Adverse effects of heat stress on reproduction in lactating dairy cows and strategies for mitigation

Jeremy Block and Peter J. Hansen

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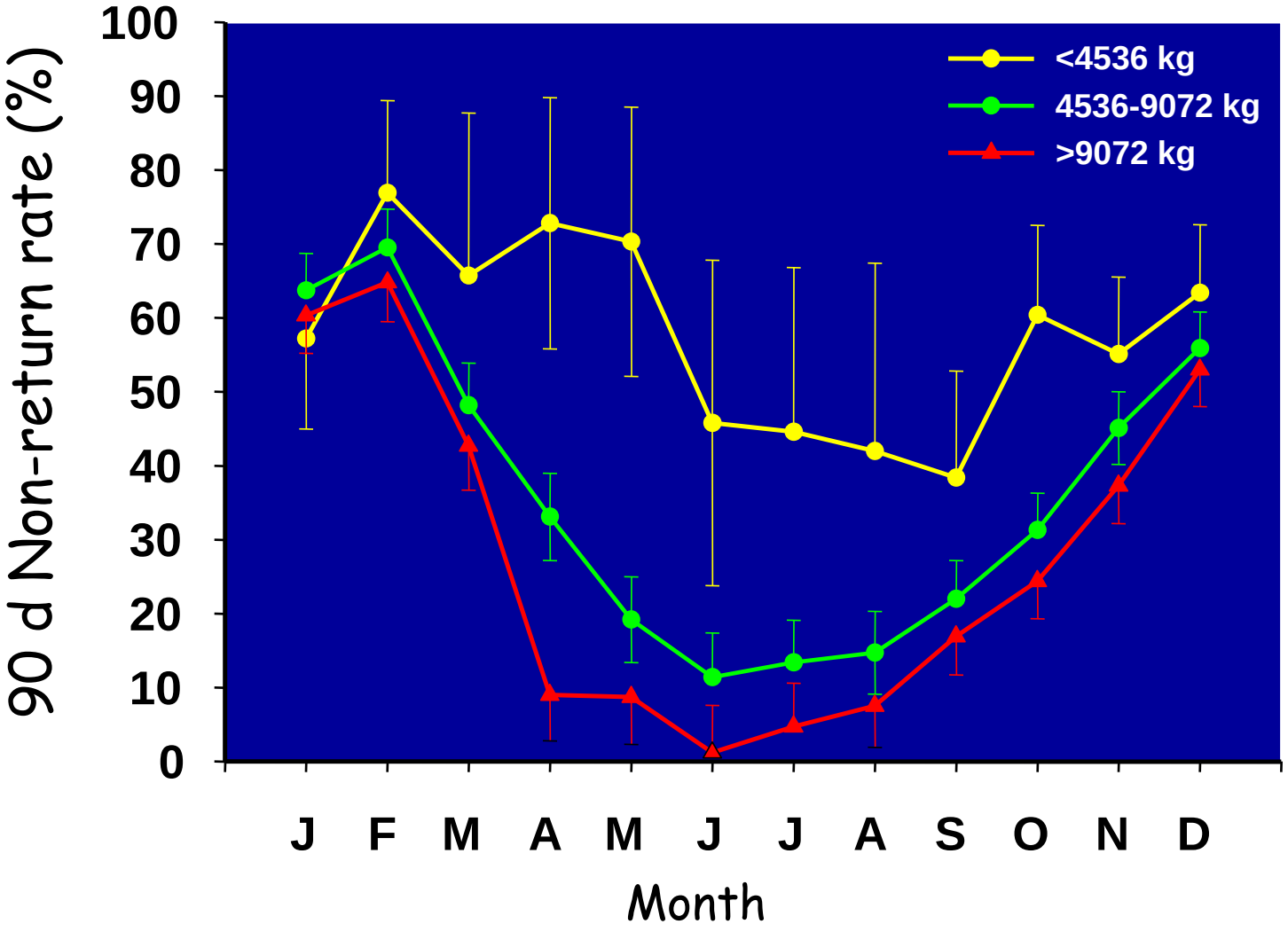
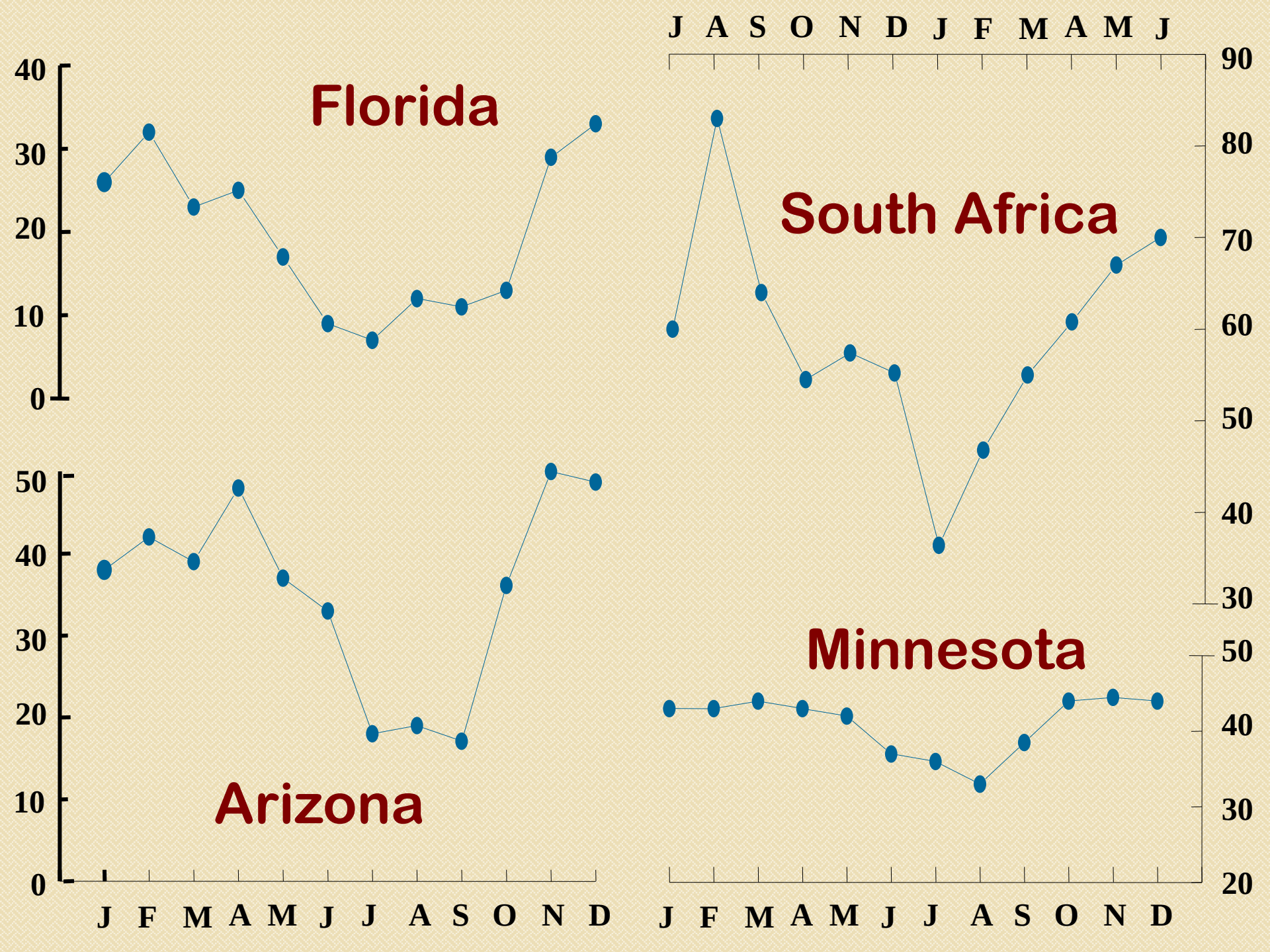
Seasonal variation in pregnancy rate in lactating dairy cows: Florida & Georgia



