Consequences of Nutrition & Growth During Gestation for Beef Production

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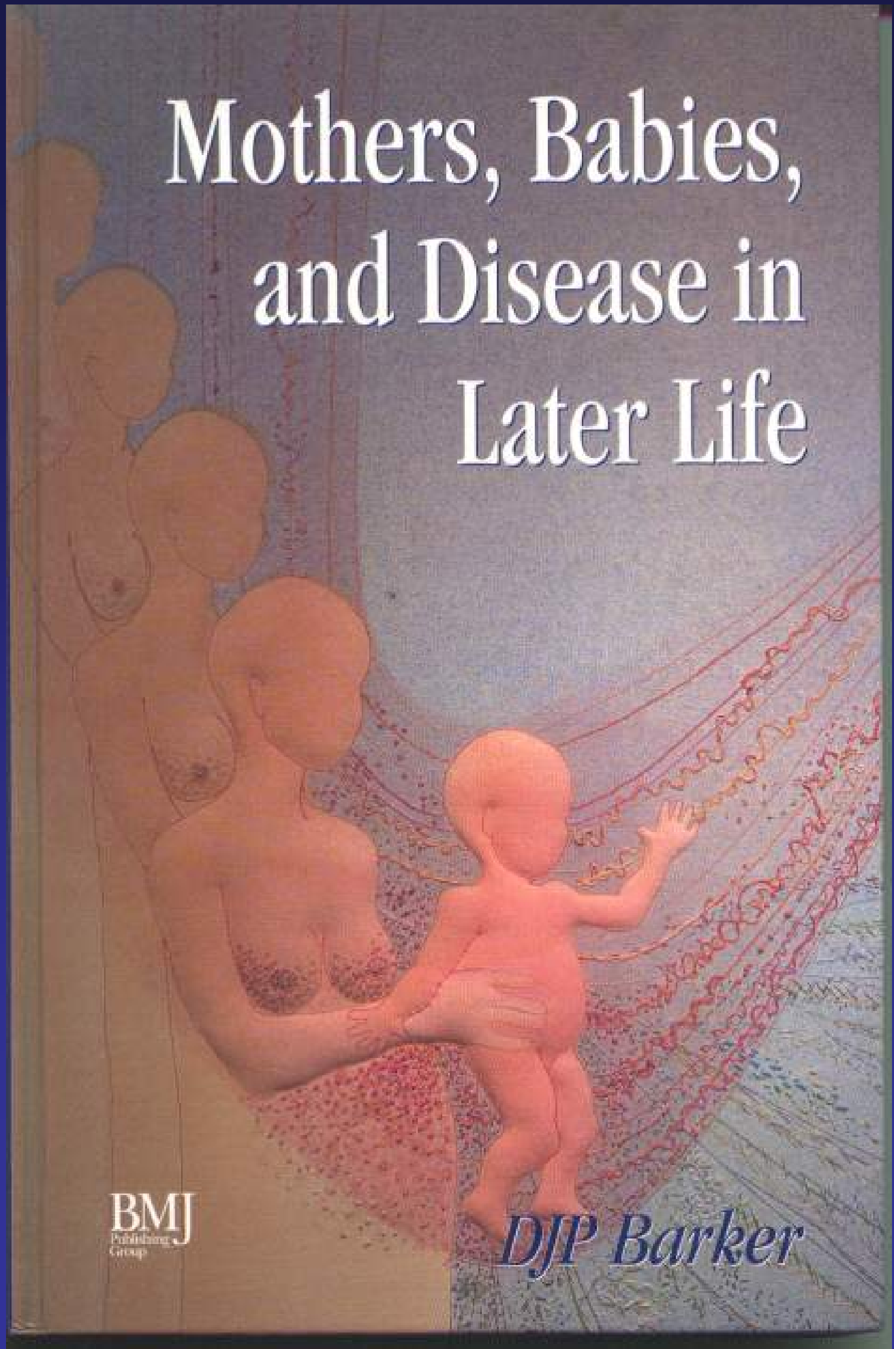
AUSTRALIA


Mothers, Babies, and Disease in Later Life
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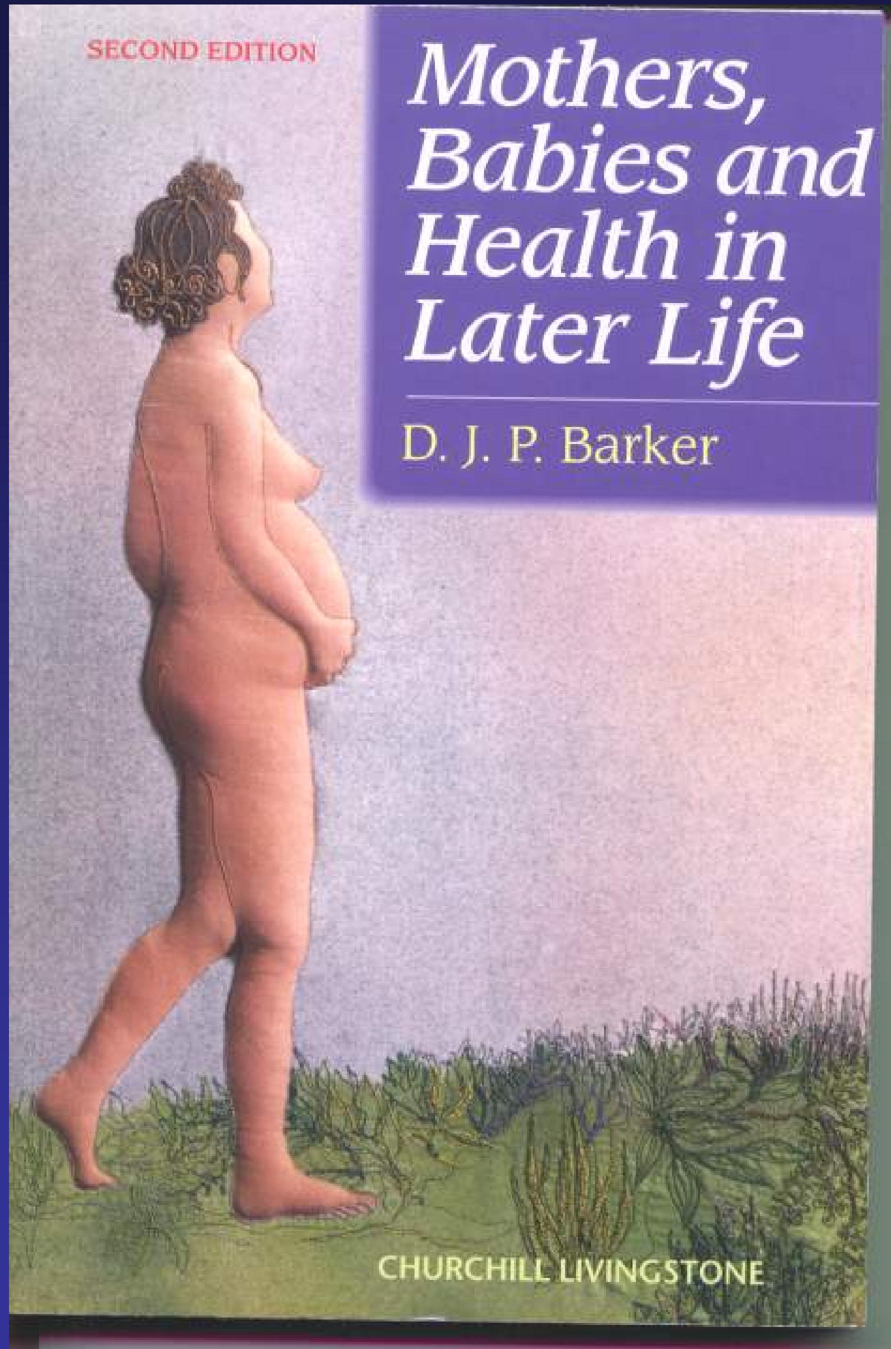
SECOND EDITION
Mothers, Babies and Health in Later Life
D. J. P. Barker
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This presentation

