  - Dogs also linked – Why?
  - The effects of dogs and straydogs are MEDIATED through Neospora
  - Straydogs only have an indirect effect, but should be in the model
  - Dogs have a direct and indirect effect

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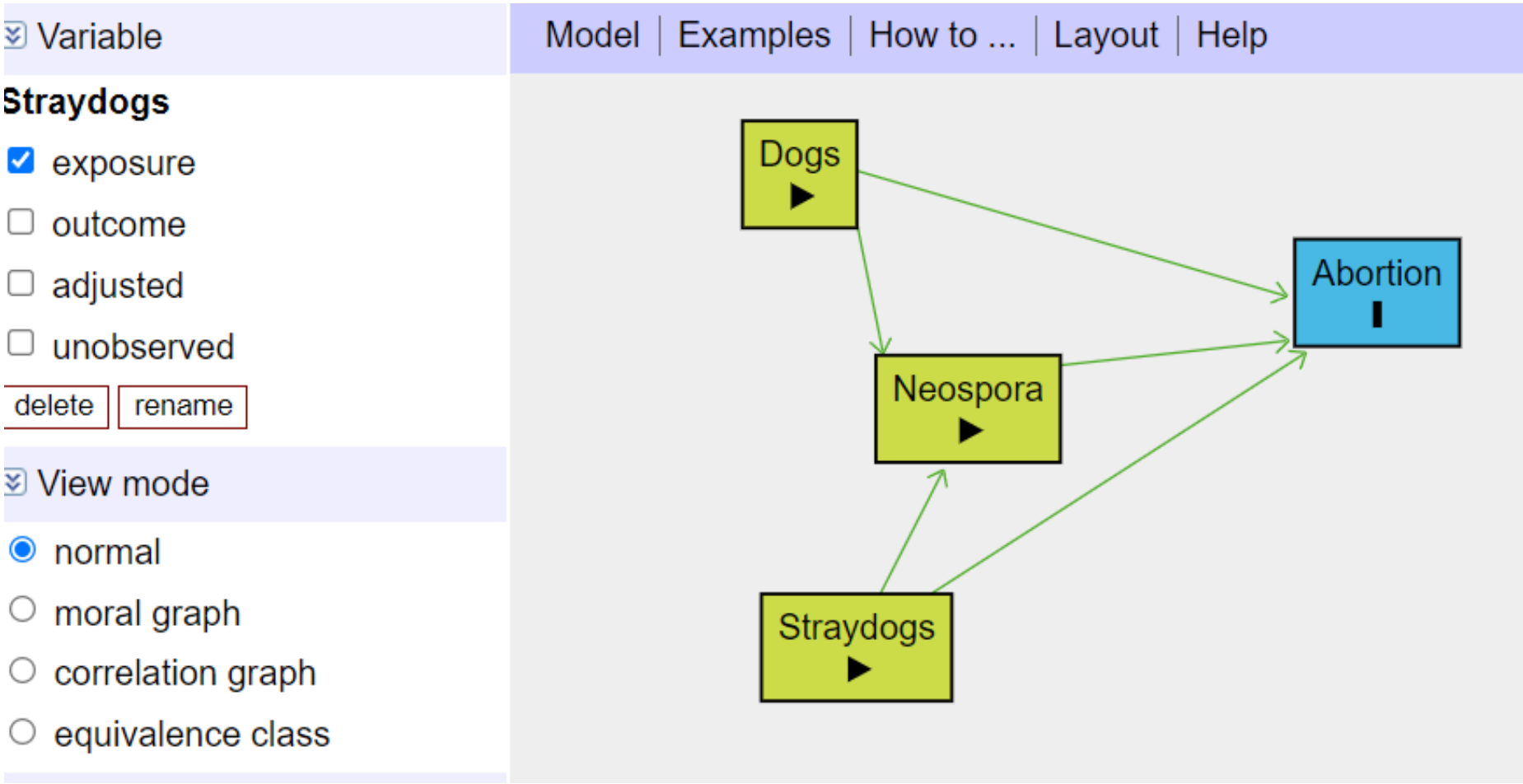