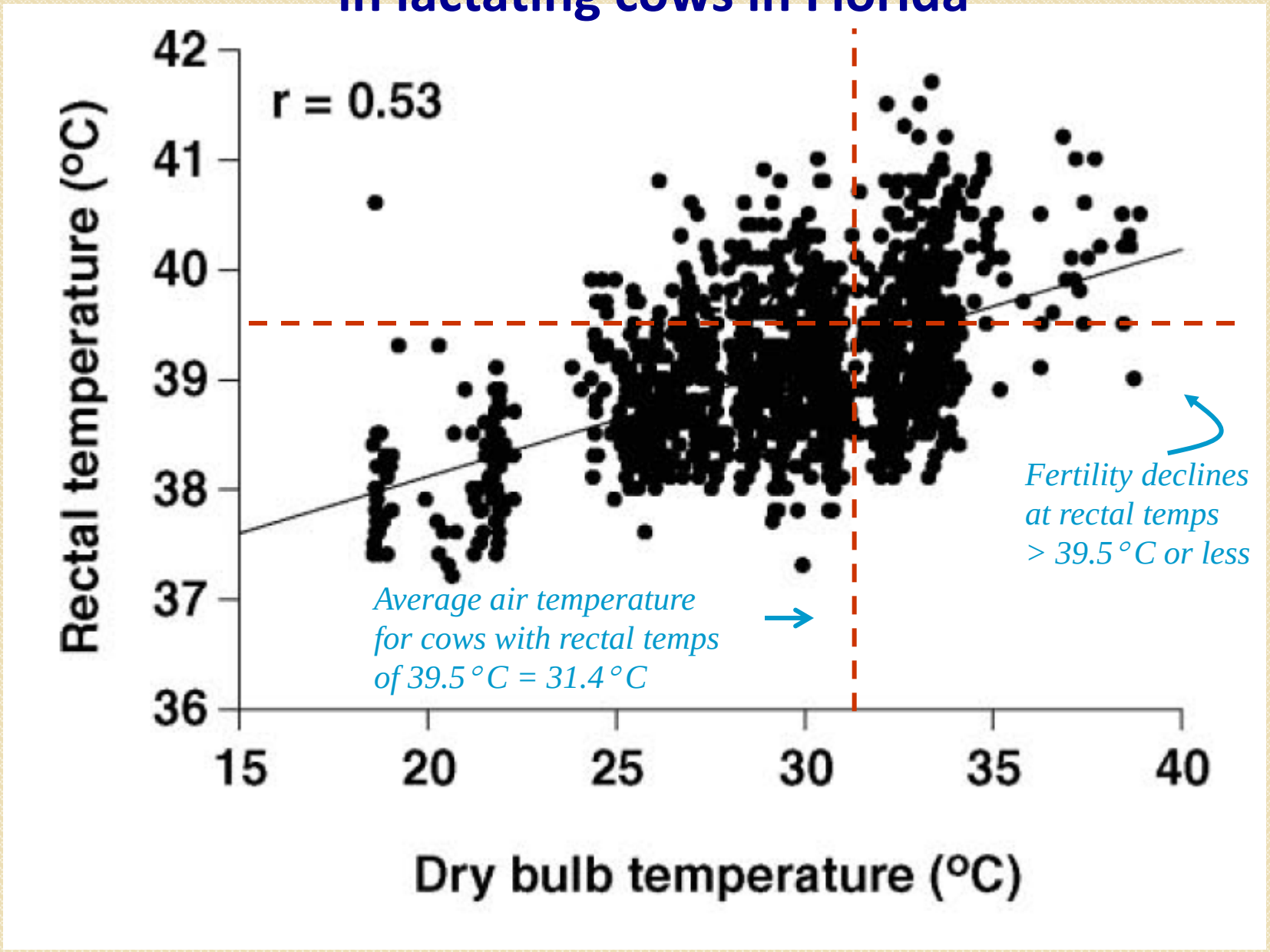
Al-Katanani et al., 1999

Effects of Heat Stress on Fertility
A Growing Problem - Difficult to Solve

- Effects occur within a wide range of environments and at relatively low ambient temperatures
- Effects increase in severity as milk yield increases
- At least in hot and humid environments, effects cannot be overcome by cooling cows


Florida
40
30
20
10
0
Arizona
50
40
30
20
10
0
J F M A M J J A S O N D
South Africa
J A S O N D J F M A M J
90
80
70
60
50
40
30
Minnesota
50
40
30
20
J F M A M J J A S O N D

Relationship between air temperature and rectal temperature in lactating cows in Florida