- Background on the Australian Beef Industry
- Consequences of nutrition of pregnant cows
- Longer-term consequences for offspring
  - Growth and efficiency
  - Carcass and yield
  - Muscle cellular development
  - Beef quality
- Conclusions and context

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CRC BEEF

Background

- Australian beef industry:
  - ~24,000 farms
  - 2.1 million tonnes of beef p.a.
  - Gross value of $8 billion p.a.
- National breeding herd is pasture-based
- Early-life and backgrounding on pasture
- Two-thirds finished & slaughtered off pasture & one-third feedlotted
- Prolonged droughts & nutritional restriction common

Background

- Paucity of information on longer-term consequences of maternal nutrition and early-life growth for commercial outcomes in beef production systems
- Australian beef industry advice:

  Growth restriction prior to weaning reduces subsequent growth and increases fatness in later life

Characteristics of the severely growth-retarded newborn lamb

- More fetal-like metabolic and endocrine status at birth
- Lower maintenance energy requirements
- Limited capacity for lean tissue growth
- High early-postnatal relative feed intake

Propensity to fatten in early-postnatal period

Greenwood *et al.* (1998-2004), Rhoads *et al.* (2000a,b), Ehrhardt *et al*. (2003)

Objectives

Answer research questions:

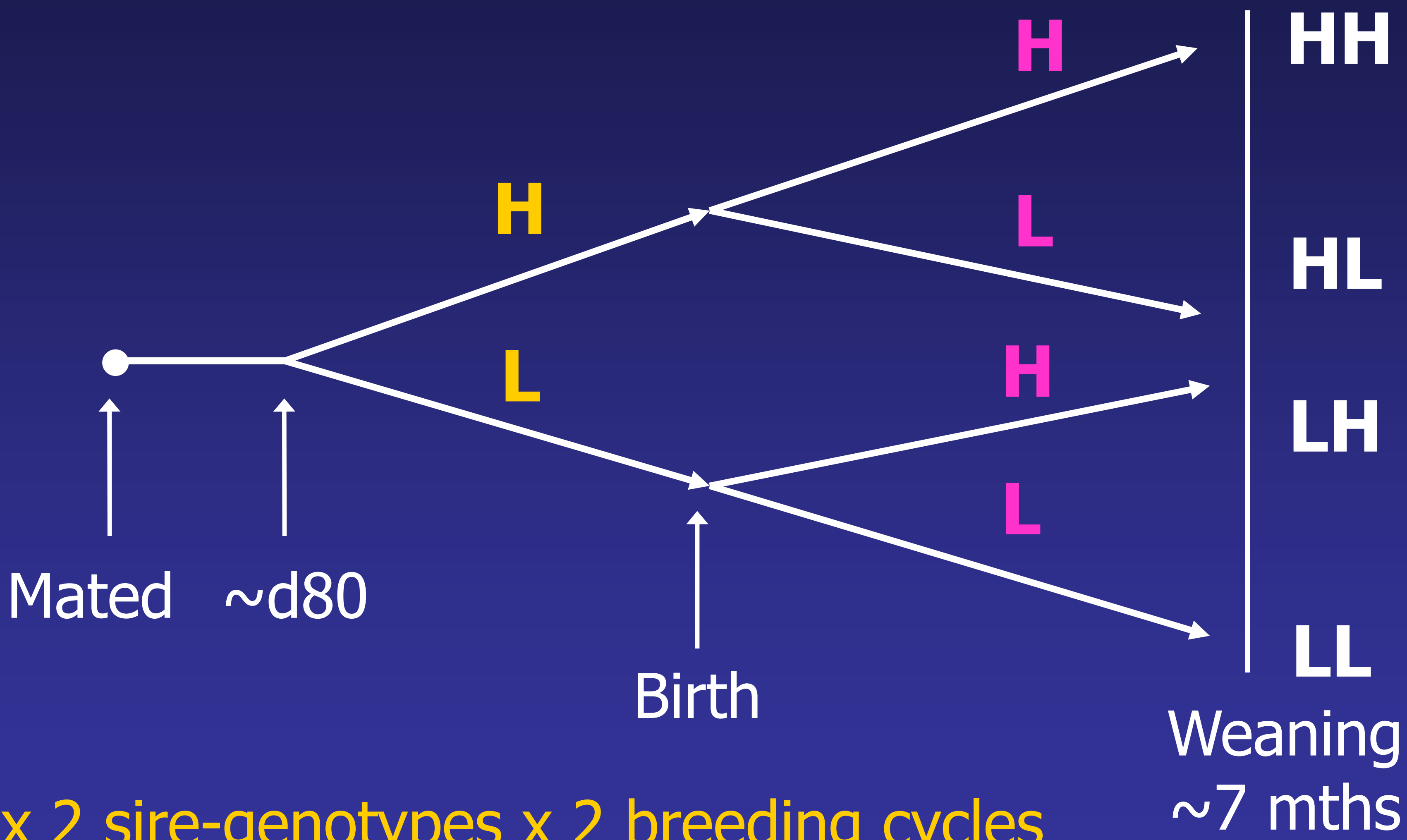
- Does severe, chronic maternal nutritional restriction of beef cows have long-term effects on offspring?
- Do prenatal and pre-weaning nutrition and growth interact to influence beef production?
- Do sire-genotype and early-life nutrition and growth interact to influence beef production?

