Feeding the Future: How maternal nutrition impacts the next generation

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Acknowledgments

- Collaborators at NDSU
  - Kendall Swanson
  - Joel Caton
  - Marc Bauer
  - Christopher Schauer
  - Steve O'Rourke
  - Larry Reynolds
  - Dale Redmer
  - Anna Grazul-Bilska
  - Justin Luther
  - Gerry Stokka
  - Carrie Hammer
  - Greg Lardy
  - Kasey Carlin
  - Eric Berg
  - Alison Ward

- Other collaborators
  - Rick Funston—UNL
  - Bret Taylor—USDA-ARS SES
  - Caleb Lemley– MSU

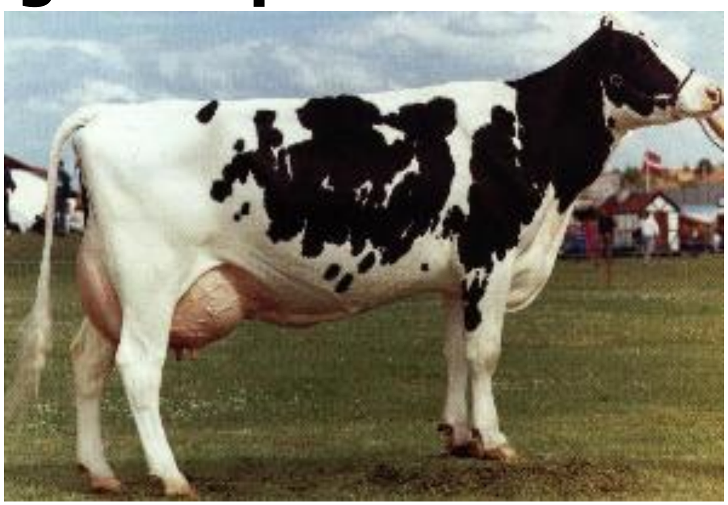
- Students and Staff
  - Bethany Mordhorst
  - Arshi Reyaz
  - Leslie Lekatz
  - Megan Van Emon
  - Leticia Camacho
  - Victoria Kennedy
  - Allison Meyer
  - Tammi Neville
  - Jim Kirsch
  - Sheri Dorsam
  - Veselina Valkov
  - Alex Vasquez
  - Amelia Tanner
  - Hanaa Mansour
  - Briana Ferguson
  - Erin Harris
  - Craig Zimprich
  - Jake Reed
  - James Gaspers
  - Praveen Shukla
  - Many others……

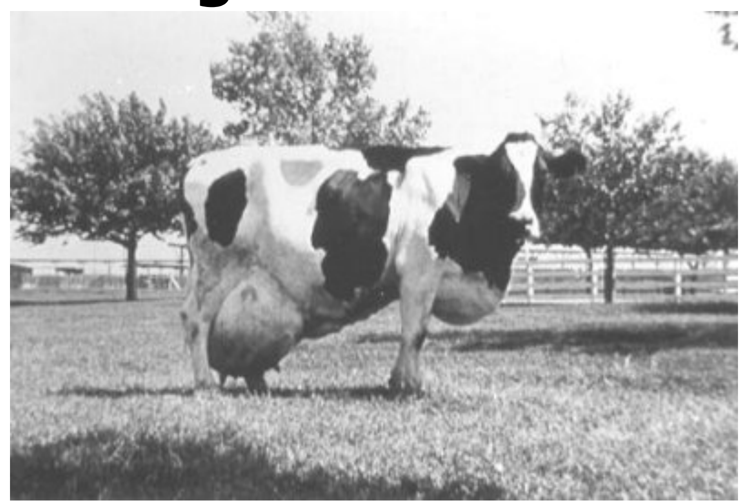
Phenotype

Classic Animal Breeding Example

Phenotype = Genotype + Environment

Eg. Milk production = Holstein genetics + Mastitis



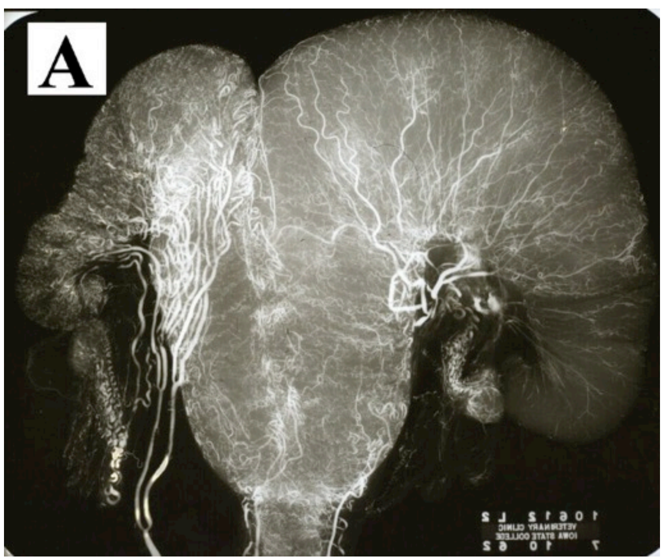


Phenotype

Future Animal Breeding Example

Phenotype = Genotype + Environment

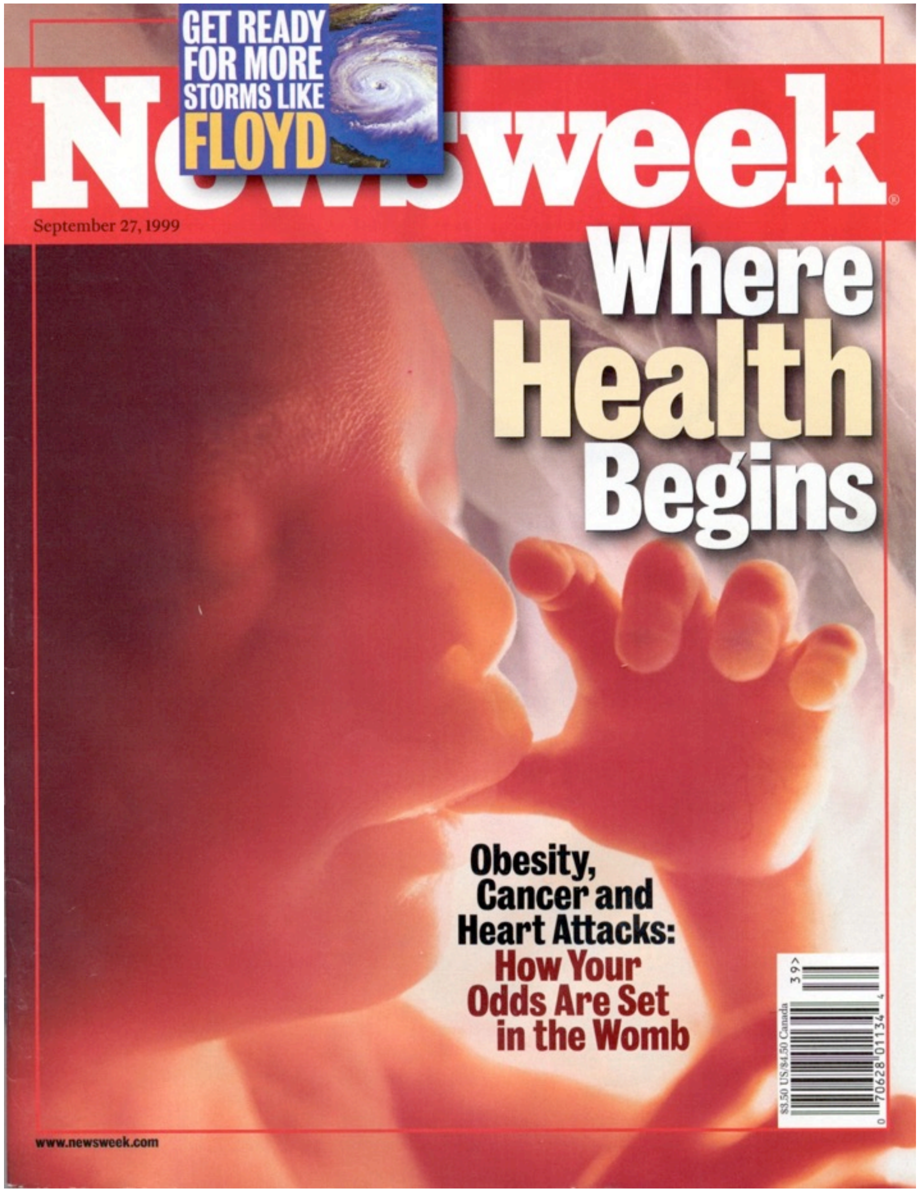
Eg. Yield grade = Angus genetics + Uterine environment