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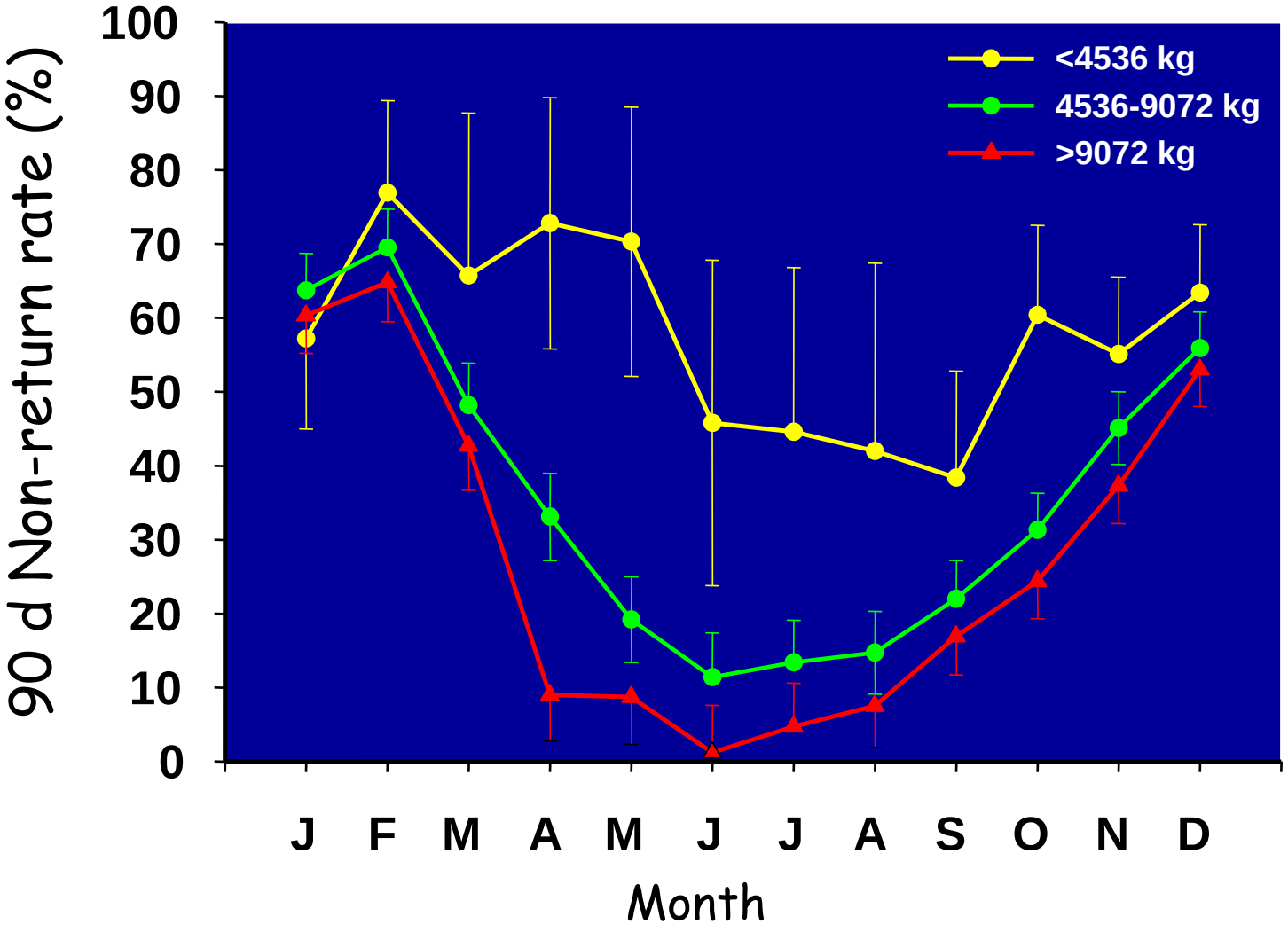
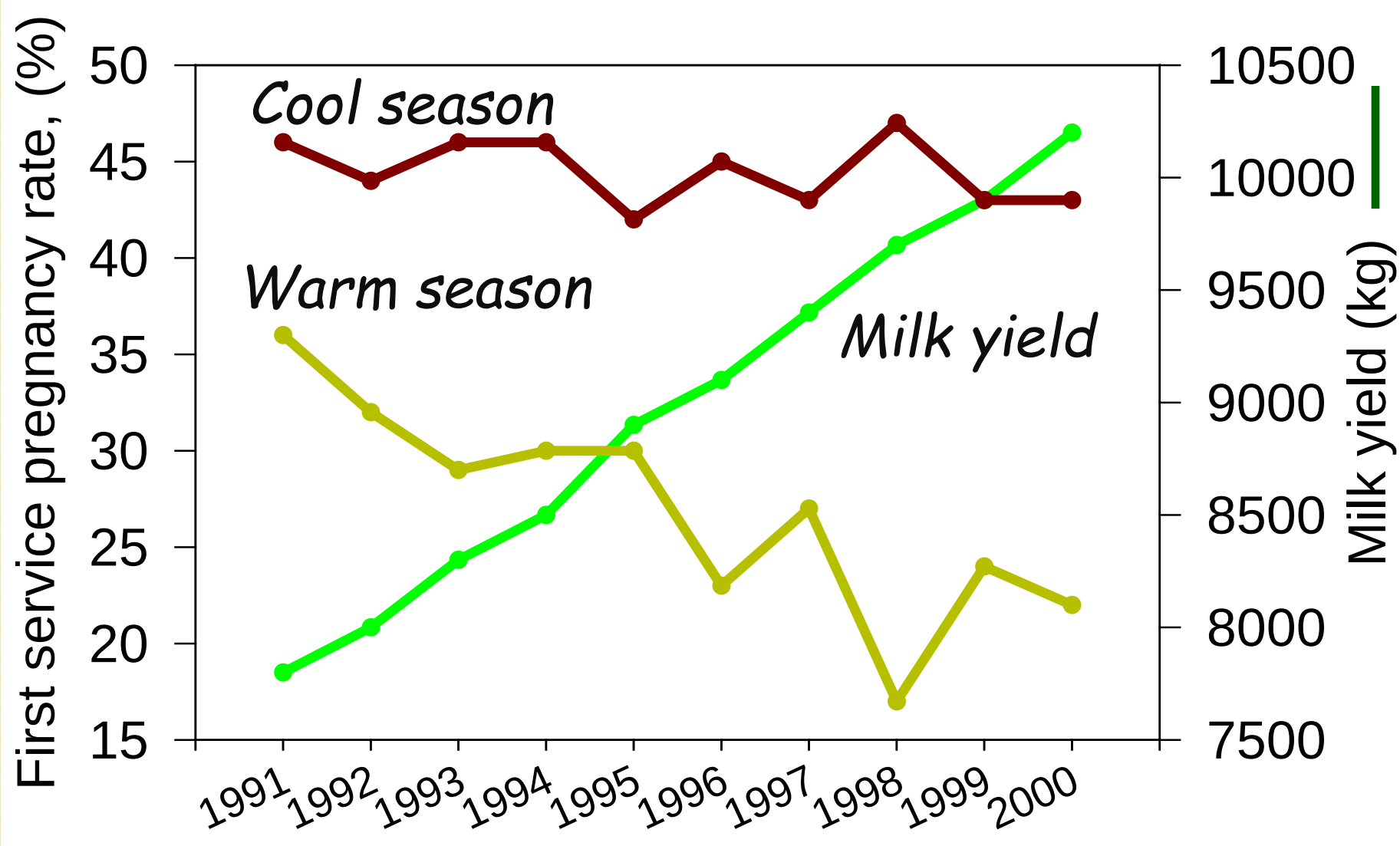