Objectives

- Conduct research within commercial systems on commercial outcomes
- Help refine advisory information for the Australian beef industry

Consequences of Nutrition of Pregnant Cows

Pregnancy nutrition **Lactation nutrition**



x 2 sire-genotypes x 2 breeding cycles
(n = 514 cows/calves)

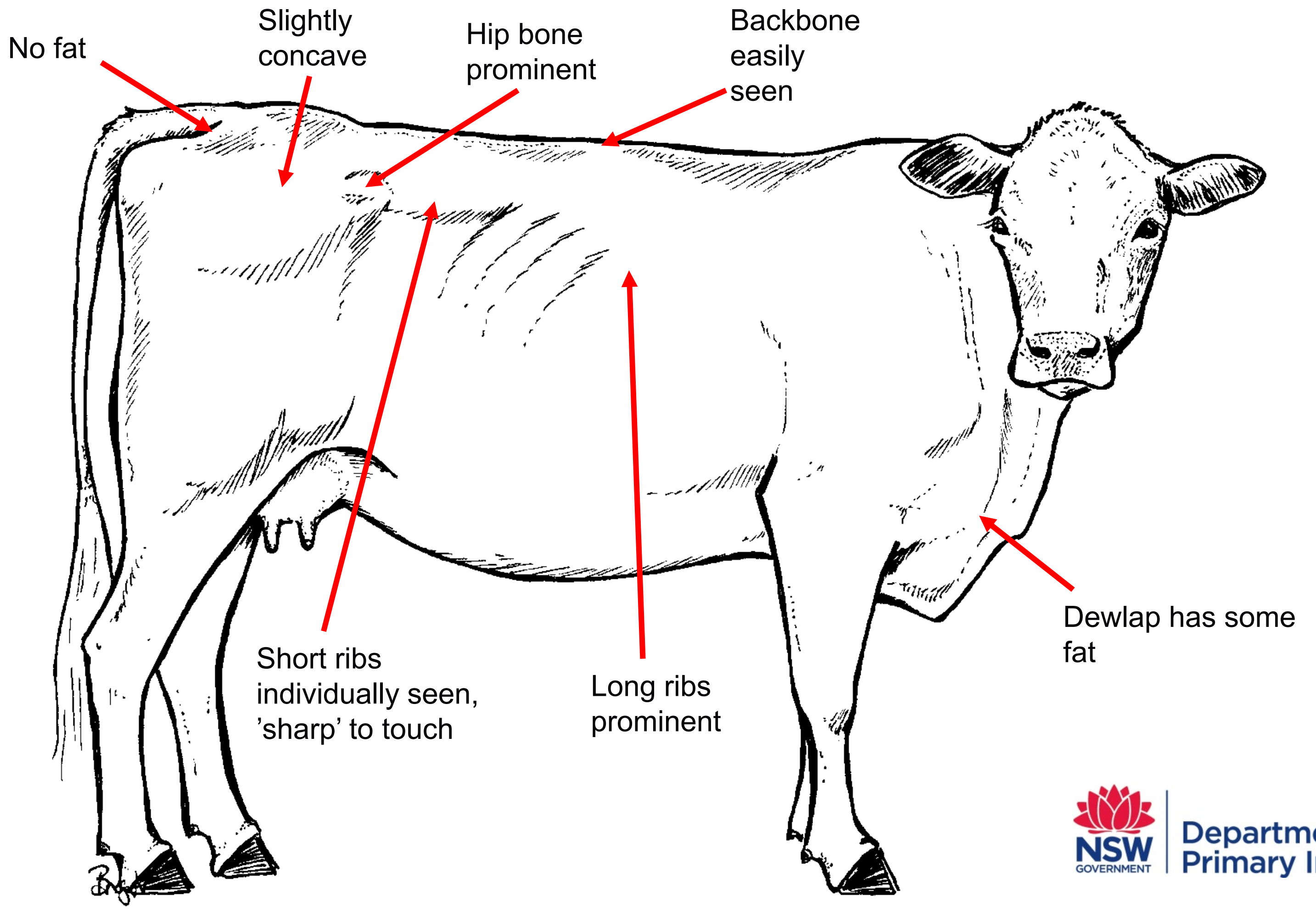
Cafe *et al.* (2006)


Maternal Nutritional Restriction

	Pregnant cow nutrition	
	High (n=285)	**Low** (n=229)
Cow LW post-partum (kg)	500	394
Cow pregnancy LW Δ (kg)	+102	-11
Cow treatment LW Δ (kg)	+55	-45

Cafe *et al*. (2006)

Low Nutrition = Fat Score 1 – "At Risk"



