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The Long Lasting Impact of Nutrition: Developmental Programming

Kimberly Vonnahme, PhD
Associate Professor
Department of Animal Sciences

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NDSU Animal Nutrition and Physiology Center

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OUTLINE

- What is developmental programming?
- Primary focus on beef cattle
- How maternal nutrition impacts uterine blood flow in the beef cow

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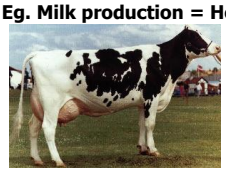
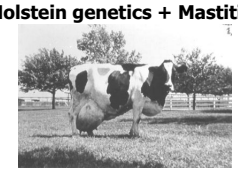
Phenotype

Classic Animal Breeding Example

Phenotype = Genotype + Environment

Eg. Milk production = Holstein genetics + Mastitis





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Phenotype

Future Animal Breeding Example

Phenotype = Genotype + Environment

Eg. Yield grade = Angus genetics + Uterine environment

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Programming

- The process through which a ***stimulus*** or ***insult*** establishes a ***permanent*** response
- **Developmental programming hypothesis**
- Exposure during a ***critical period*** in development may influence later metabolic or physiological functions in adult life

Consequences in beef cattle

Overall nutrient restriction

- Early pregnancy restriction
  - Similar birth weights
  - Postnatal growth not impacted
  - Carcass weights not impacted
- Mid pregnancy restriction
  - Similar birth weights
  - Reduced weaning weights
  - Reduced carcass weights
  - Decreased beef tenderness

Protein Supplementation During Late Pregnancy

Steer Feedlot Performance

	Treatment				P-value		
	PS/ WR	NS/ WR	PS/ CR	NS/ CR	Sys	Sup	S*S
ADG, kg/d	1.71	1.66	1.69	1.66	0.85	0.09	0.65
Final Live BW, kg	622^{a}	591^{b}	609^{ab}	614^{a}	0.52	0.10	0.02
HCW, kg	376^{a}	357^{b}	368^{ab}	371^{a}	0.52	0.10	0.02

Slide courtesy of Rick Funston

Steer Feedlot Performance

	Treatment				P-value		
	PS/ WR	NS/ WR	PS/ CR	NS/ CR	Sys	Sup	S*S
12th rib fat, cm	1.2	1.1	1.2	1.2	0.84	0.31	0.58
REA, cm^2	88.5	88.4	90.3	89.7	0.21	0.75	0.85
Yield Grade	2.94	2.69	2.74	2.77	0.55	0.26	0.16
Empty body fat	29.9	28.7	29.3	28.8	0.48	0.06	0.38
Choice, %	84.5	76.5	88.2	64.6	0.57	0.04	0.28
Upper 2/3	43.2	26.6	35.4	15.0	0.34	0.03	0.81

Slide courtesy of Rick Funston

Reproductive Performance

	Treatment			
Item	Prot	NoProt	SEM	P-value
Age at Puberty, d	339	334	10	0.70
Cycling at beginning of breeding season, %	61	67	-	0.45
Calved in first 21 d, %	77	49	-	0.005
Overall pregnancy rate, %	93	80	-	0.05
Calving date, Julian d	71	75	3	0.15
Calf birth wt, kg	33	33	1	0.94
Unassisted births, %	78	64	-	0.24

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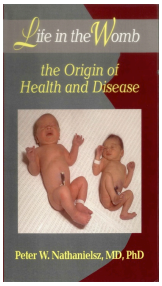
10 PRINCIPLES OF DEVELOPMENTAL PROGRAMMING

1) During development in the womb, there are **critical periods of vulnerability** to suboptimal conditions.

Vulnerable periods occur at different times for different tissues.