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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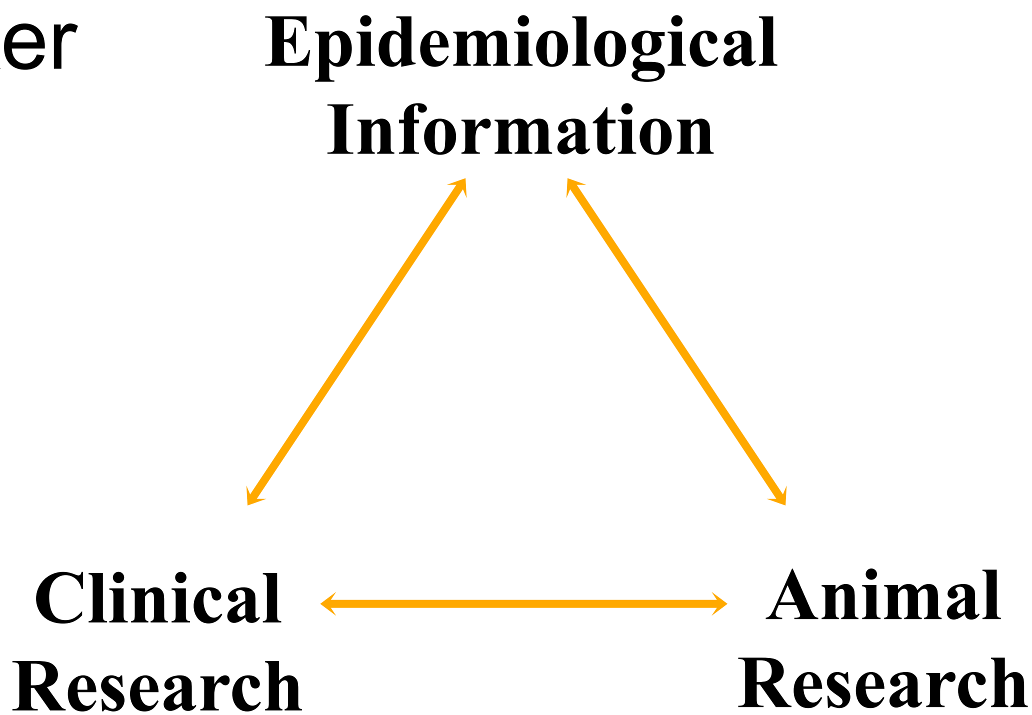
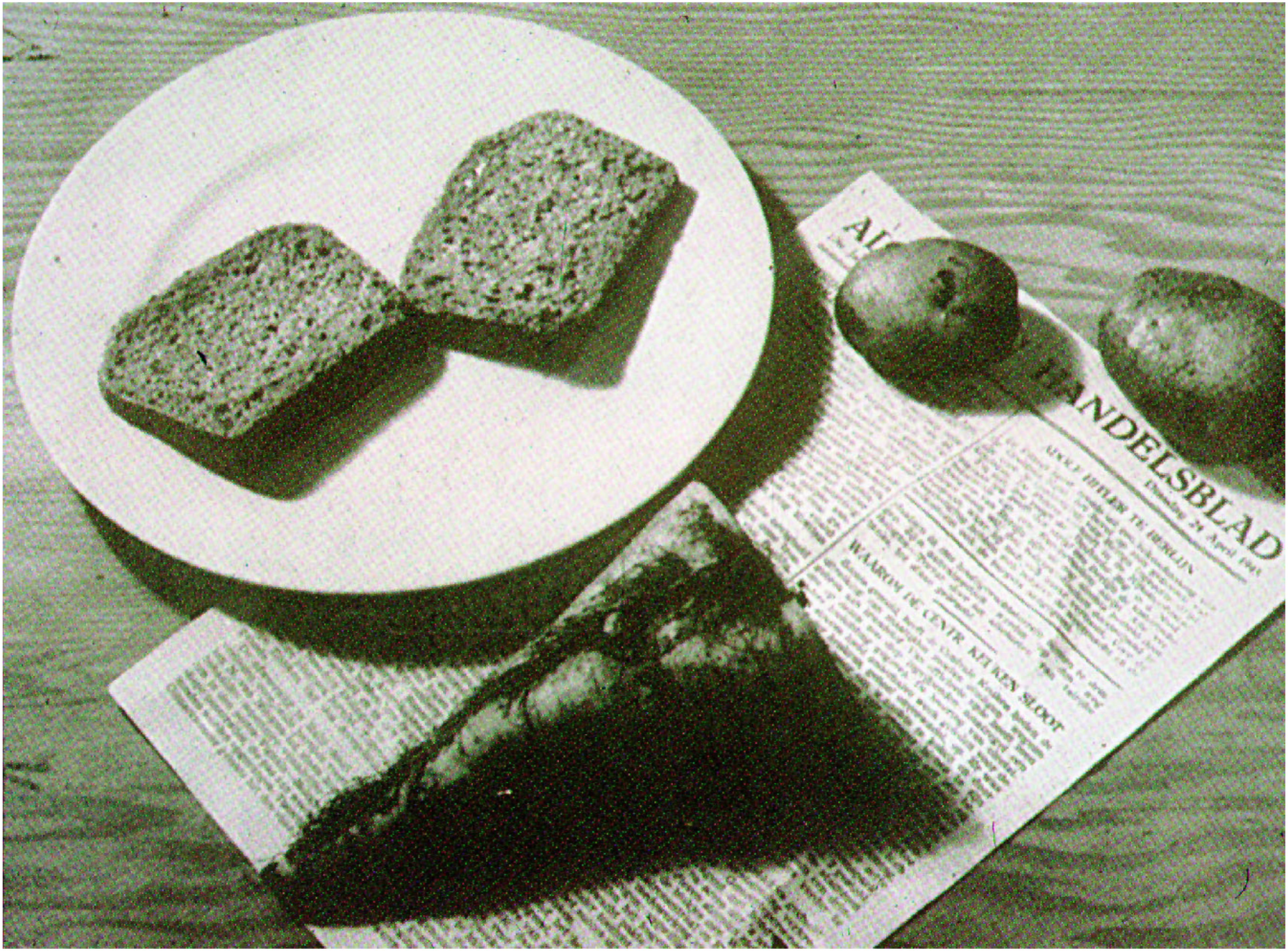
TIME
How the first nine months shape the rest of your life
The new science of fetal origins
BY ANNIE MURPHY PAUL

Developmental (Fetal) Programming

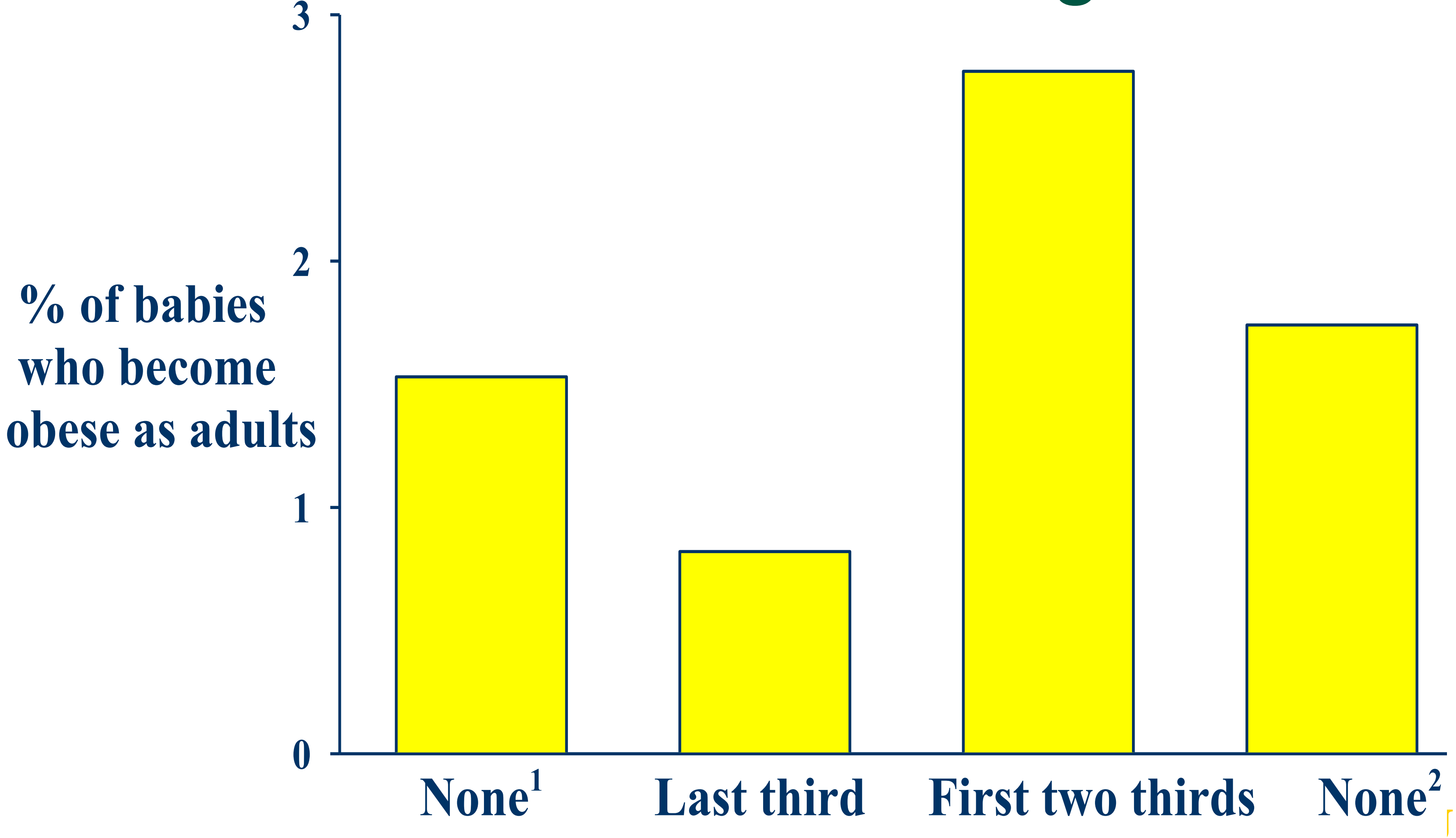
- Also known as the “Barker Hypothesis”
- Dr. David Barker