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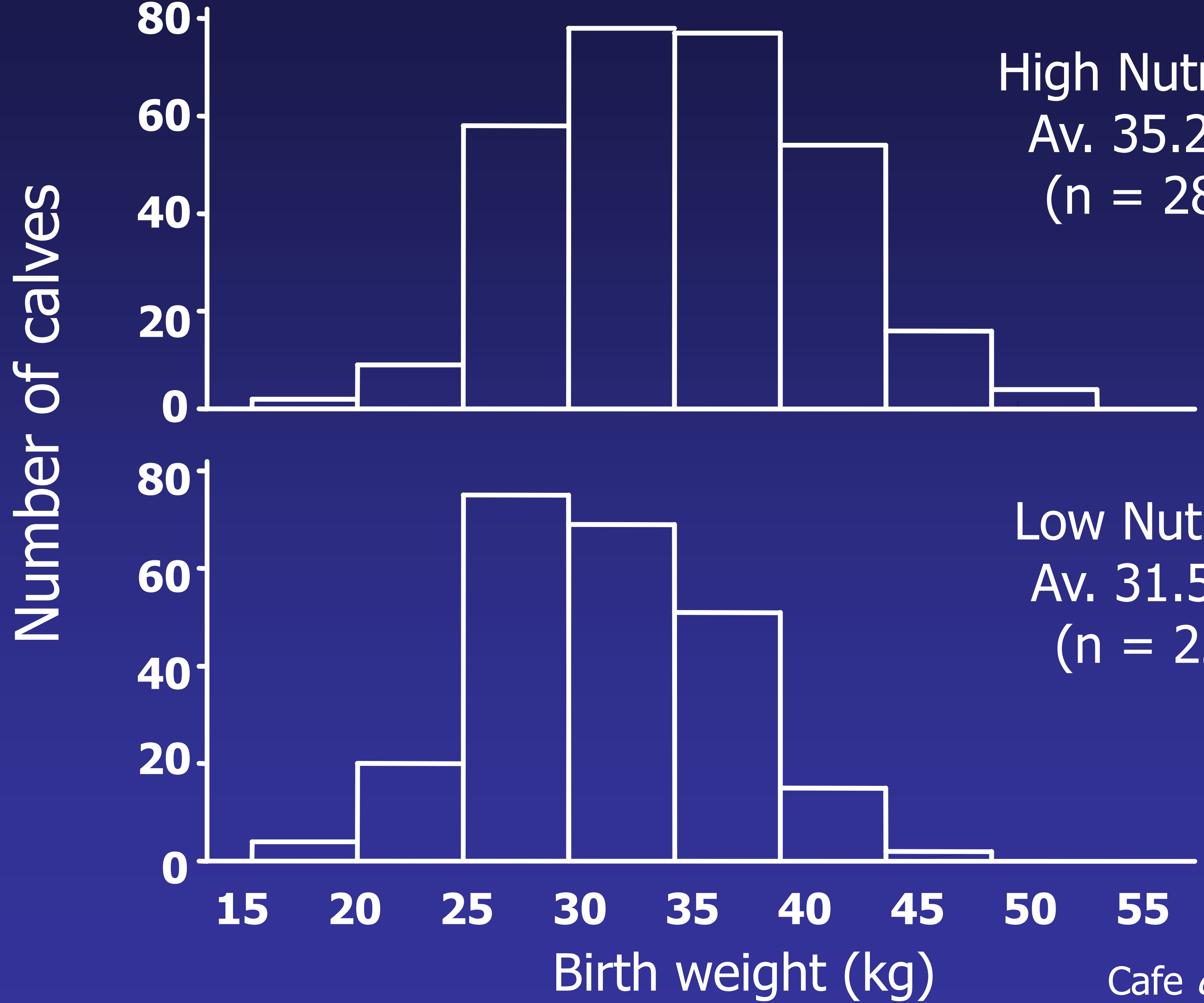
Low = ~ CS 3 & 400 kg *vs.* High = ~ CS 6 & 500 kg

Birth weights



Cafe *et al*. (2006)

Factors affecting birth weight

- Maternal nutrition
- Cow genotype, age, weight and parity
- Fetal genotype and sex
- Placenta
- Thermal environment
- Litter size

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Statistical analyses

- Stepwise regression

exclusion at *F* - ratio < 5.49, *P* > 0.02 for 1 d.f.

  - Covariates: Dam age, Dam previous lactation status; Days pregnant at start of nutritional treatment; Dam BW at parturition
  - Fixed Effects: Pregnancy nutrition; Lactation nutrition; Calf sex; Sire breed; Year
  - First order interactions: Between fixed effects; Between covariates and fixed effects

Robinson *et al*. (2013)

Dam and calf weights at birth (n = 228)

Variable	Mean	Model R^2	Pregnancy nutrition r^2
Dam LW at parturition (kg)	445	71%	50%

Robinson *et al.* (2013)

Dam and calf weights at birth (n = 228)

Variable	Mean	Model R^2	Pregnancy nutrition r^2
Dam LW at parturition (kg)	445	71%	50%
Birth wt (kg)	33.7	43%	20%

Robinson *et al.* (2013)

Birth weight (n = 228)

Mean	Model R^2	Terms (r^2)
33.7	48%	Dam LW parturition (26%)

Robinson *et al.* (2013)

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Birth weight (n = 228)

Mean	Model R^2	Terms (r^2)
33.7	48%	Dam LW parturition (26%)
33.7	43%	Pregnancy nutrition (20%)

Robinson *et al.* (2013)

Calf weaning weights (kg)
(n = 514)

Stage of treatment	Maternal Nutrition Low (n=229)	 High (n=285)	diff.
Lactation	164	207	43
Pregnancy	177	195	18

Cafe *et al*. (2006)

Weaning weight
(n = 228)

Mean (kg)	Birth wt (Δ/kg)	Model R^2	Terms (r^2)
189	1.53	74%	Lactation nutrition (41%) Dam LW at parturition (14%) Birth Wt (3%)

Robinson *et al.* (2013)

Maternal Nutrition

- Cows buffer the growing fetus
- 3.7 kg difference in birth weight despite >100kg difference in post-partum cow live weight
- Birth weight from heifers & cows was similarly affected by nutrition during pregnancy

Cafe *et al*. (2006), Robinson *et al*. (2013)

Maternal Nutrition

- Nutrition during pregnancy, especially during later pregnancy, also affects milk production
- Growth to weaning is sensitive to effects of nutrition of cows & milk production

Carry-over effects of maternal nutrition during pregnancy on lactation confound attempts to define the extent of fetal programming

Cafe *et al*. (2006), Robinson *et al*. (2013)