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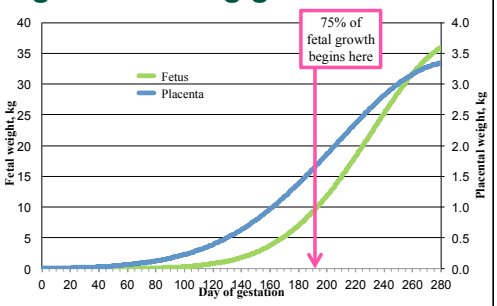
Bovine Fetal Growth Time Line

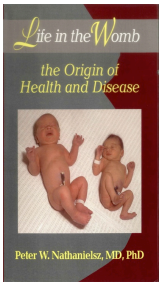
Relationship of fetal and placental growth during gestation



Based on data from Prior and Laster, 1979

10 PRINCIPLES OF DEVELOPMENTAL PROGRAMMING

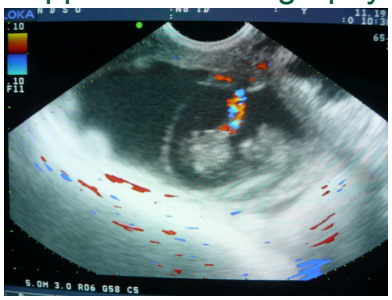
5) The placenta plays a key role in programming.



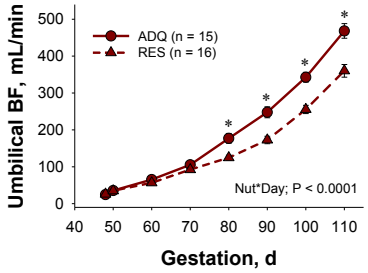
The Cow Placenta

It's gotta be blood flow!

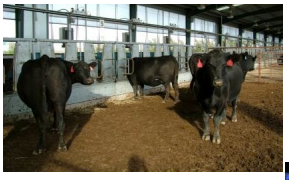
Doppler Ultrasonography

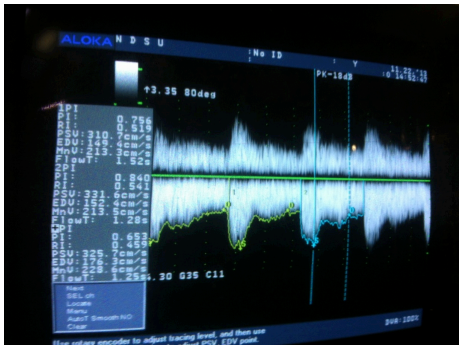


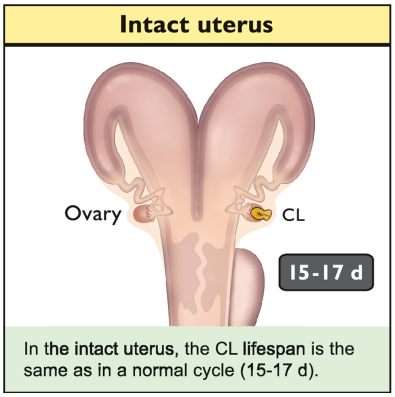
Umbilical Blood Flow



Lemley et al., 2012

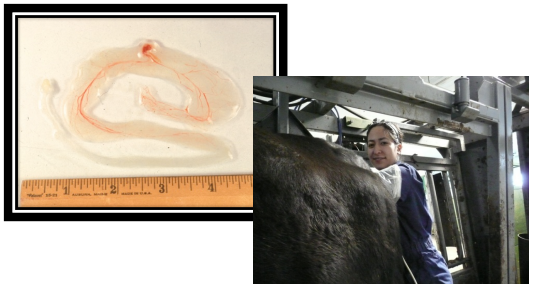




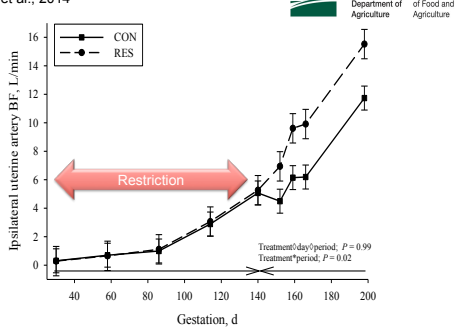


Senger text

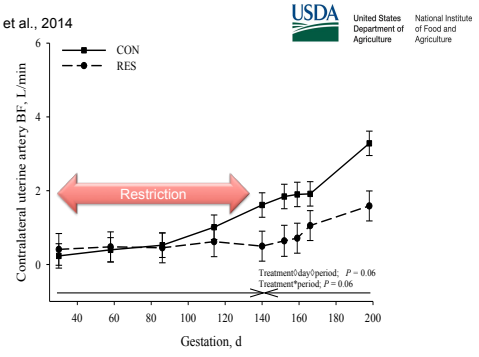
What does restriction do?