The Dutch Hunger Winter
September 1944 - May 1945


NDELSBLAD

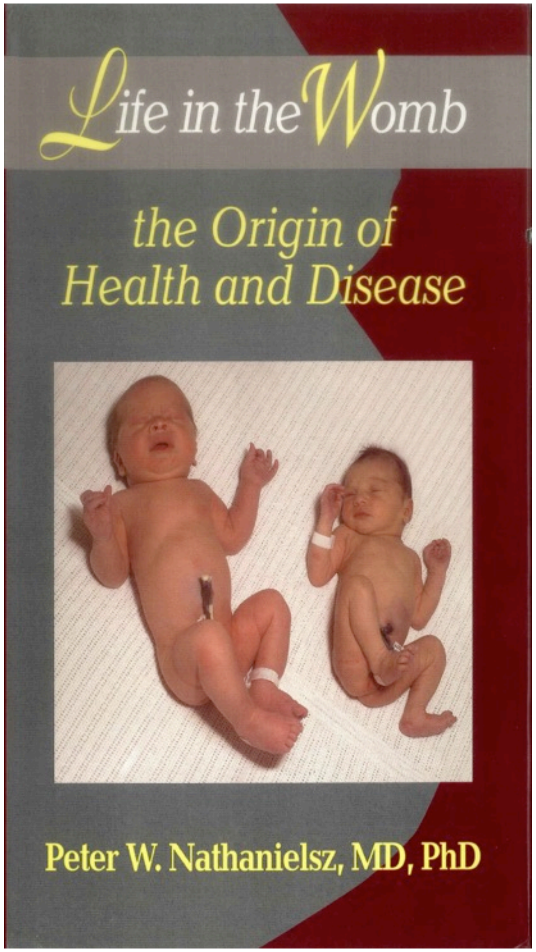
Incidence of adult obesity in the children of the Dutch Hunger Winter



10 PRINCIPLES OF DEVELOPMENTAL PROGRAMMING

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

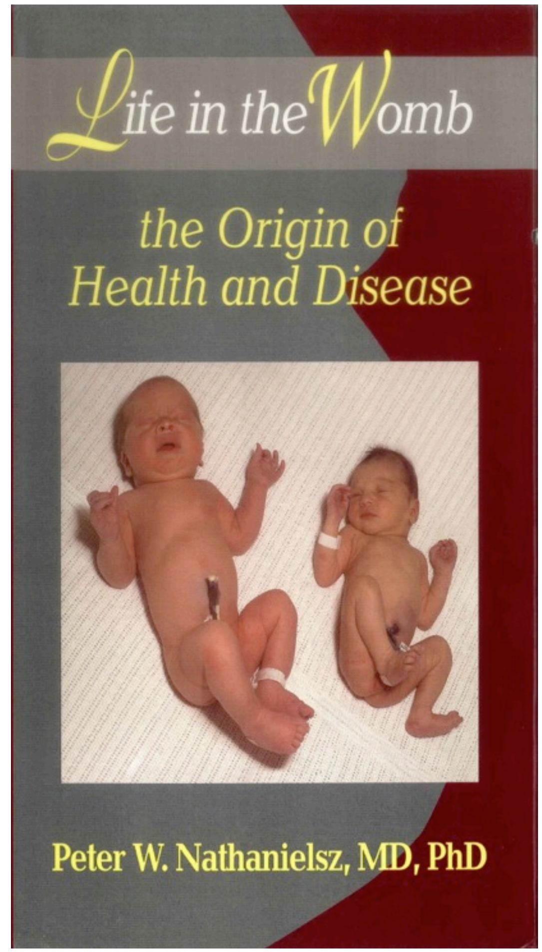
Vulnerable periods occur at different times for different tissues.



Bovine
Fetal
Growth
Time Line

10 PRINCIPLES OF DEVELOPMENTAL PROGRAMMING

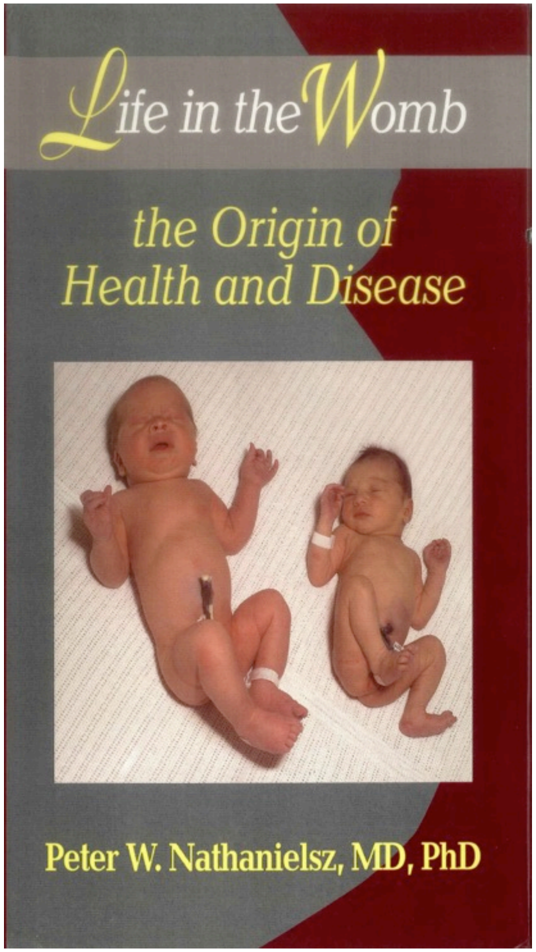
5) The placenta plays a key role in programming.

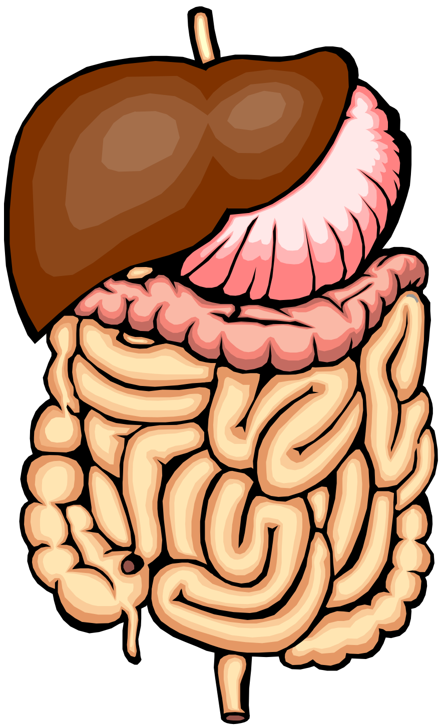


SHEEP AND COW PLACENTAS

10 PRINCIPLES OF DEVELOPMENTAL PROGRAMMING

6) **Compensation carries a price.** In an unfavorable environment, the developing baby makes attempts to compensate for deficiencies. However, the compensatory effort often carries a price.