Al-Katanani et al., 1999

Changes in Pregnancy Rate in Dairy Cows In Northeastern Spain



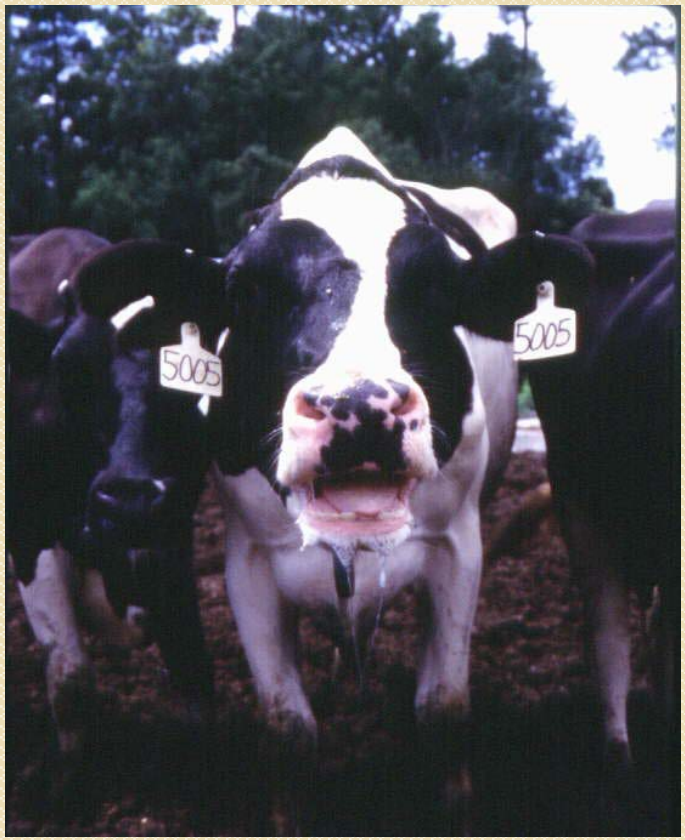
Lopez-Gatius, Theriogenology 60: 203 (2003)

Effects of cooling on conception rates in lactating dairy cows in Israel

	High Production		Low Production	
Conception rate (%)	Intensive cooling	Moderate cooling	Intensive cooling	Moderate cooling
Winter	39	39	40	39
Summer	19	12	25	3

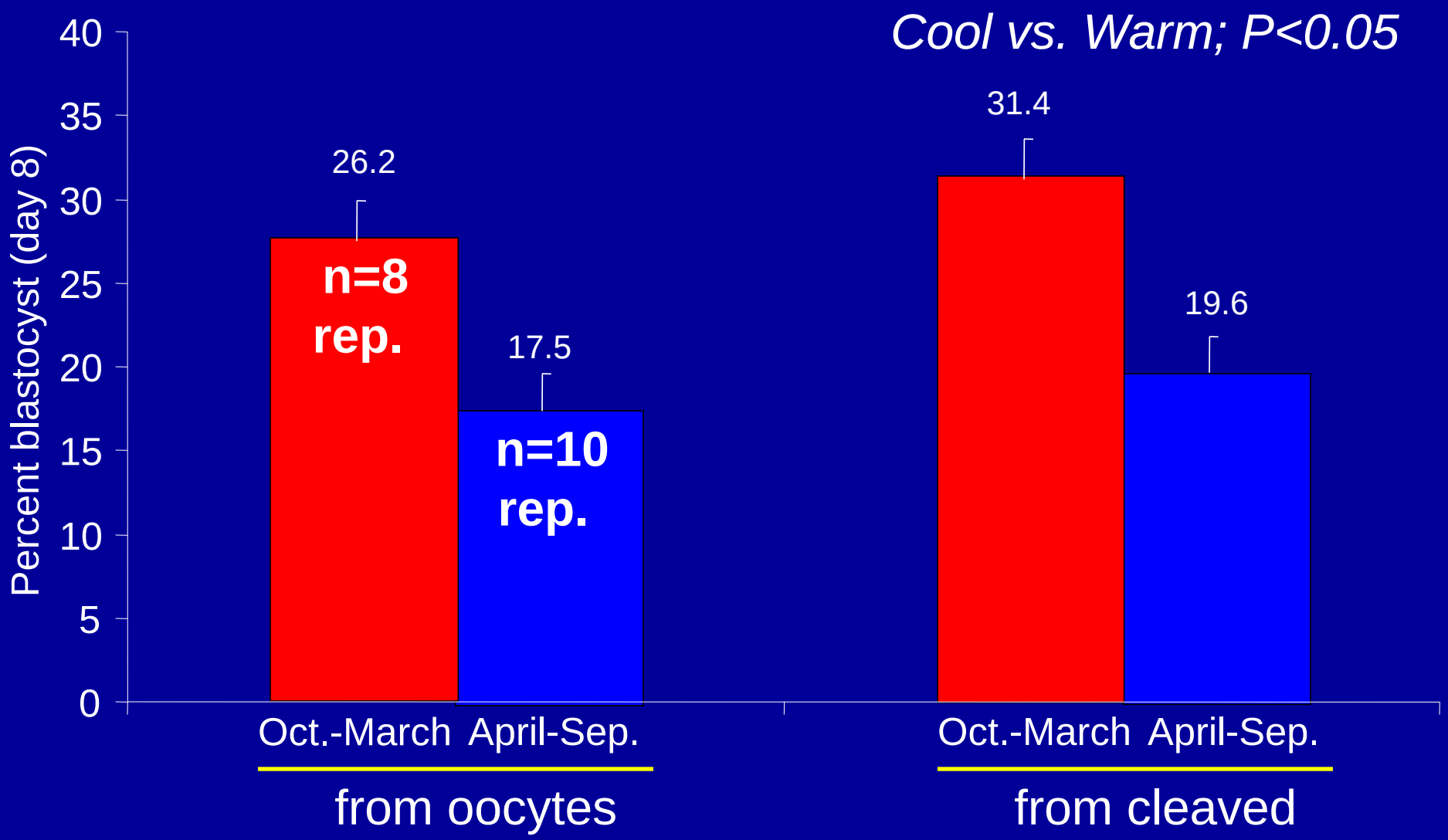
Flamenbaum and Ezra, 2006

Effects of Heat Stress on Reproductive Function of Dairy Cows that Compromise Fertility



- Intensity/Duration of estrus
- Follicular dynamics
- Hormonal profiles
- Blood flow
- Oocyte competence
- Embryonic development