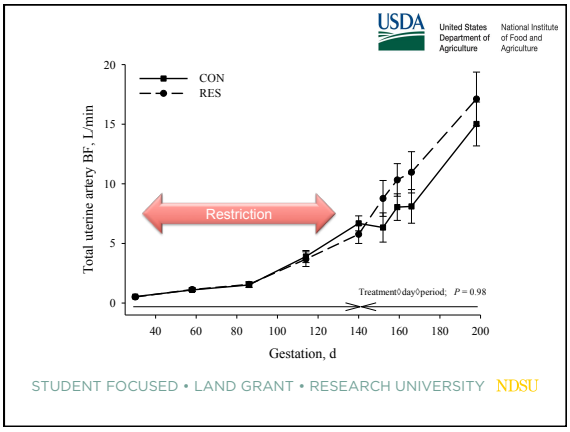


Camacho et al., 2014



Camacho et al., 2014




USDA
United States Department of Agriculture
National Institute of Food and Agriculture
CON
RES
Restriction
Total uterine artery BF, L/min
Gestation, d
Treatment×day×period; P = 0.98
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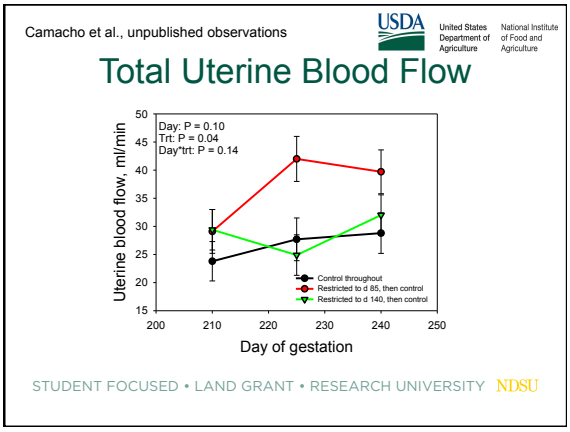
Camacho et al., unpublished observations
USDA
United States Department of Agriculture
National Institute of Food and Agriculture
Total Uterine Blood Flow
Day: P = 0.10
Trt: P = 0.04
Day*trt: P = 0.14
Uterine blood flow, ml/min
Day of gestation
Control throughout
Restricted to d 85, then control
Restricted to d 140, then control
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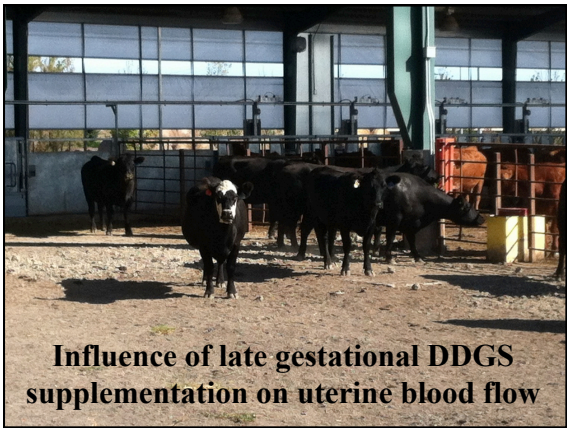
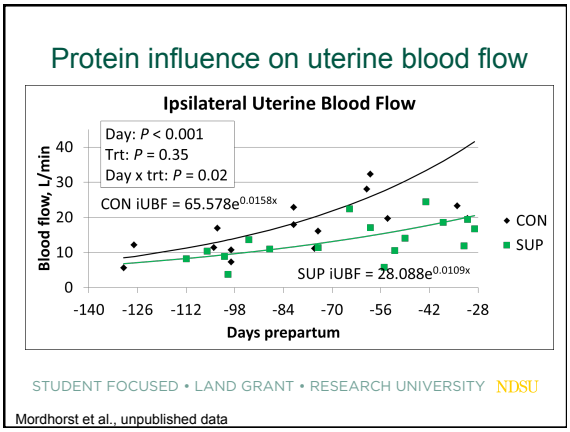