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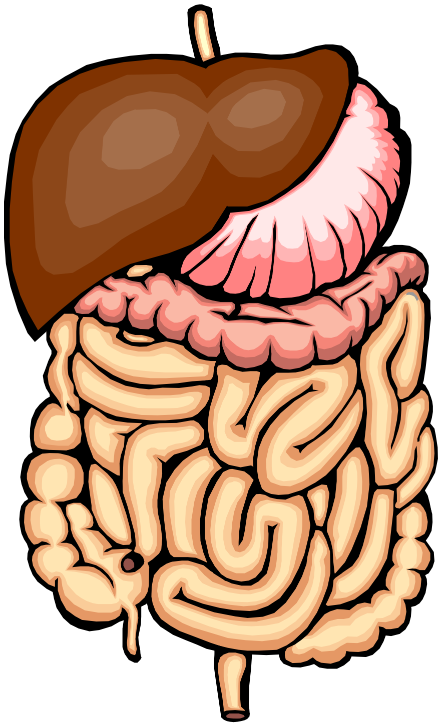

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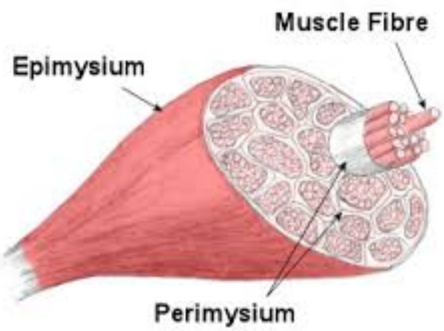
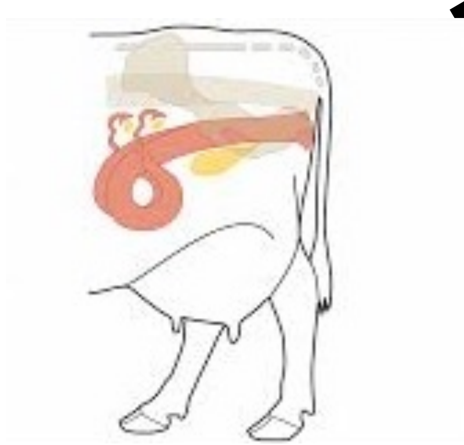

Muscle Fibre
Epimysium
Perimysium



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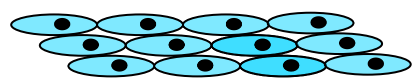
Mechanisms of Programming?

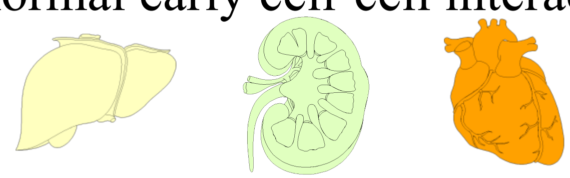
Nutritional Influence

Altered cell number or
intracellular organization

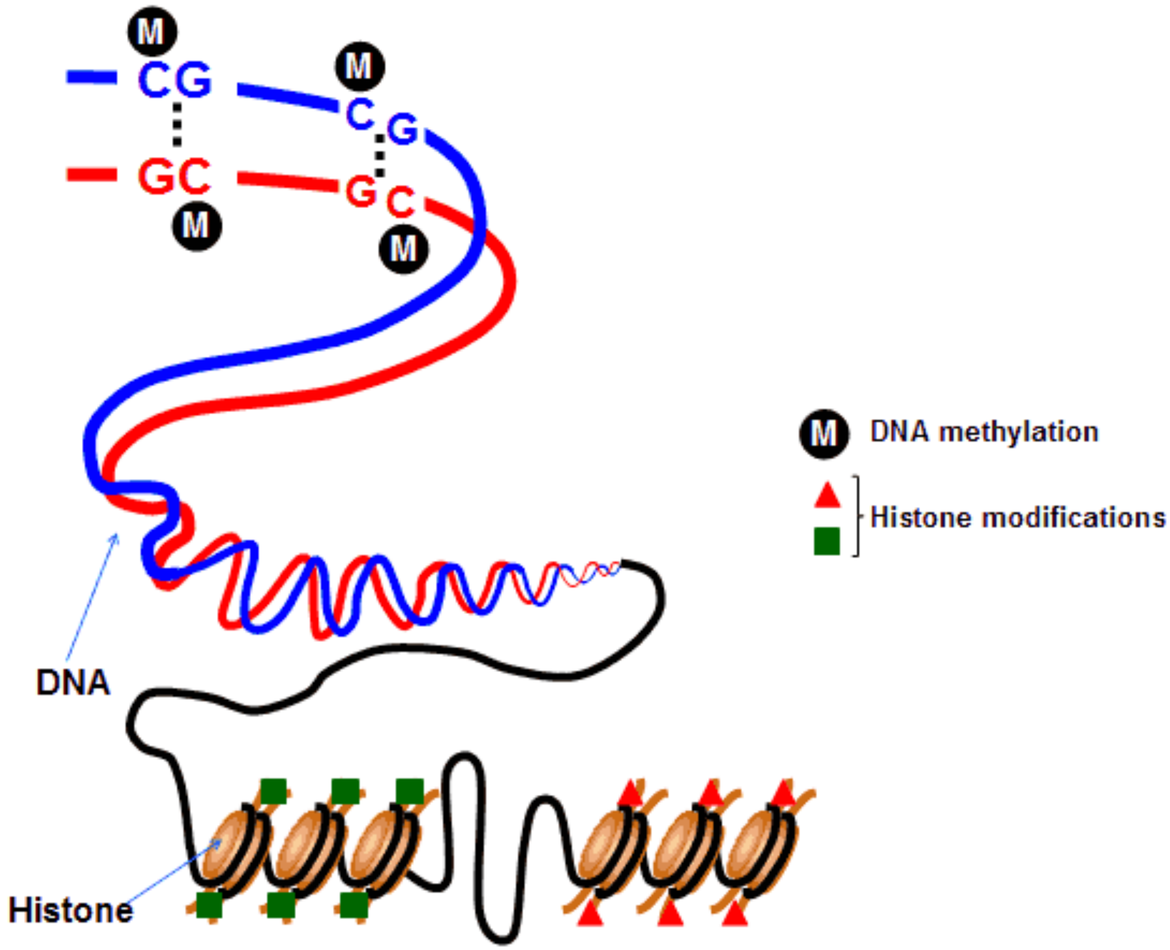


Metabolic Differentiation
DNA Control?
(altered cell specific gene regulation)
DNA Environment?
(altered DNA binding proteins)
Altered DNA methylation?

Reorganisation of organ structure
Abnormal early cell-cell interactions?