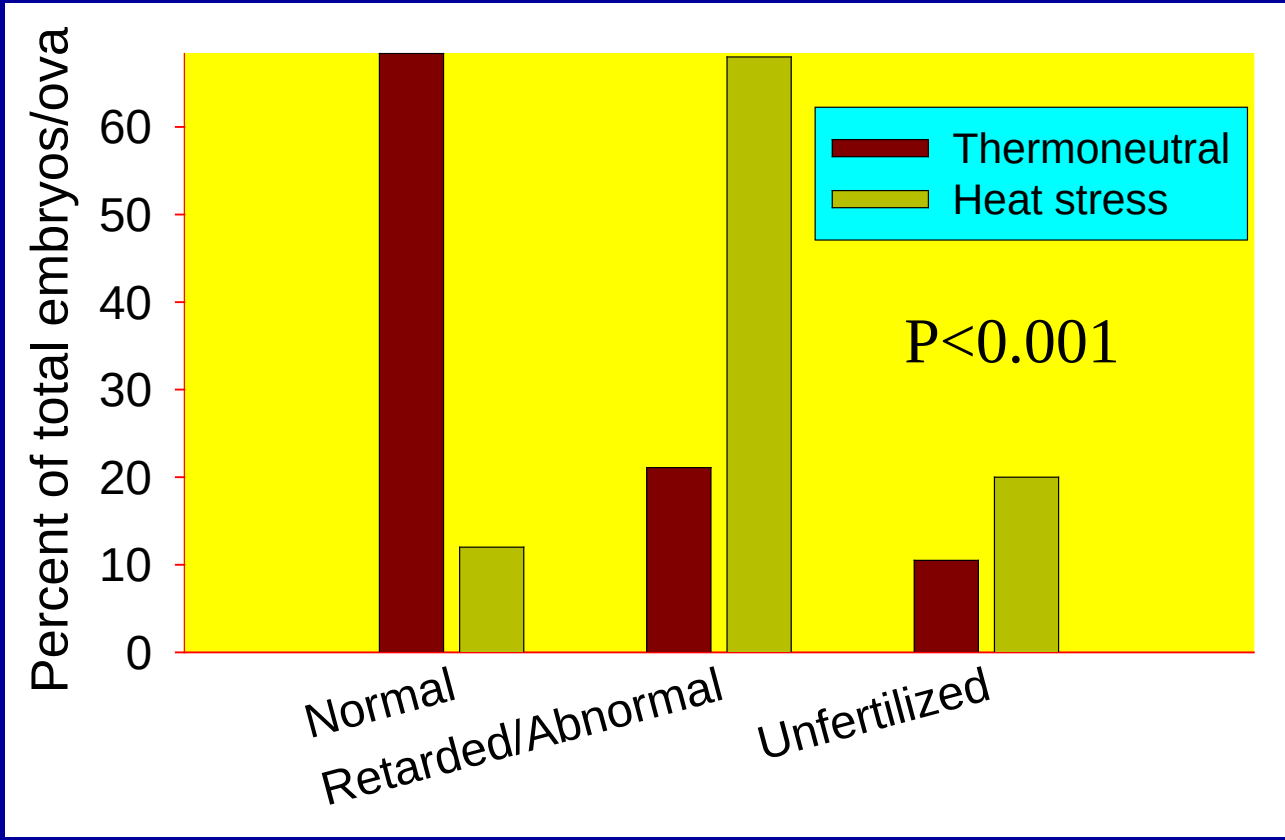
Seasonal Variation in IVF Performance in Holstein Cows



Effect of 10 h of Heat Stress from the Onset of Estrus on Embryonic Development in Superovulated Heifers