Influence of late gestational DDGS supplementation on uterine blood flow


Protein influence on uterine blood flow
Ipsilateral Uterine Blood Flow
Day: P < 0.001
Trt: P = 0.35
Day x trt: P = 0.02
CON iUBF = 65.578e0.0158x
SUP iUBF = 28.088e0.0109x
Blood flow, L/min
Days prepartum
CON
SUP
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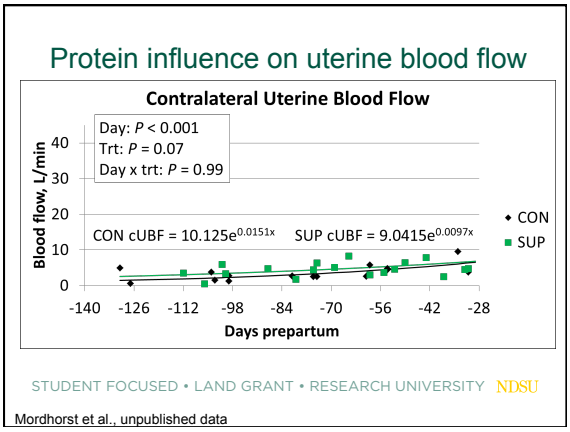
Mordhorst et al., unpublished data


Protein influence on uterine blood flow
Contralateral Uterine Blood Flow
Day: P < 0.001
Trt: P = 0.07
Day x trt: P = 0.99
CON cUBF = 10.125e0.0151x
SUP cUBF = 9.0415e0.0097x
Blood flow, L/min
Days prepartum
CON
SUP
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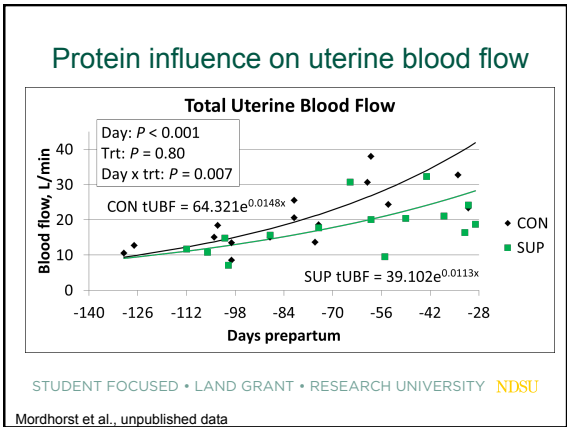
Mordhorst et al., unpublished data


Protein influence on uterine blood flow
Total Uterine Blood Flow
Day: P < 0.001
Trt: P = 0.80
Day x trt: P = 0.007
CON tUBF = 64.321e0.0148x
SUP tUBF = 39.102e0.0113x
Blood flow, L/min
Days prepartum
CON
SUP
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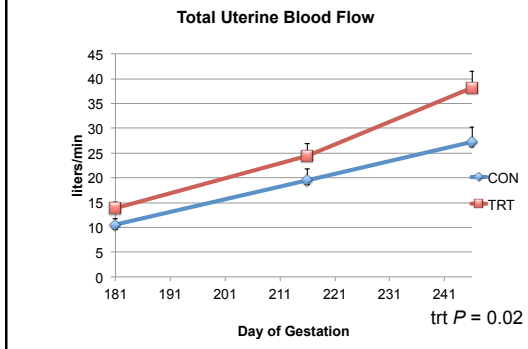
Mordhorst et al., unpublished data

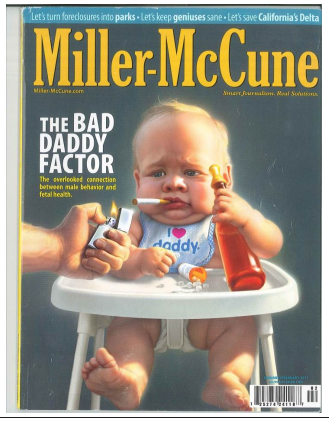
Protein in 2013-2014



Kennedy et al., unpublished data

UPDATE: 2013-2014

- Harsh winter
- Same cows (plus more) as last protein project
- Poorer quality forage (Cornstalks)
- Increased birth weights (no dystocia)
- Milk production measured



Don't Just Blame Your Mom!

- Research studies performed in rodents
  - Drugs
  - Carcinogens
  - Environmental estrogens (BPA)
- Conclusions: Dad can impact fetal development
- Work in livestock is largely lacking.

Developmental Programming

- Placenta plays a key role in developmental programming
  - "Plastic"
  - Ability to compensate
  - Target for therapeutics

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Future Directions

- Maternal intake
- Maternal efficiencies
- Timing of supplementation
- Specific components of the diet?

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Goal: Healthy Offspring!!!

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Acknowledgements

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