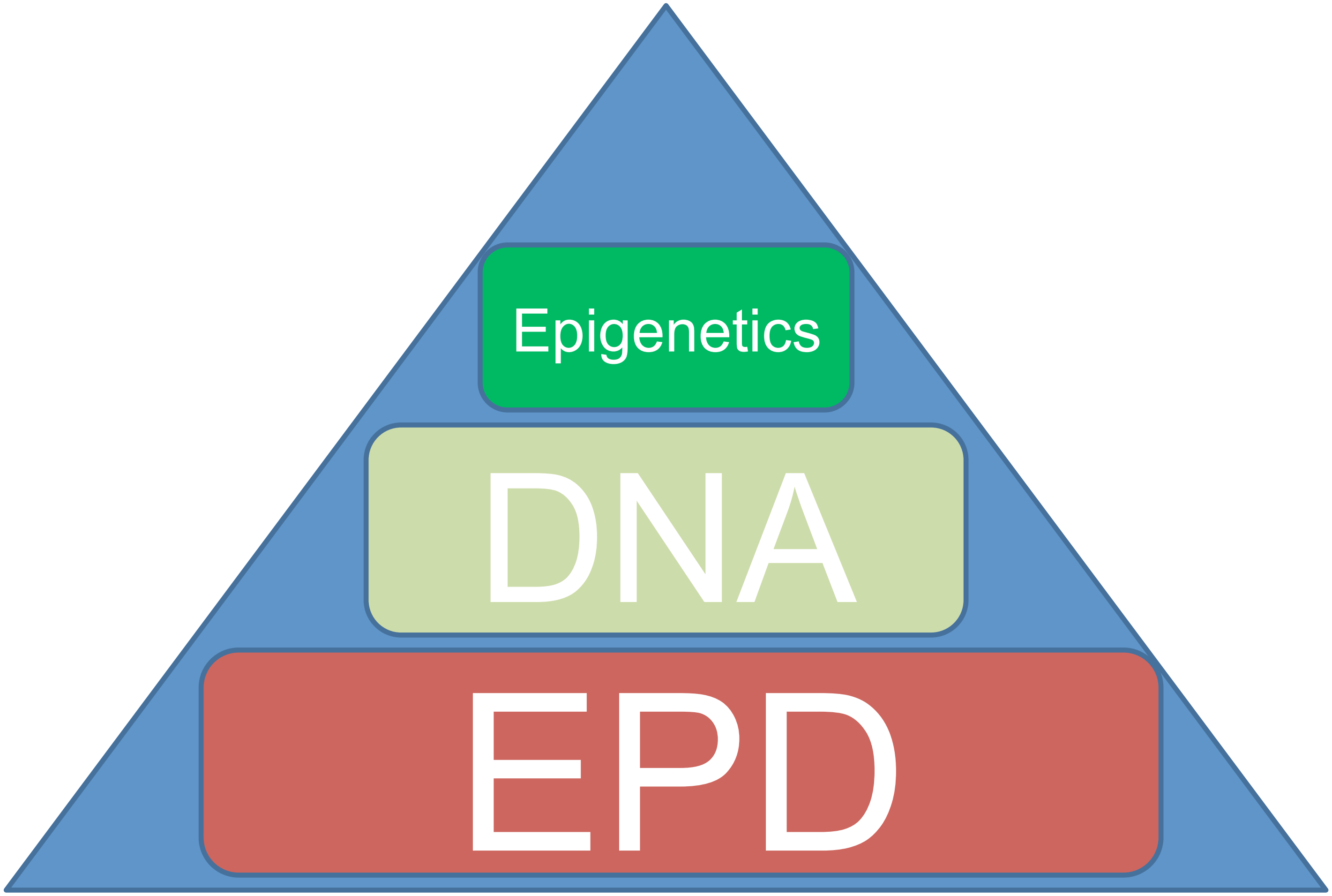


Epigenetics



The study of changes in gene expression or cellular phenotype, caused by mechanisms other than changes in the underlying DNA sequence

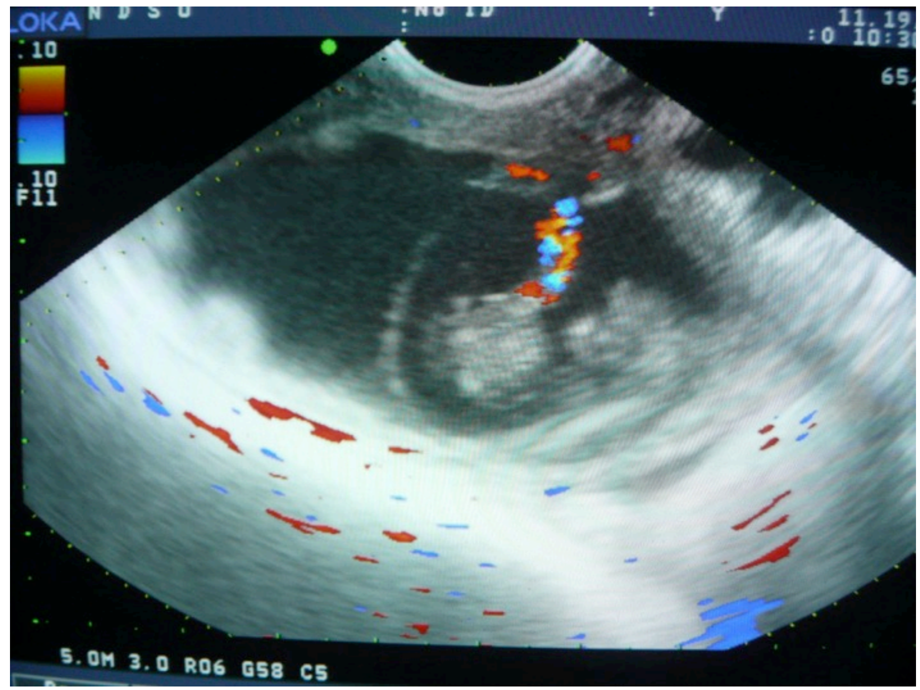
How does epigenetics fit into selection?



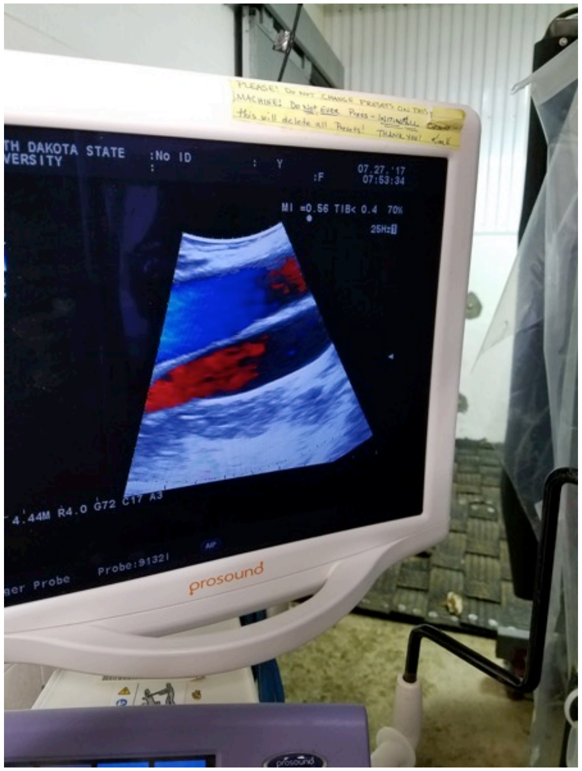
What's Happening at NDSU?

Goal of my lab

- How is nutrition altering placental function?



Doppler Ultrasonography

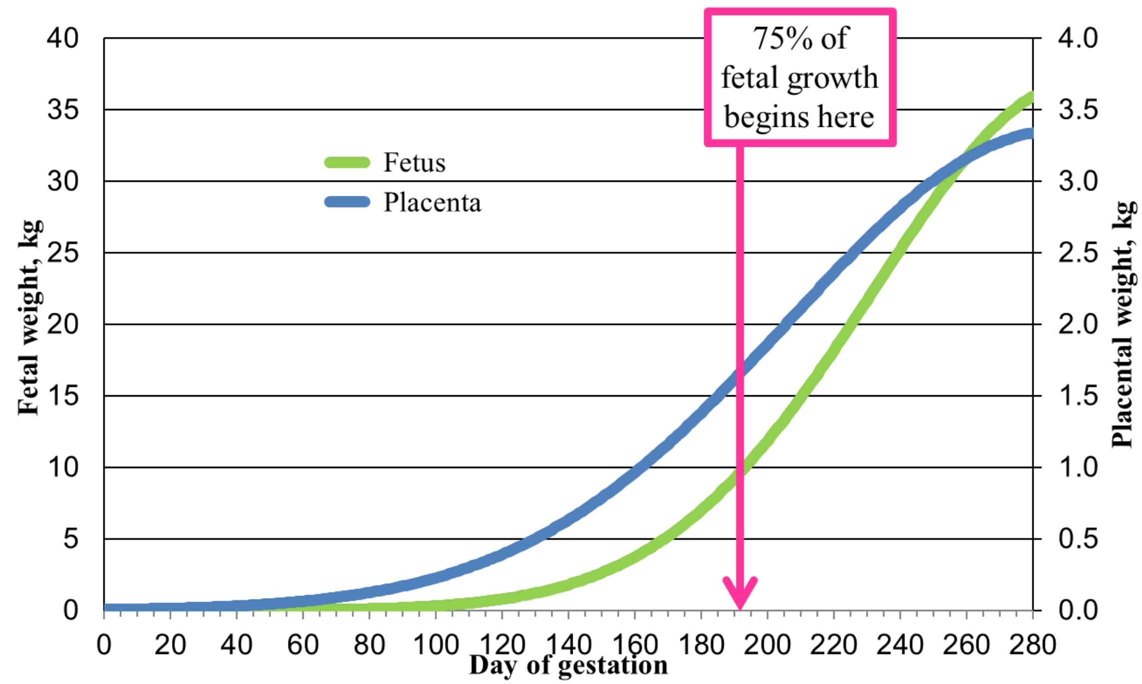


Consequences in beef cattle

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

*References are not NDSU; happy to provide



Based on data from Prior and Laster, 1979

USDA United States Department of Agriculture
National Institute of Food and Agriculture