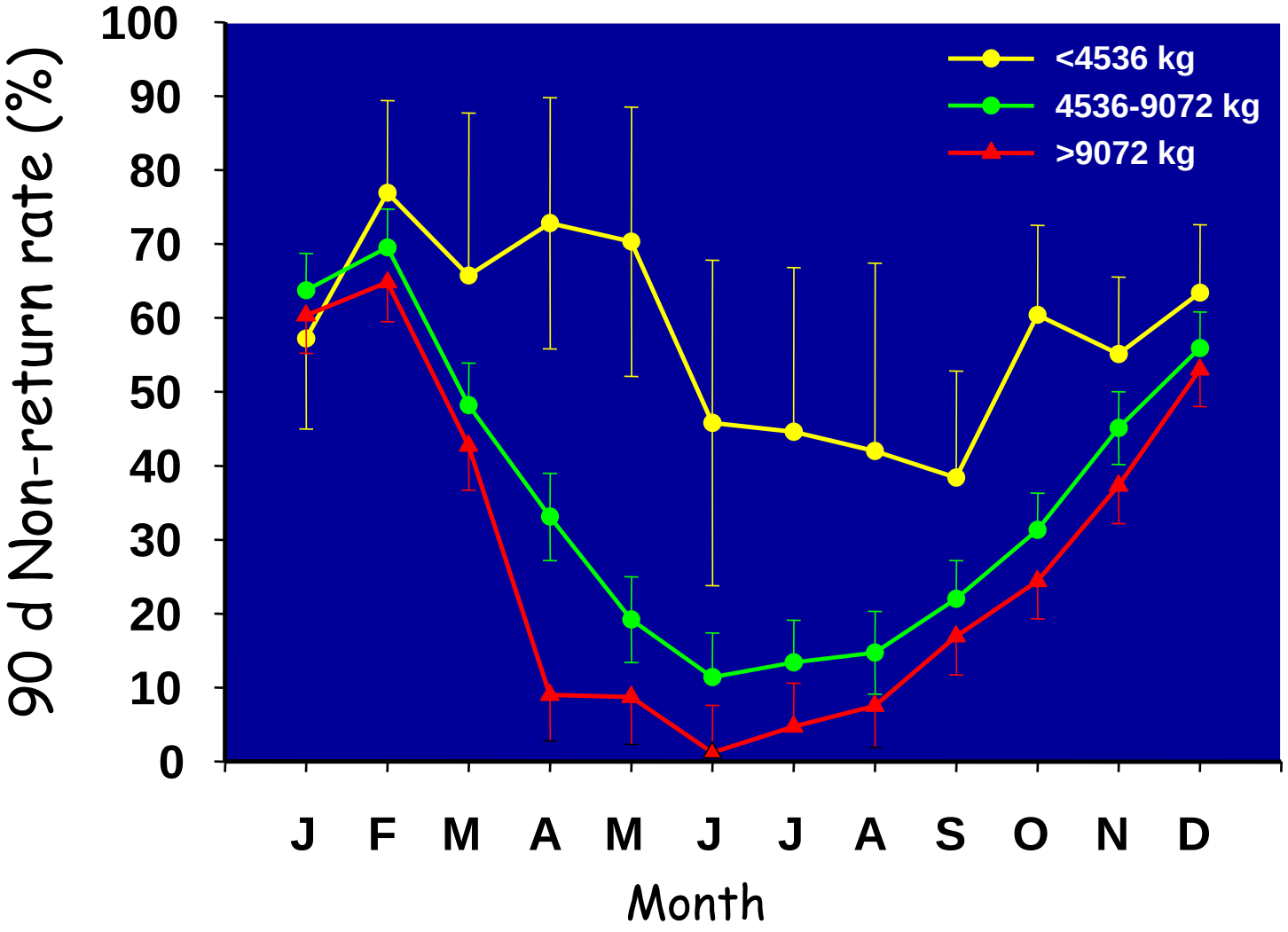
Control (n=8)
chamber= 24 C
RT=38.9 C

Heat Stress (n=6)
42 C for 10 h
AI at 15-20 h after estrus
RT=41.3 C



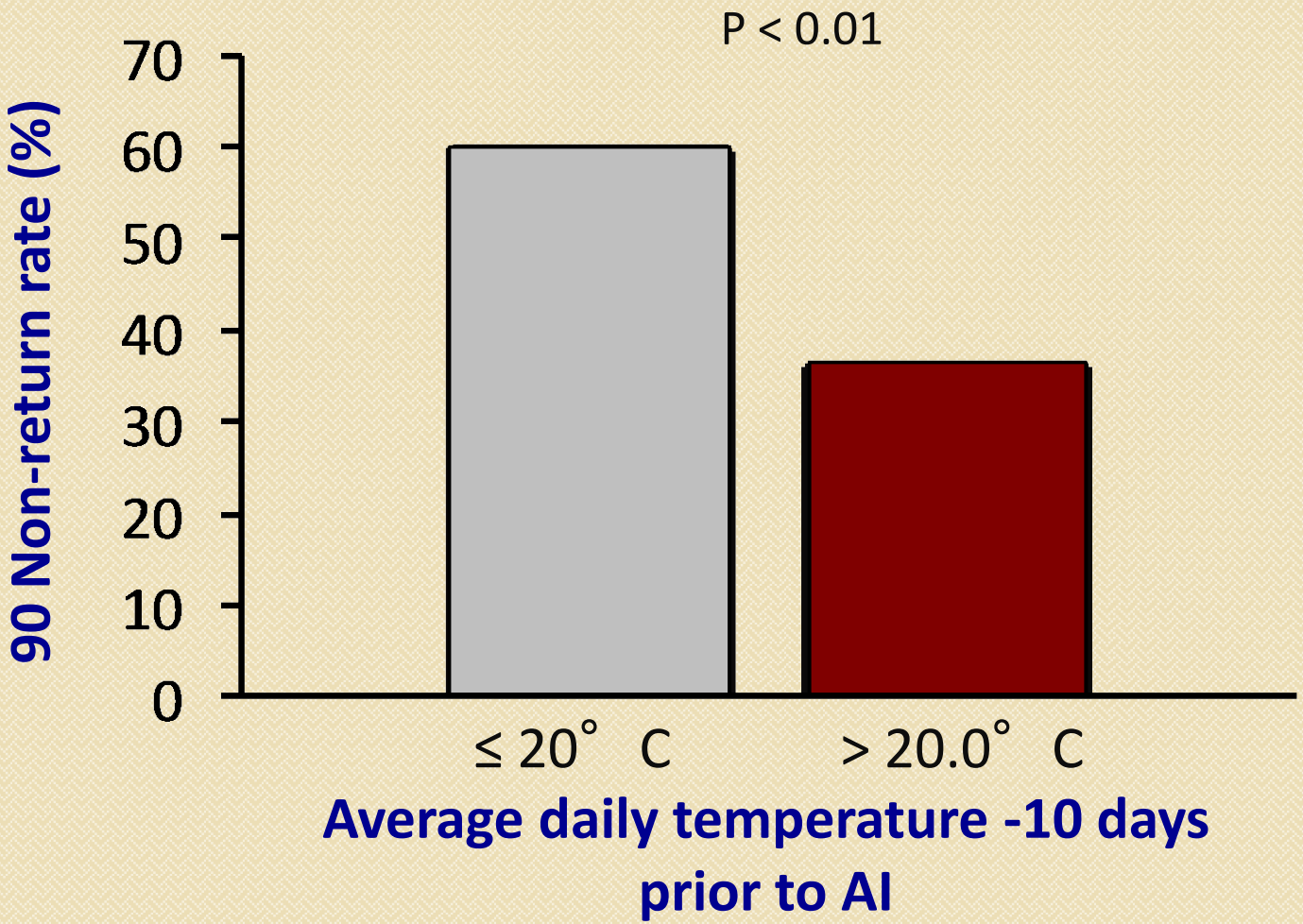
Putney et al., Anim Reprod Sci 1989; 19: 37

Seasonal variation in pregnancy rate in lactating dairy cows: Florida & Georgia



Al-Katanani et al., 1999

Effects of heat stress prior to peri-ovulatory period



Al-Katanani et al., 1999

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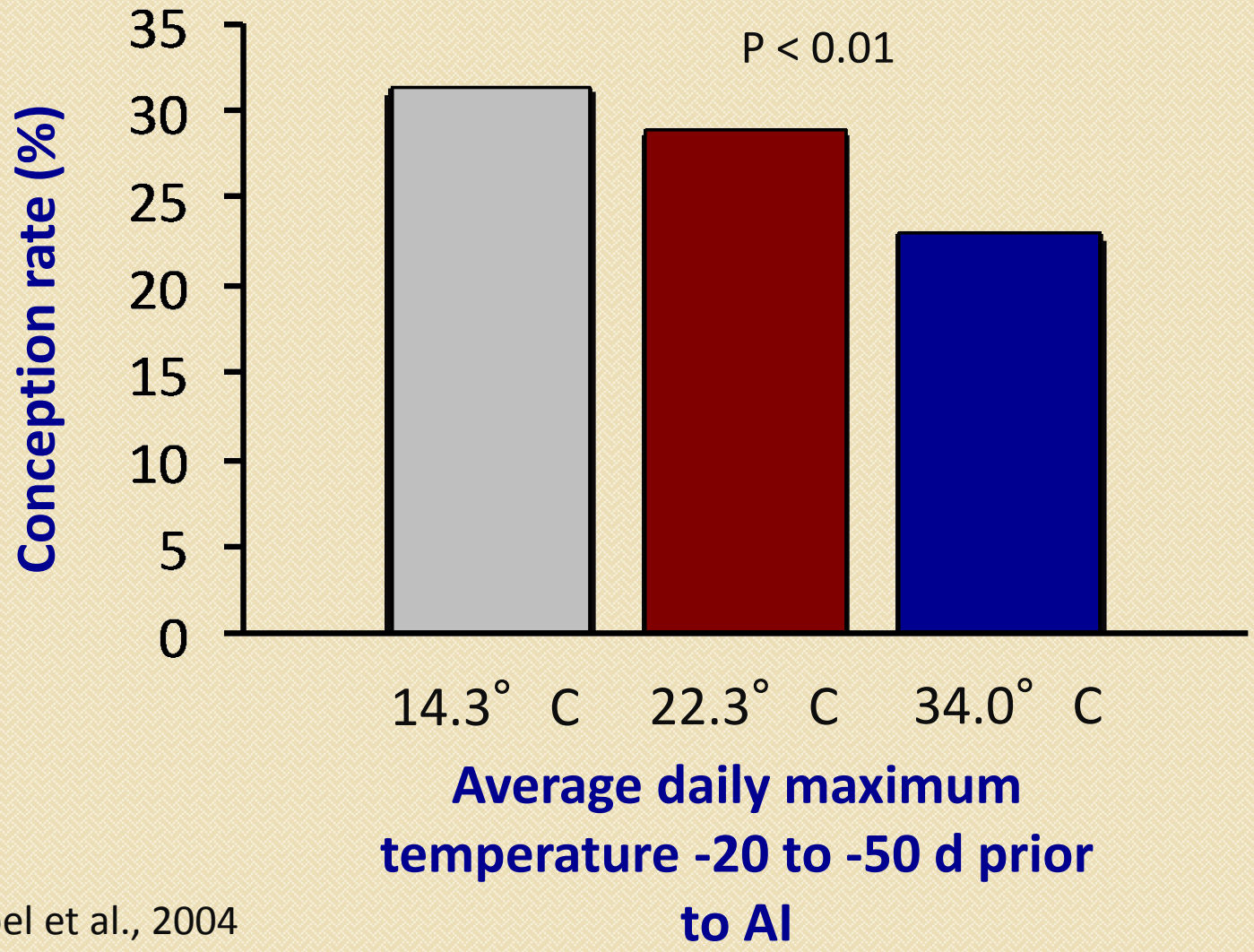