Errors made

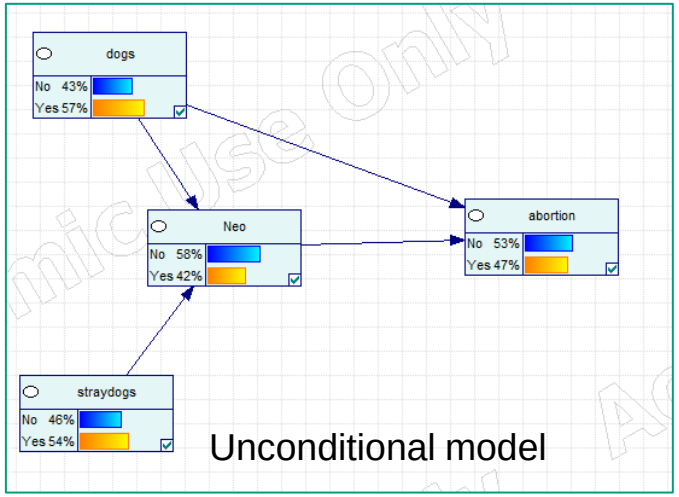
- Association-based statistics is not enough for causal inference
- Causal inference is a MUST for intervention
- Intervention means a focus on variables we can manipulate and adjust the effect of
- In our example: **Controlling dogs and straydogs will lead to a lower lwecel of Neospora and thus prevent abortion**

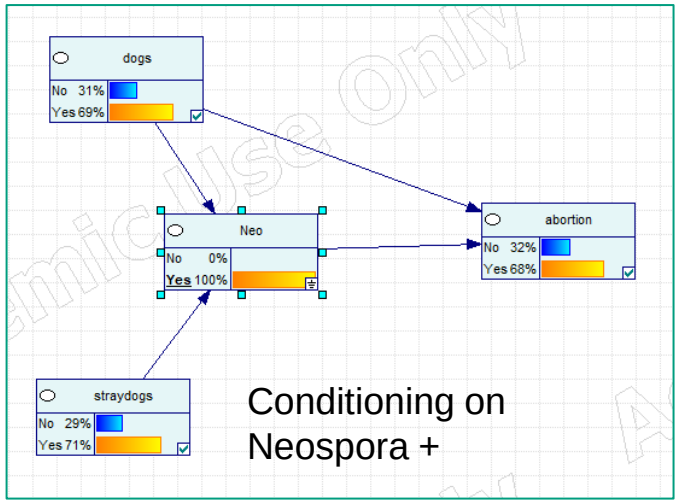
The multivariable trap

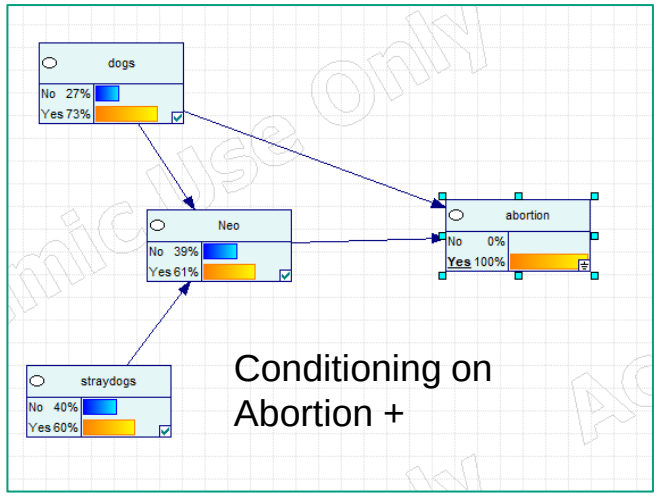
We have been trained to believe that running a multivariable (multilevel) model solves all problems. But:

1. Nothing can save us from design flaws
2. Causal structures should be identified starting from basic biological causality
3. Adjusting for «confounders» may be misleading
4. Most important: Causal model requires teamwork focusing on graphical models – either models as SEM or e.g. Bayesian networks

The Bayesian network alternative (same model)







A Bayesian network may be a better alternative for group discussions on causality, as it can be updated – and updated in both directions

Have we been wrong all the way?

- Many pre-harvest studies have been valuable
- But – some have focused too much on conventional association-based statistics, often killing the reader with long tables and discussion or univariable associations
- Discussing through causality and interventions is more transparent – and enables everyone to discuss using graphical patterns
- Causal inference may be simple, or a painful exercise into uncertainty, BUT NECESSARY
- Good luck!