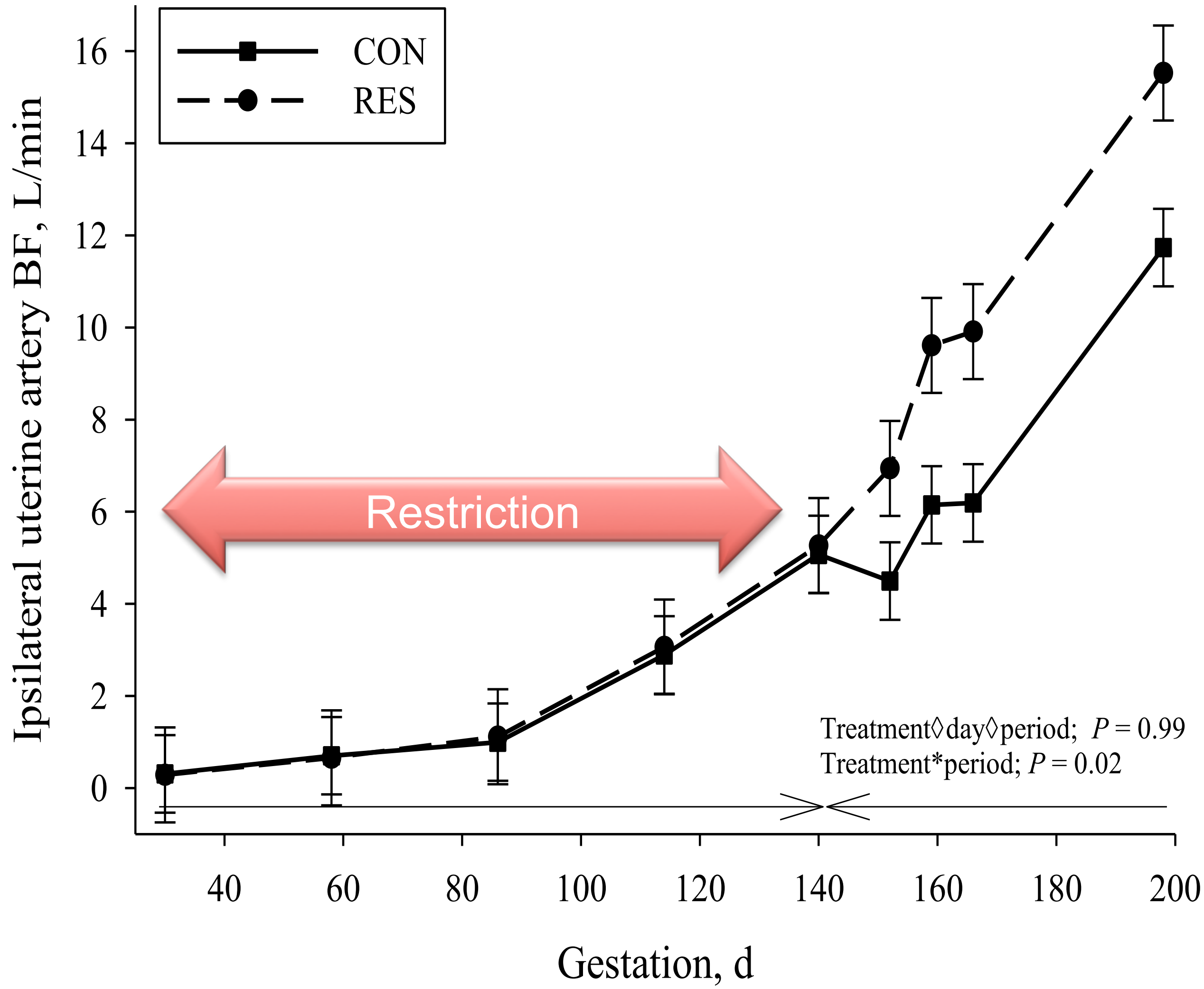
Percentage NRC recommendations

100%	100%	100%	100%
	60%	100%	
	60%	60%	

d 0 d 30 d 85 d 140 d 260

United States Department of Agriculture

National Institute of Food and Agriculture



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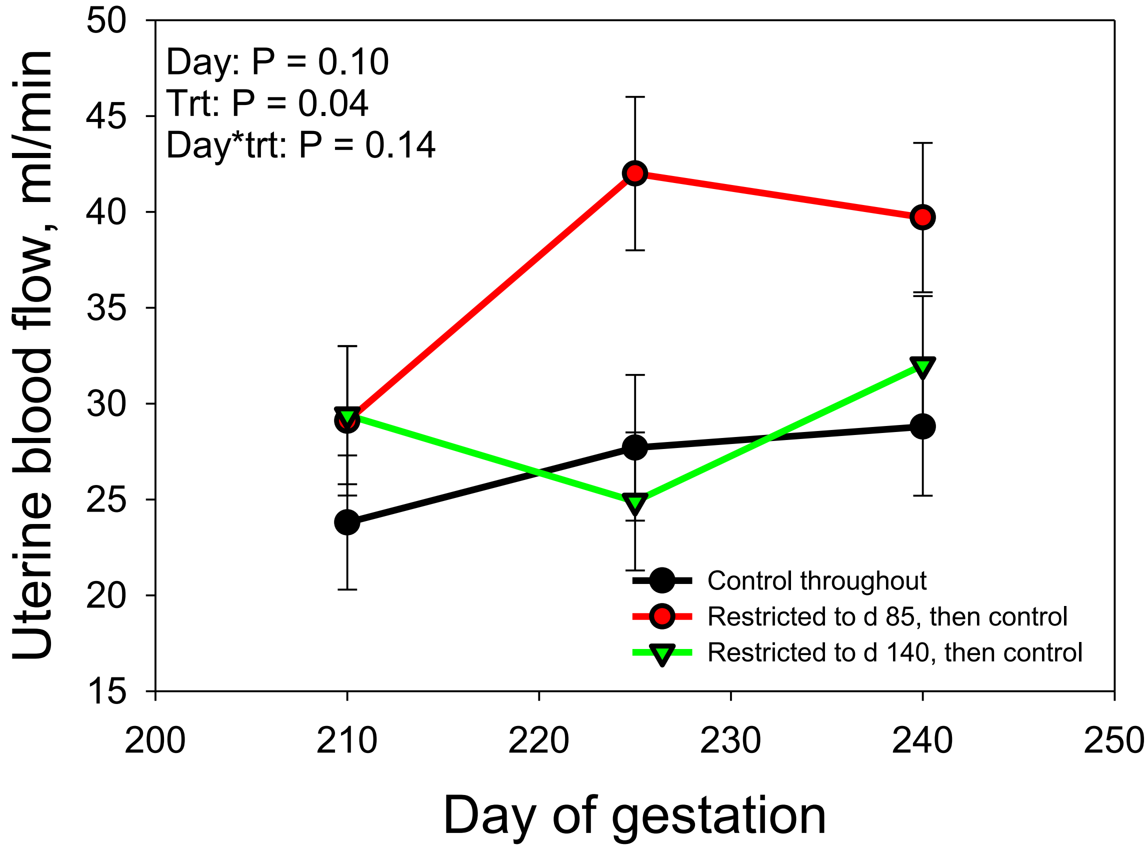
Camacho et al., 2014

United States Department of Agriculture
National Institute of Food and Agriculture

Total Uterine Blood Flow



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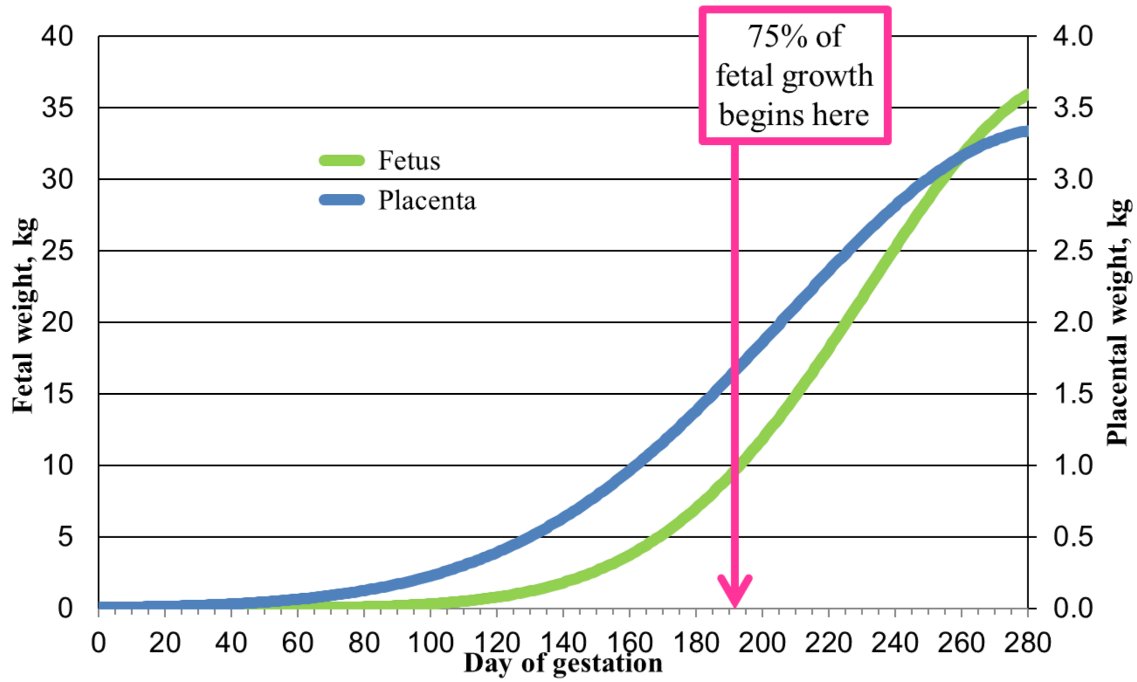
Camacho et al., unpublished observations