Chebel et al., 2004

Effects of heat stress prior to peri-ovulatory period

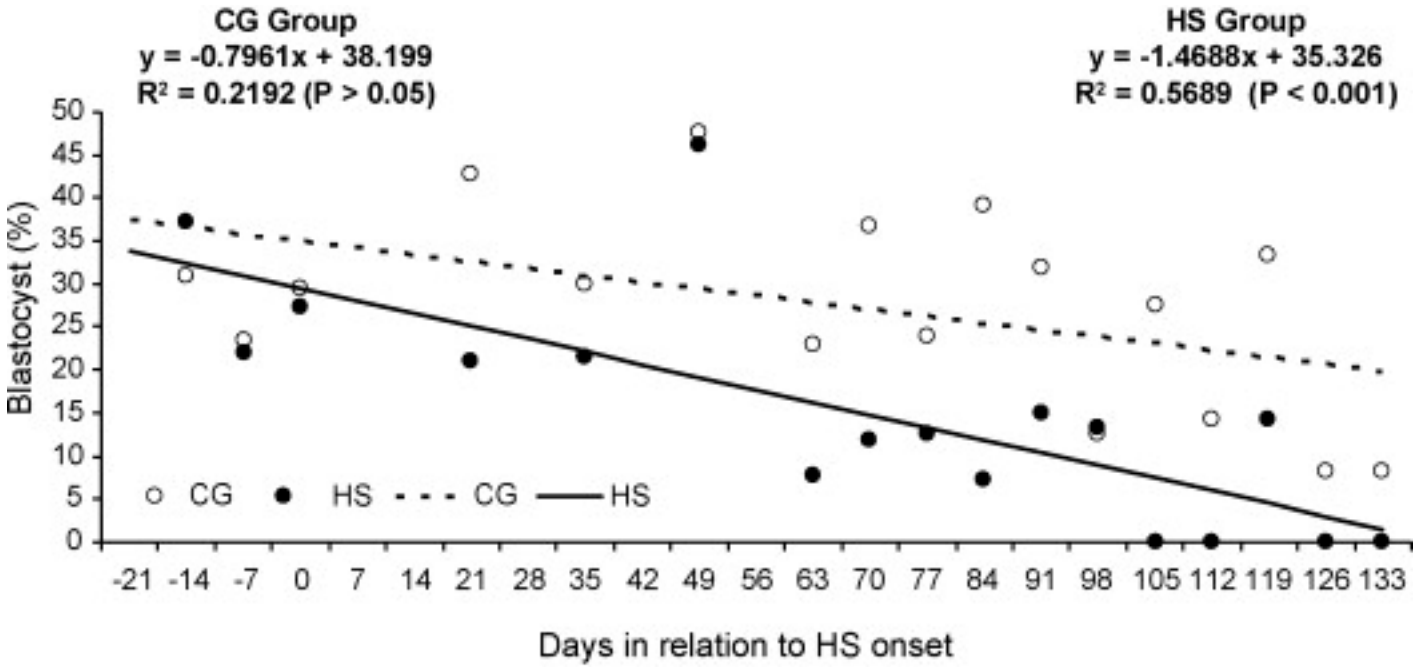
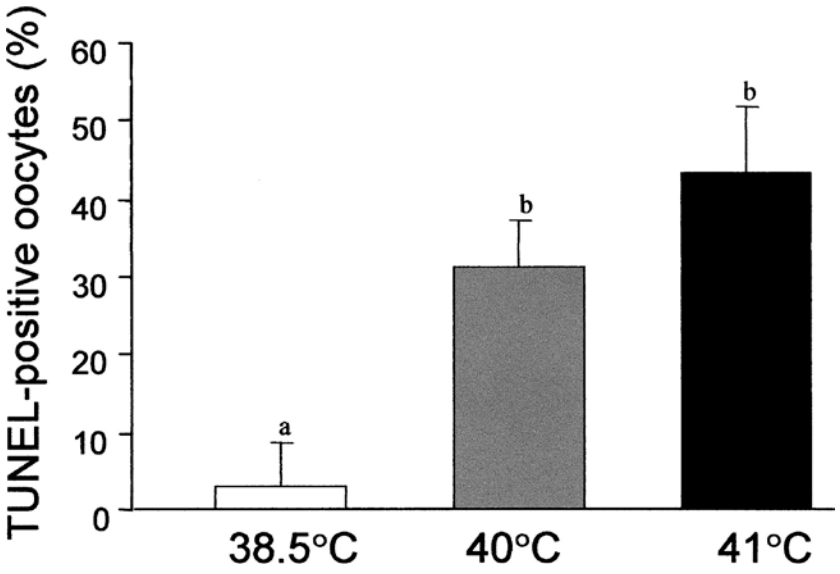
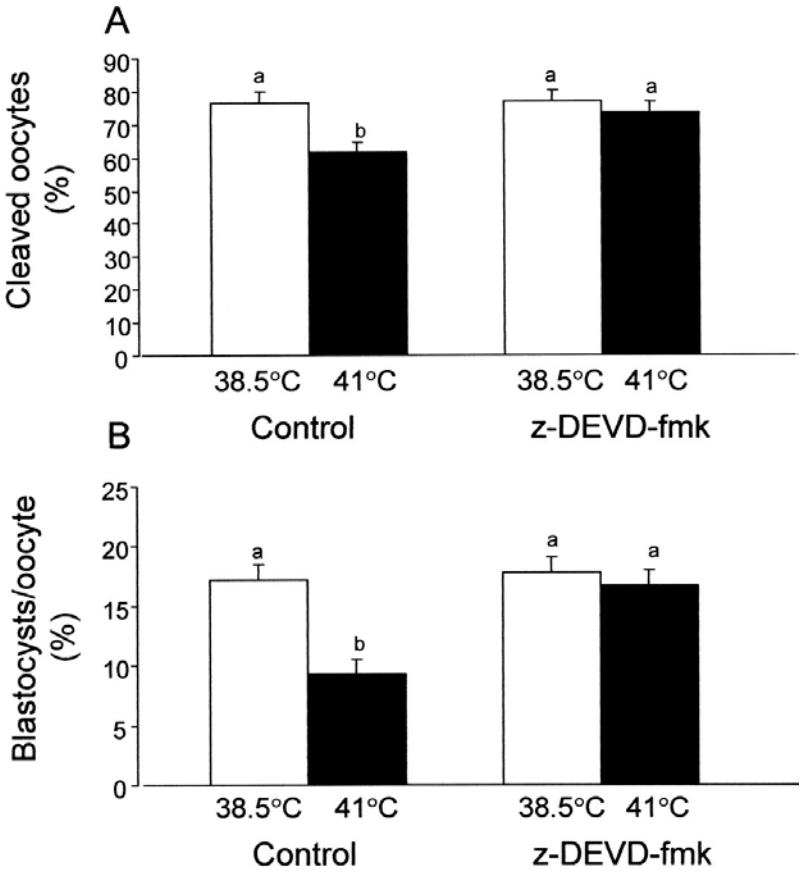


Fig. 5 Percentage (CG, open circles and HS, solid circles) and regression equation's adjusted lines (CG, dotted lines and HS, solid lines) of Gir (Bos indicus) COCs that reached the blastocyst stage following in vitro fertilization.