Design considerations
Fetal programming studies

Uncoupling of prenatal & postnatal effects

– Artificial rearing

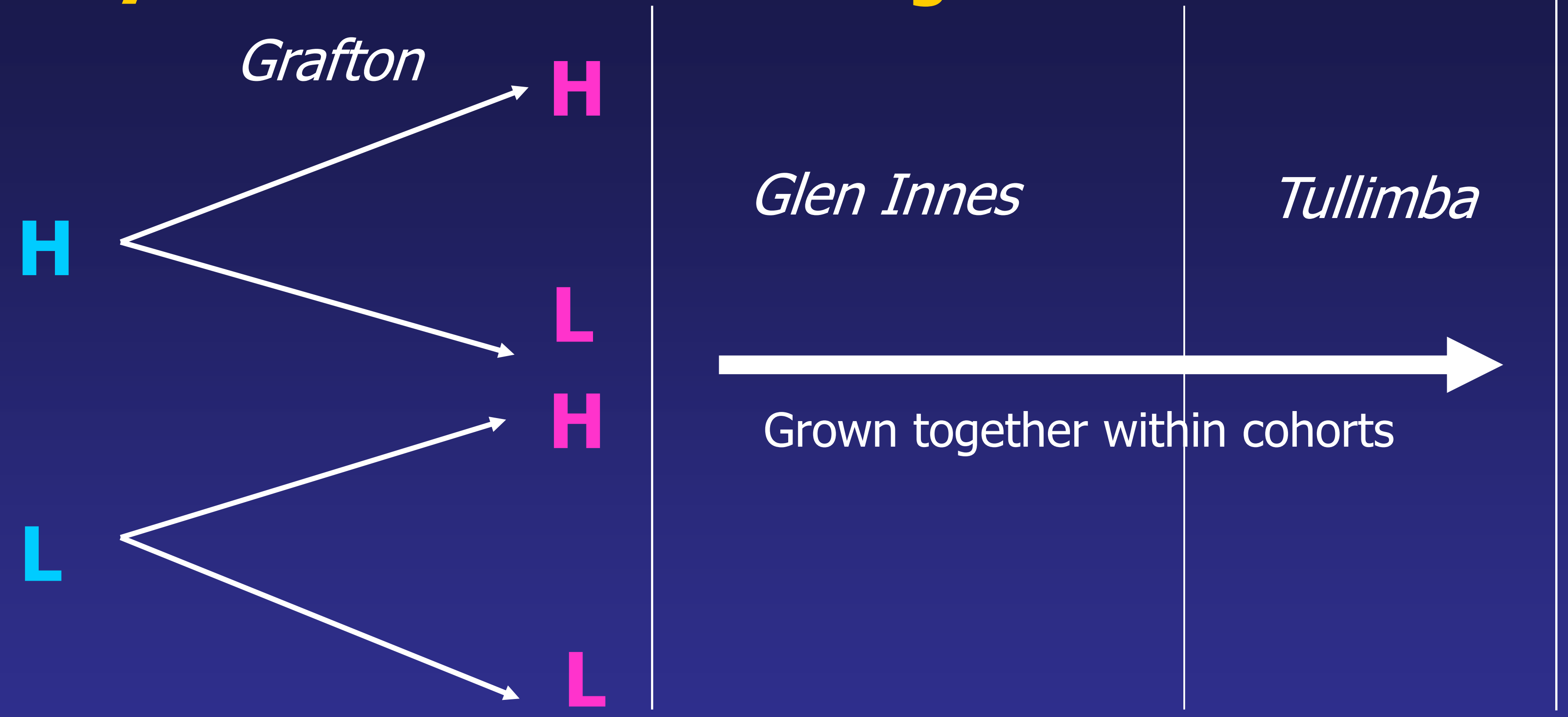
– Cross-fostering

– Factorial experimental designs

Robinson *et al.* (2013)

Longer-term Consequences

Early-Life Nutrition Background Feedlot



Pregnancy nutrition from ~d 80	Lactation nutrition	~ 7 mth av. 189 kg	~ 26 mth av. 514 kg	~ 30 mth av. 678 kg Slaughter

x 2 sire-genotypes x 3 cohorts (n = 240)

Cafe *et al*. (2006), Greenwood *et al*. (2006)

Statistical analyses

- Stepwise regression

  exclusion at *F* - ratio < 5.49, *P* > 0.02 for 1 d.f.

  – Covariates: Dam age, Dam previous lactation status; Days pregnant at start of nutritional treatment; Dam BW at parturition; Birth day; Birth weight; Age at weaning; Weaning weight; Feedlot entry weight; Carcass weight

  – Fixed Effects: Pregnancy nutrition; Lactation nutrition; Calf sex; Sire breed; Year

  – First order interactions: Between fixed effects; Between covariates and fixed effects

Robinson *et al*. (2013)

Liveweights (n = 228)

Stage	Mean (kg)	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Weaning	189	1.5	n.a.	74%	Birth wt (3%) Dam wt partur. (14%)

Robinson *et al*. (2013)

Liveweights (n = 228)

Stage	Mean (kg)	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Weaning	189	1.5	n.a.	74%	Birth wt (3%) Dam wt partur. (14%)
End background	514	3.0	0.7	71%	Birth Wt (13%) Weaning Wt (48%)

Robinson *et al.* (2013)

Liveweights (n = 228)

Stage	Mean (kg)	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Weaning	189	1.5	n.a.	74%	Birth wt (3%) Dam wt partur. (14%)
End background	514	3.0	0.7	71%	Birth Wt (13%) Weaning Wt (48%)
Feedlot exit	678	4.4	0.8	72%	Birth Wt (34%) Weaning Wt (11%)

Robinson *et al.* (2013)

Feedlot intake (kg DM/d, n = 146)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
	12.1	0.1	0.01	75%	Year/Sex (56%) Birth Wt (15%) Weaning Wt (2%) Weaning age x Dam age (2%)

Robinson *et al.* (2013)

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Feedlot intake (kg DM/d, n = 146)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
	12.1	0.1	0.01	75%	Year/Sex (56%) Birth Wt (15%) Weaning Wt (2%) Weaning age x Dam age (2%)
Adj. for feedlot entry weight (Wfe)	12.1	n.s.	n.s.	84%	Wfe (63%) Year/Sex (19%) Age weaned (1%) Wfe x Year/Sex (1%)

Robinson *et al.* (2013)

Feed efficiency (n = 146)

kg DM/kg gain

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
	9.4	n.s	0.02	38%	Year/Sex (18%) Prev Lact (5%) Weaning wt (6%) Year/Sex x Weaning wt weaned (3%) Year/Sex x Prev Lact (3%) Lact Nutr (3%)

Robinson *et al.* (2013)

Feed efficiency (n = 146)

kg DM/kg gain

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
	9.4	n.s	0.02	38%	Year/Sex (18%) Prev Lact (5%) Weaning wt (6%) Year/Sex x Weaning wt weaned (3%) Year/Sex x Prev Lact (3%) Lact Nutr (3%)
Adj. for feedlot entry wt (Wfe)	9.4	n.s.	n.s.	32%	Year/Sex (19%) Wfe (6%) Prev Lact (5%) Wfe x Year/Sex (3%)

Robinson *et al.* (2013)

Carcass and yield at 30 mo. (n = 228)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Carcass wt (kg)	382	2.7	0.5	70%	Birth Wt (36%) Weaning Wt (11%)