Protein Supplementation During Late Pregnancy



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

Martin et al., 2007

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Item	Prot	NoProt	SEM	P-value
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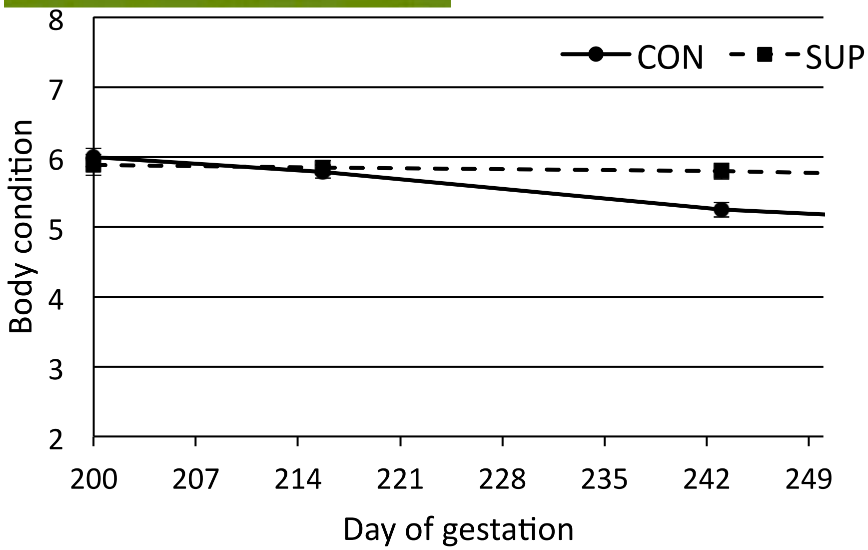
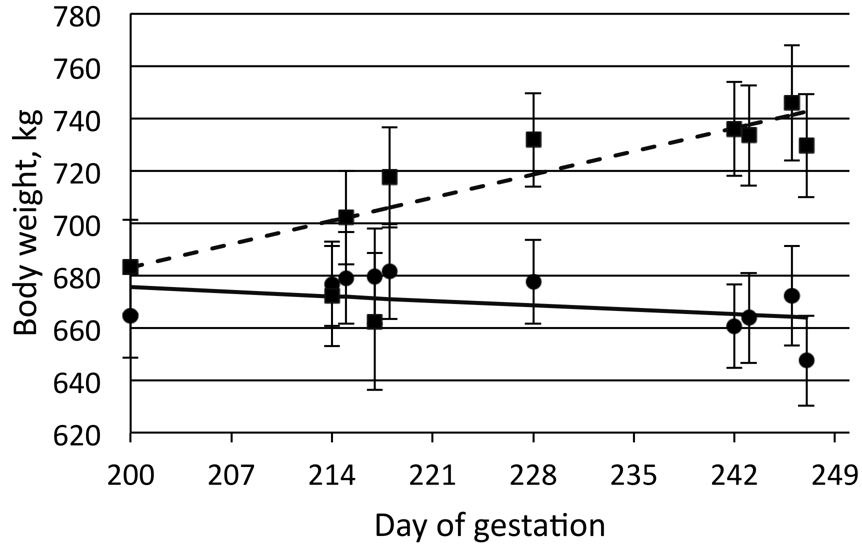
Martin et al., 2007