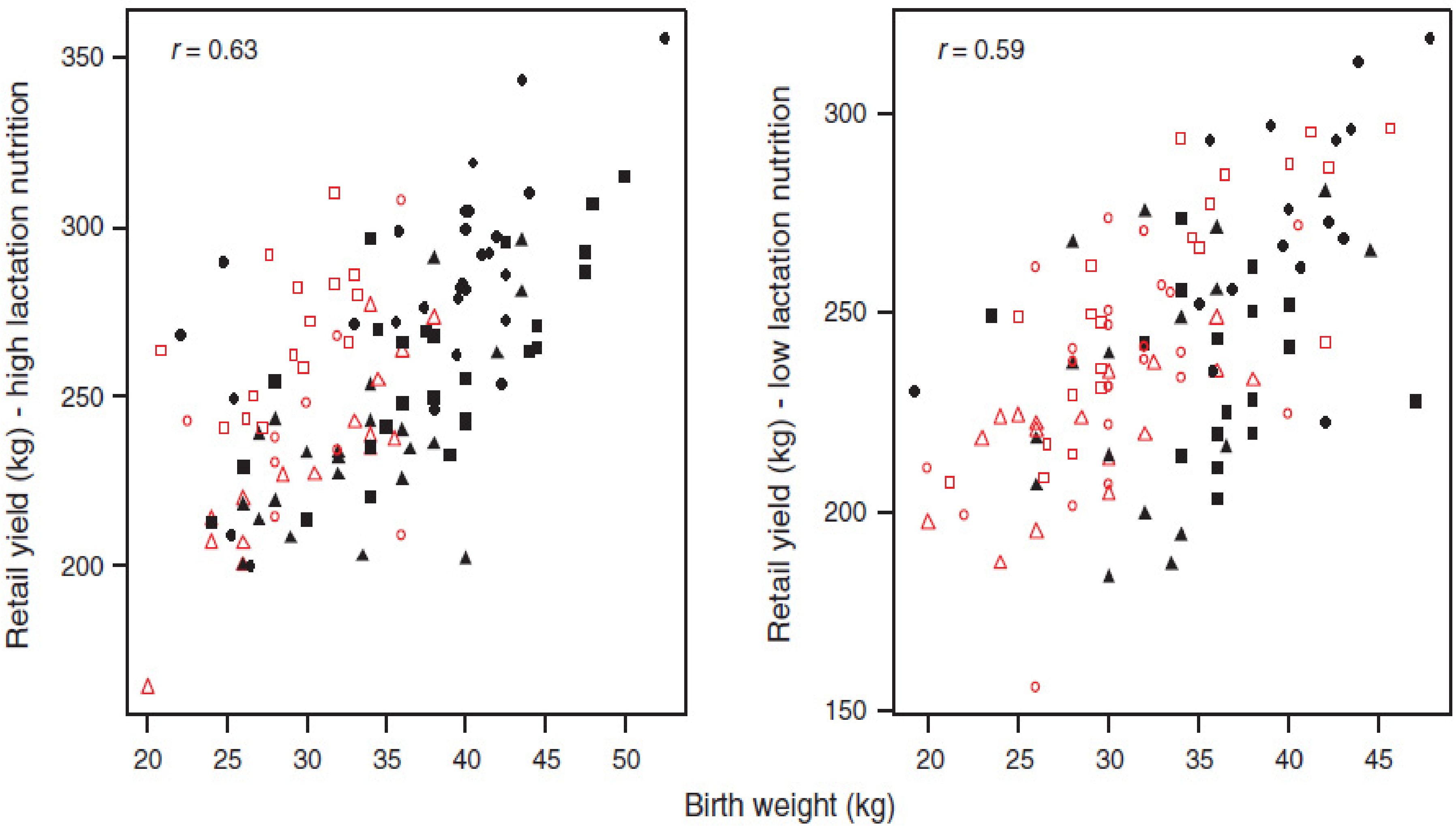
Robinson *et al*. (2013)

Carcass and yield at 30 mo. (n = 228)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Carcass wt (kg)	382	2.7	0.46	70%	Birth Wt (36%) Weaning Wt (11%)
Retail yield (kg)	249	2.0	0.03	70%	Birth Wt (37%) Weaning Wt (5%) Preg. Nutr. (0.7%)

Robinson *et al.* (2013)

Birth weight *vs.* Retail Yield (n = 228)



Robinson *et al.* (2013)

Carcass and yield at 30 mo. (n = 228)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Carcass wt (kg)	382	2.7	0.46	70%	Birth Wt (36%) Weaning Wt (11%)
Retail yield (kg)	249	2.0	0.03	70%	Birth Wt (37%) Weaning Wt (5%) Preg. Nutr. (0.7%)
Fat trim (kg)	55.4	n.s.	0.10	57%	Weaning Wt (24%)

Robinson *et al.* (2013)

Carcass and yield at 30 mo. (n = 228)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Carcass wt (kg)	382	2.7	0.46	70%	Birth Wt (36%) Weaning Wt (11%)
Retail yield (kg)	249	2.0	0.03	70%	Birth Wt (37%) Weaning Wt (5%) Preg. Nutr. (0.7%)
Fat trim (kg)	55.4	n.s.	0.10	57%	Weaning Wt (24%)
Bone (kg)	67.6	0.5	0.07	70%	Birth Wt (17%) Weaning Wt (4%)

Robinson *et al.* (2013)

Yield at 376 kg Cold Carcass Wt (n = 228)

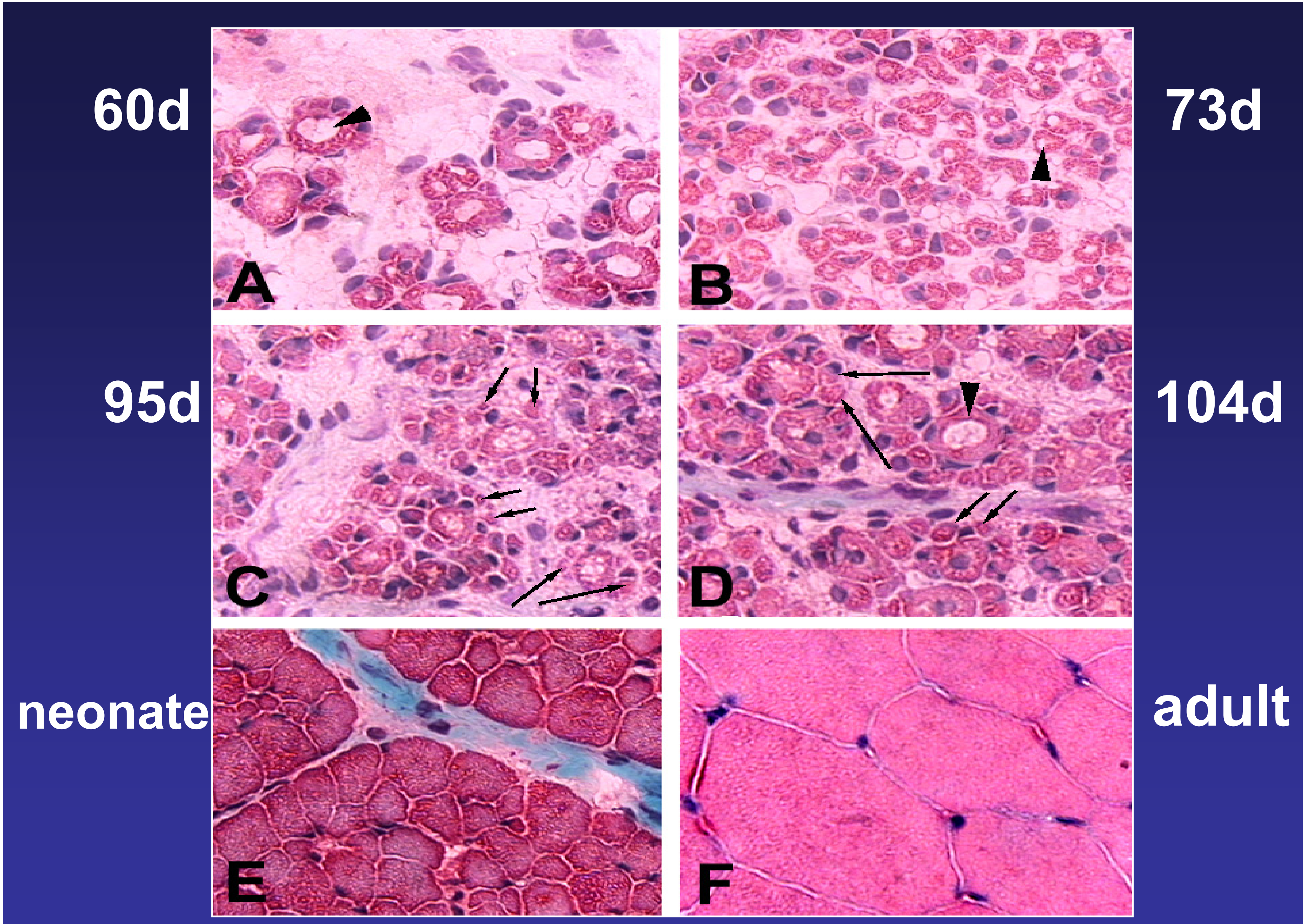
	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Retail yield (kg)	249	n.s.	-0.06	95%	Weaning Wt (1%)
Fat trim (kg)	55.4	n.s.	0.08	64%	Weaning Wt (24%)
Bone (kg)	67.6	n.s.	n.s.	87%	-

Robinson *et al.* (2013)

Marbling & Ossification (n = 228)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
USDA Marble score	446	n.s.	n.s.	41%	Breed (39%)
LD IMF%	6.94	n.s.	n.s.	45%	Breed (43%)
MSA ossification score	200	n.s.	n.s.	68%	Sex (66%)

Robinson *et al.* (2013)



H&E stain: Courtesy of D. Gerrard in Greenwood *et al*. (1999)

Longissimus myofibres

(352 kg carcass wt, heifer cohort, n = 73)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2; Terms
Number (x 10^{-6})	1.12	0.07 #	n.s.	13% BW#,G

P = 0.08

Robinson *et al.* (2013)

Immunocytochemical staining of myofibres in ruminant muscle:

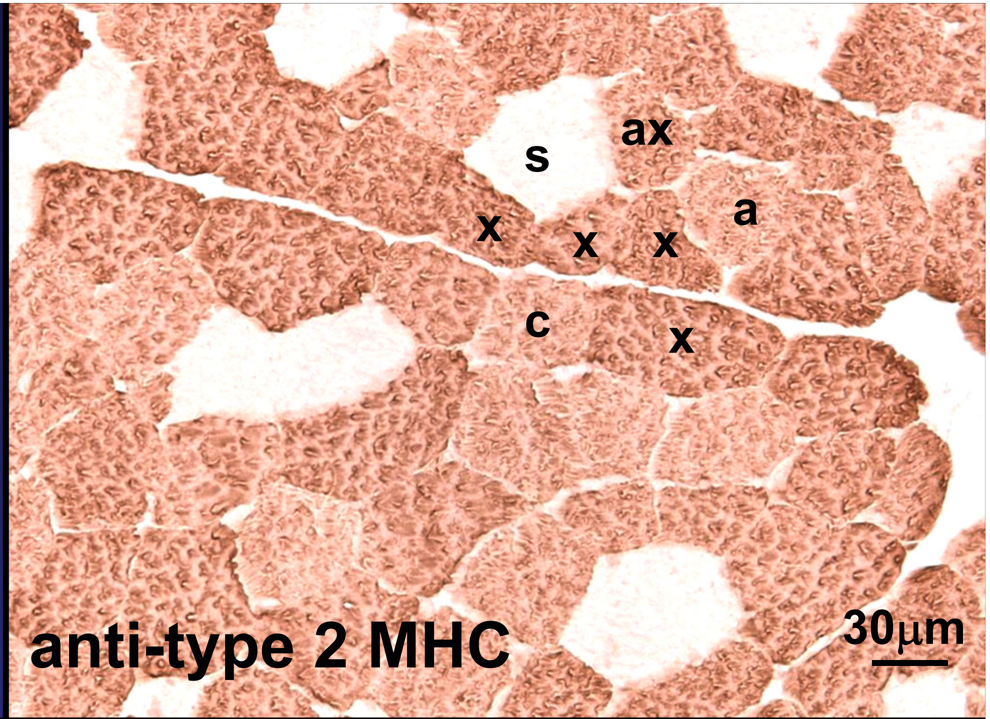
s = type 1 (slow)