Protein in 2013-2014

Gestation



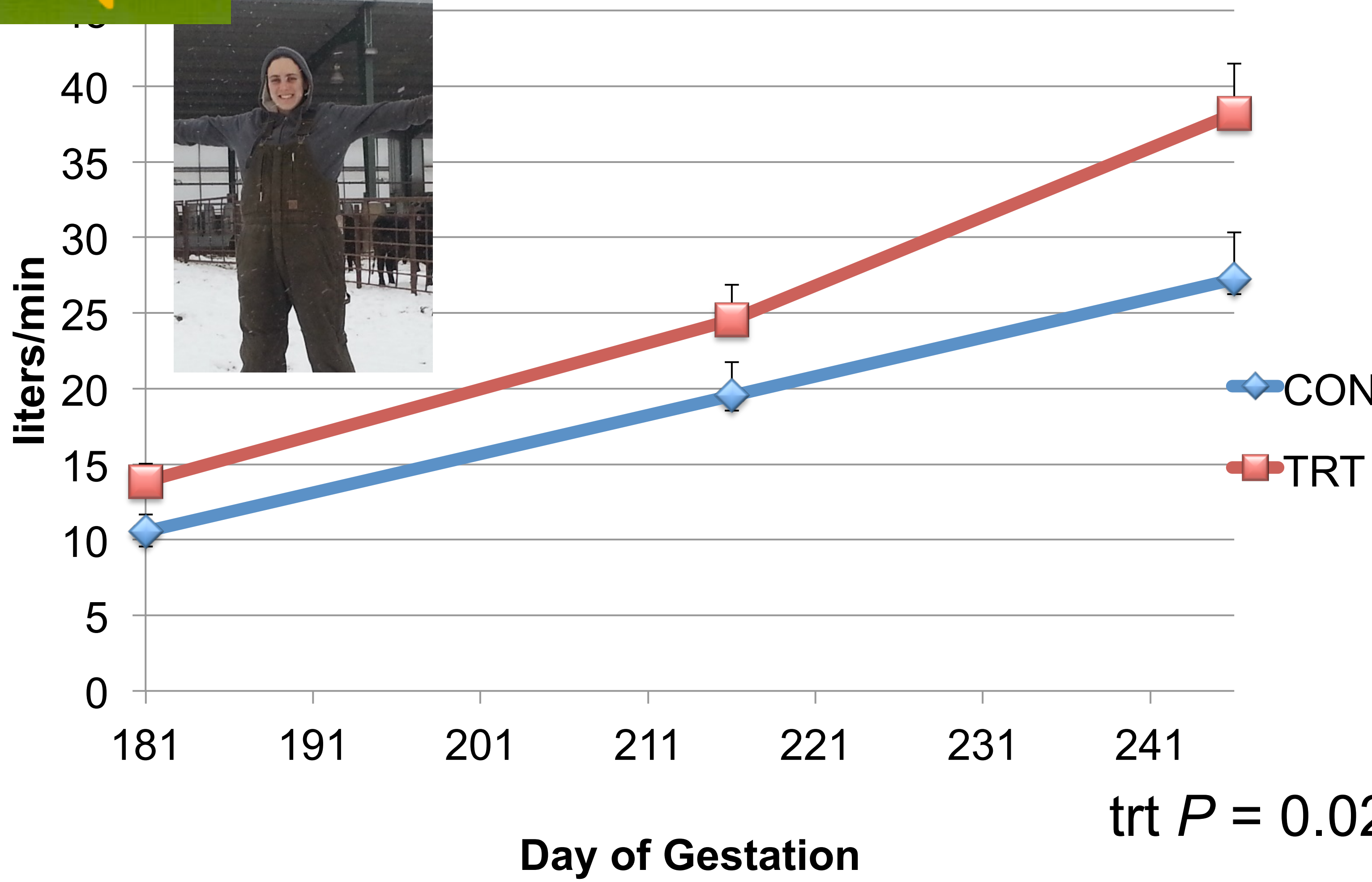


Diet*Day: (CON) $P < 0.001$ (TRT) $P = 0.80$

Diet*Day: (CON) $P = 0.06$ (TRT) $P < 0.001$

Kennedy et al., JAS 2016

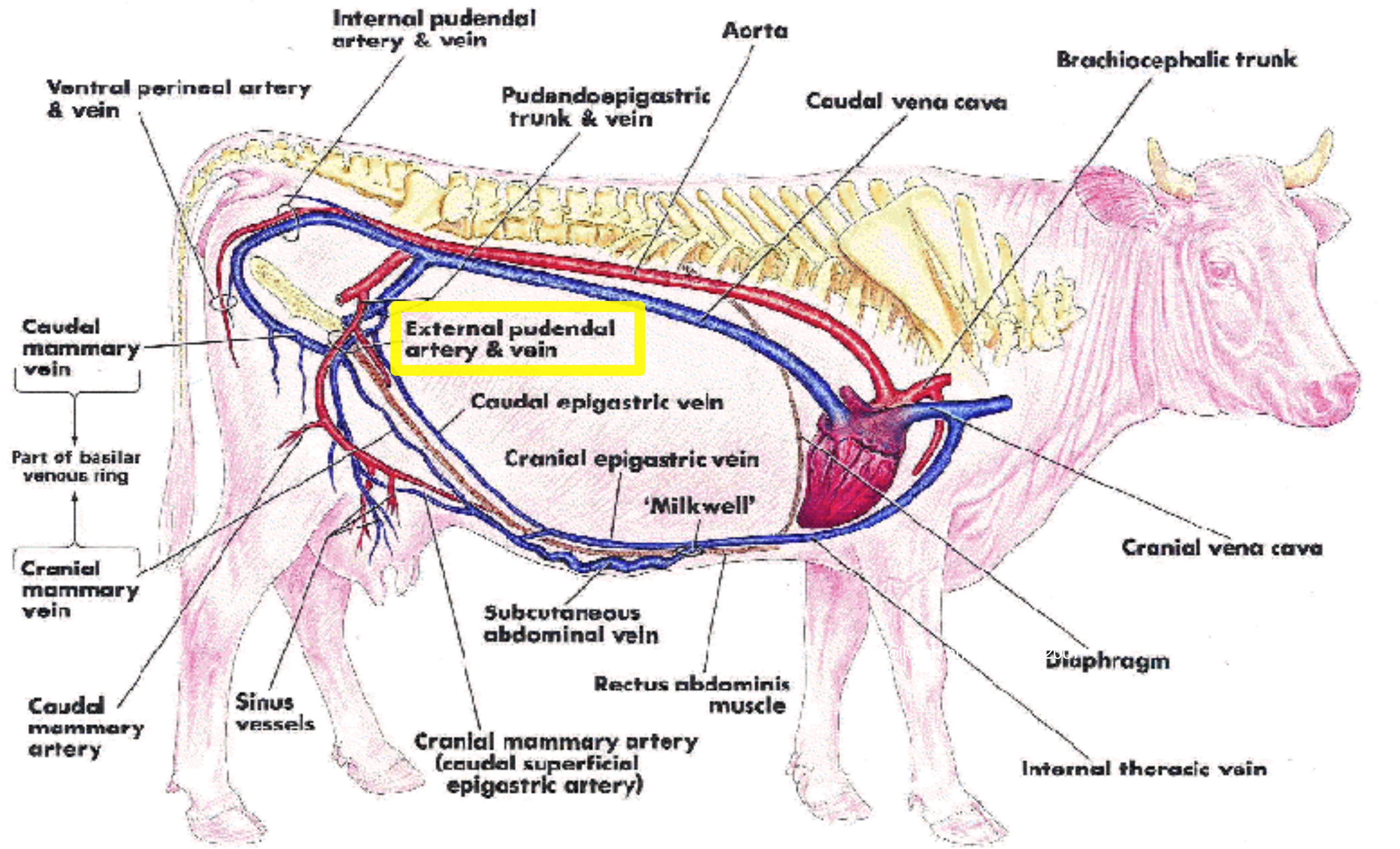
Total Uterine Blood Flow



trt $P = 0.02$

Kennedy et al., 2016

Materials and Methods



(adapted from University College Dublin, Department of Veterinary Anatomy)

NORTH DAKOTA CORN COUNCIL

Mammary BF

Table 1.
Mammary blood flow on d 245 of gestation in beef cows that were fed control or control plus supplementation from d 201 to 270 of gestation.

Variable	CON[1]	SUP[1]	SEM	*P*-value
Heart rate, bpm	63.7	75.4	2.40	**< 0.01**
Total flow volume[2], L/min	2.3	2.9	0.30	0.12
CSA[3]	0.5	0.5	0.04	0.71
Average PI[4]	1.8	1.5	0.10	**< 0.01**
Average RI[5]	0.8	0.7	0.01	**0.03**

[1] Maternal diets; CON (n = 15), control group consuming basal diet; SUP (n = 12), supplemented group consuming basal diet + DDGS at 0.3% BW

[2]Cross sectional area, cm^2

[3]Pulsatility Index = (peak systolic velocity - end diastolic velocity)/mean velocity

[4]Resistance Index = (peak systolic velocity - end diastolic velocity)/peak systolic vel

Kennedy et al., Accepted with revisions, JAS

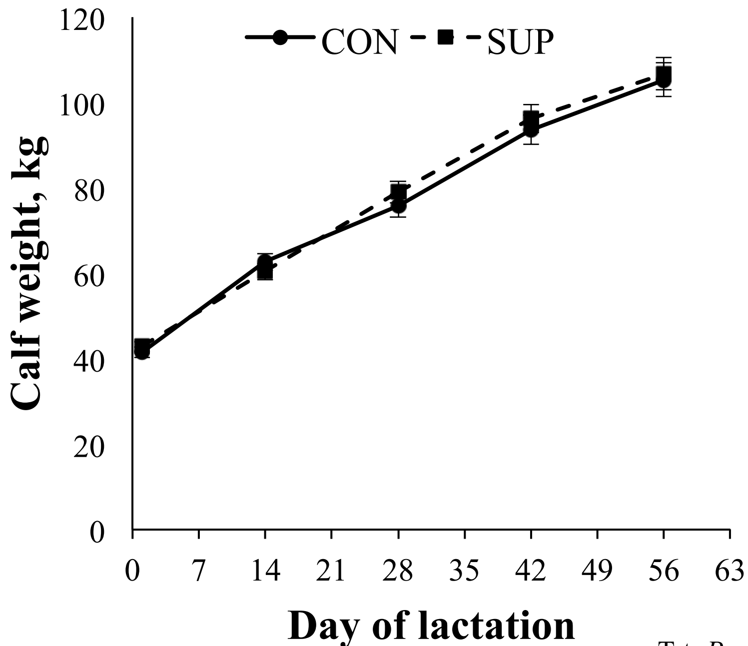
Calf weights	CON	SUP
Birth, kg (P = 0.02)	39.8 ± 1.0	43.2 ± 1.0
24 hr, kg (P = 0.02)	40.4 ± 1.1	44.0 ± 1.1
Calving ease (P = 0.39)	1.87 ± 0.36	1.44 ± 0.36

Colostrum	CON	SUP
Weight, g (P = 0.10)	614 ± 95	837 ± 95
IgG, mg/mL (P = 0.23)	119.1 ± 6.6	130.2 ± 6.6

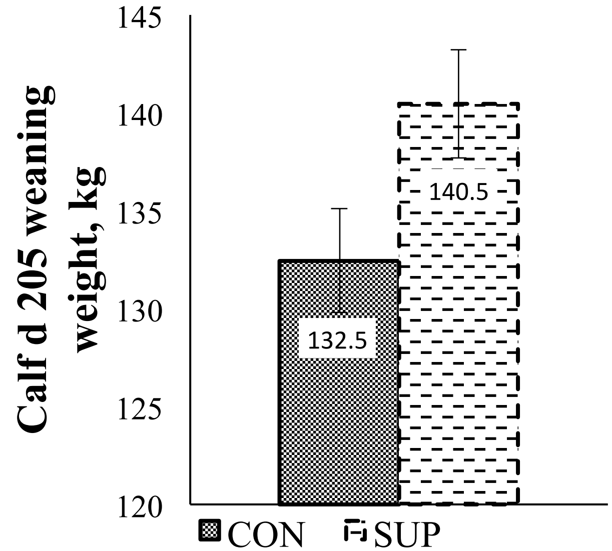
Milk, d 44	CON	SUP
Wt, kg/d (P = 0.07)	10.2 ± 1.2	13.5 ± 1.2

Kennedy et al., Accepted with revisions, JAS

Calf Growth



Trt: *P* = 0.68
Day: ***P* < 0.01**
Trt*day: *P*= 0.39



Trt: ***P* = 0.04**

Kennedy et al., Accepted with revisions, JAS

Developmental Programming

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

What now?

- Specific nutrients are probably important
  - Protein, amino acids
  - Specific minerals, vitamins
  - Too much may be detrimental; ratios
- Timing of supplement is important
  - As the metabolic demands of the dam change, so would be supplementation times
  - Being "off" could be detrimental (steroid ex)

Goal: Healthy Offspring!!!

Goal: Healthy Offspring!!!

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