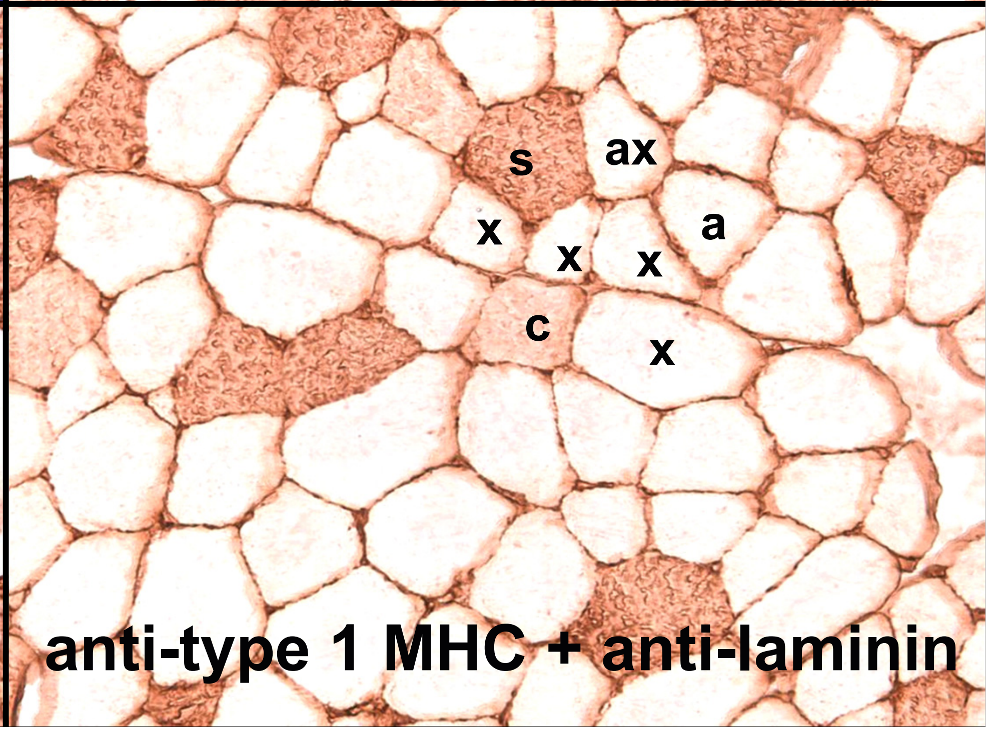
c = type 2C (slow/fast oxidative-glycolytic intermediate)

a = type 2A (fast oxidative-glycolytic)

ax = type 2AX (fast oxidative-glycolytic/ fast glycolytic intermediate)

x = type 2X (fast glycolytic)





Longissimus myofibres

(352 kg carcass wt, heifer cohort, n = 73)

% myofibre area	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2; Terms
Type 1	22.2	n.s.	n.s.	17%: G
Type 2C	0.6	n.s.	n.s.	0%
Type 2A	22.8	n.s.	n.s.	21%: G
Type 2AX	5.9	n.s.	n.s.	0%
Type 2X	48.4	n.s.	n.s.	21%: G

Robinson *et al.* (2013)

Striploin meat quality (n = 228)

(382 kg carcass weight)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Shear force (N)	39.7	n.s.	n.s.	14%	S,Y
Compression (N)	14.1	n.s.	n.s.	29%	S,G,Y
Cooking loss (%)	21.5	n.s.	n.s.	66%	S,Y,A
Ultimate pH	5.48	n.s.	n.s.	29%	S,Y
Lightness (L)	**39.8**	**0.07**	**n.s.**	**11%**	G,Y **Birth Wt (2.3%)**
Red/green (a)	26.5	n.s.	n.s.	8%	Y
Yellow/blue (b)	13.7	n.s.	n.s.	5%	Y

Robinson *et al.* (2013)

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Eye round meat quality (n = 228)

(382 kg carcass wt)

	Mean	Birth wt (Δ/kg)	Weaning wt (Δ/kg)	Model R^2	Terms (r^2)
Shear force (N)	46.1	n.s.	n.s.	42%	S,Y,G
Compression (N)	**22.4**	**-0.01**	**n.s.**	35%	S,Y **Birth Wt (1.6%)**
Cooking loss (%)	21.3	n.s.	n.s.	70%	S,Y

Robinson *et al.* (2013)

Severe Growth Restriction

	Prenatal	Pre-weaning
Pre-weaning growth	↓	
Backgrounding growth	↓	↑
Feedlot growth	↓	↔
Feedlot efficiency	↔	↔
Carcass weight & yield	↓	↓
Age at specification	↑	↑
At equivalent carcass weight (~380 kg)		
Carcass fatness	↔	↓*
Marbling	↔	↔
Retail yield	↔	↑*
Ossification	↔	↔
Beef quality	↔	↔

* *Opposite may occur if recovered on concentrates for prolonged period*

Pasture vs feedlot "recovery"

% Carcass Fat at ~ 400 kg LW

Post-weaning	Pre-weaning nutrition: High	Low
Pasture	23.8	23.6
Intensive	29.9a	34.1b

Tudor *et al.* (1980)

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Conclusions

- Feed cows to ensure survival and to optimise capacity to re-breed (weaning rate)
- If severe growth-retardation occurs the time to market weight may be longer
- Carcasses and beef quality were little affected in our pasture-based systems

Conclusions

Hence, beyond effects related to size:

Few long-term effects of cow nutrition during pregnancy &/or fetal growth on commercial characteristics of offspring within our pasture-based system

Conclusions

- Few interactions with genotype
- Few interactions between prenatal and pre-weaning nutrition or growth
- Better maternal nutrition more profitable in our systems (Alford *et al*. 2009)

Concluding Remarks

- Present study = severe, chronic nutritional restriction & prolonged recovery on pasture
- Effects may also occur as a result of:
  - acute &/or specific influences within developmental windows
  - carry-on effects in accelerated or concentrate-based systems

Concluding Remarks

- Consideration also needs to be given to:
  - maternal genotype and frame size
  - weight cycling: Freetly, Ferrell and Jenkins (2000, 2005)
  - lactation (confounding of fetal programming)
  - subsequent reproductive capacity
  - production system and market end-points
  - economics of production systems (Alford *et al*. 2009)

Concluding Remarks

- Soft carcass tissues are highly plastic & have strong capacity to recover, especially given adequate time (epigenetics)

- Much variation remains to be explained, commercially and biologically

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- NSW Department of Primary Industries
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