Torres-Junior et al., 2008

Role of Apoptosis in the Reduced Developmental Competence of Oocytes Exposed to Heat Shock



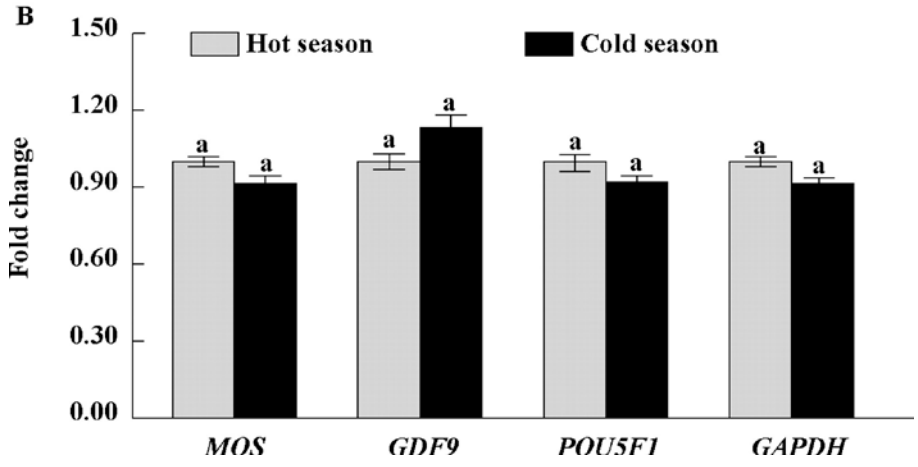


Z-DEVD-fmk an inhibitor of group II caspases

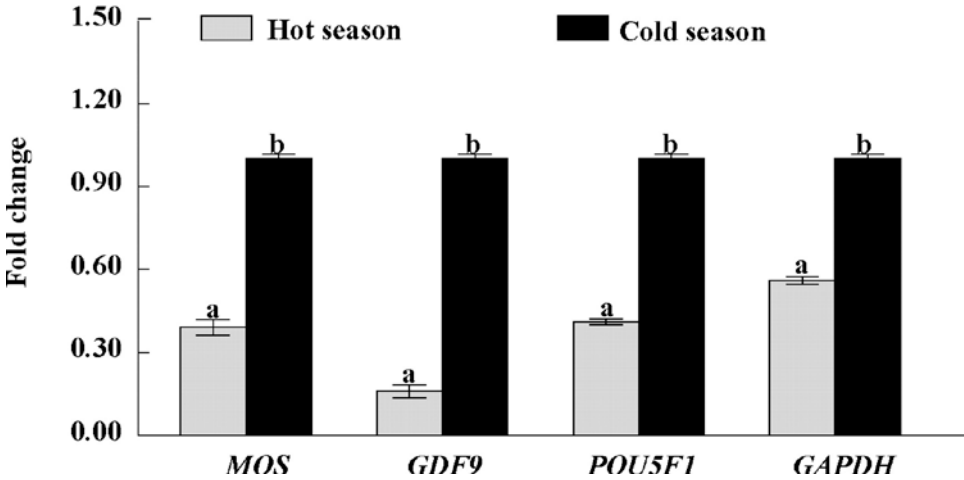
Roth and Hansen, 2004

Effect of season of collection on transcript levels of MOS, GDF9, POU5F1, and GAPDH in oocytes and embryos

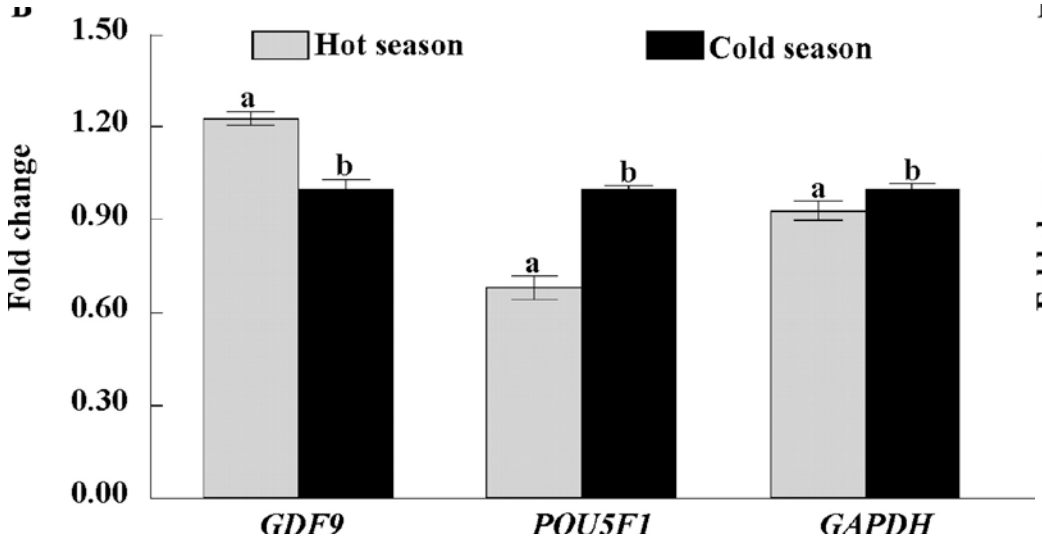
Gendelman and Roth, 2012



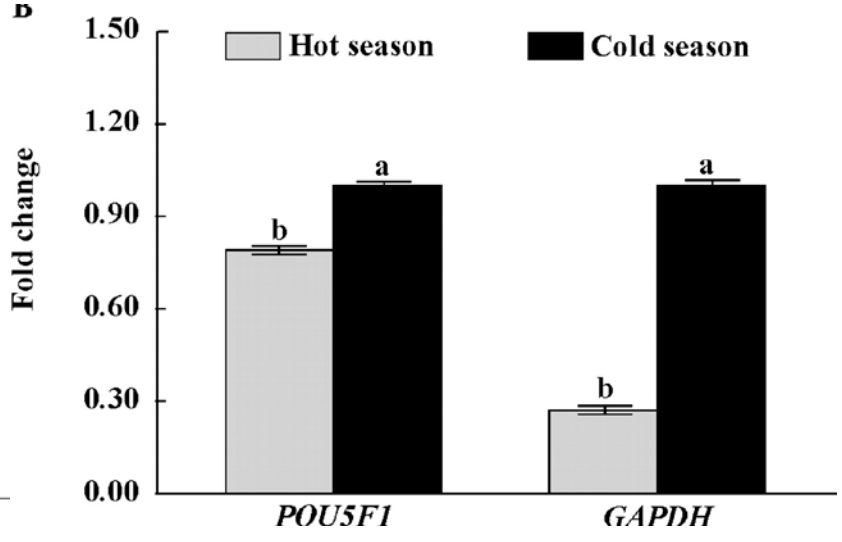
Germinal Vesicle Oocytes



Metaphase II Oocytes



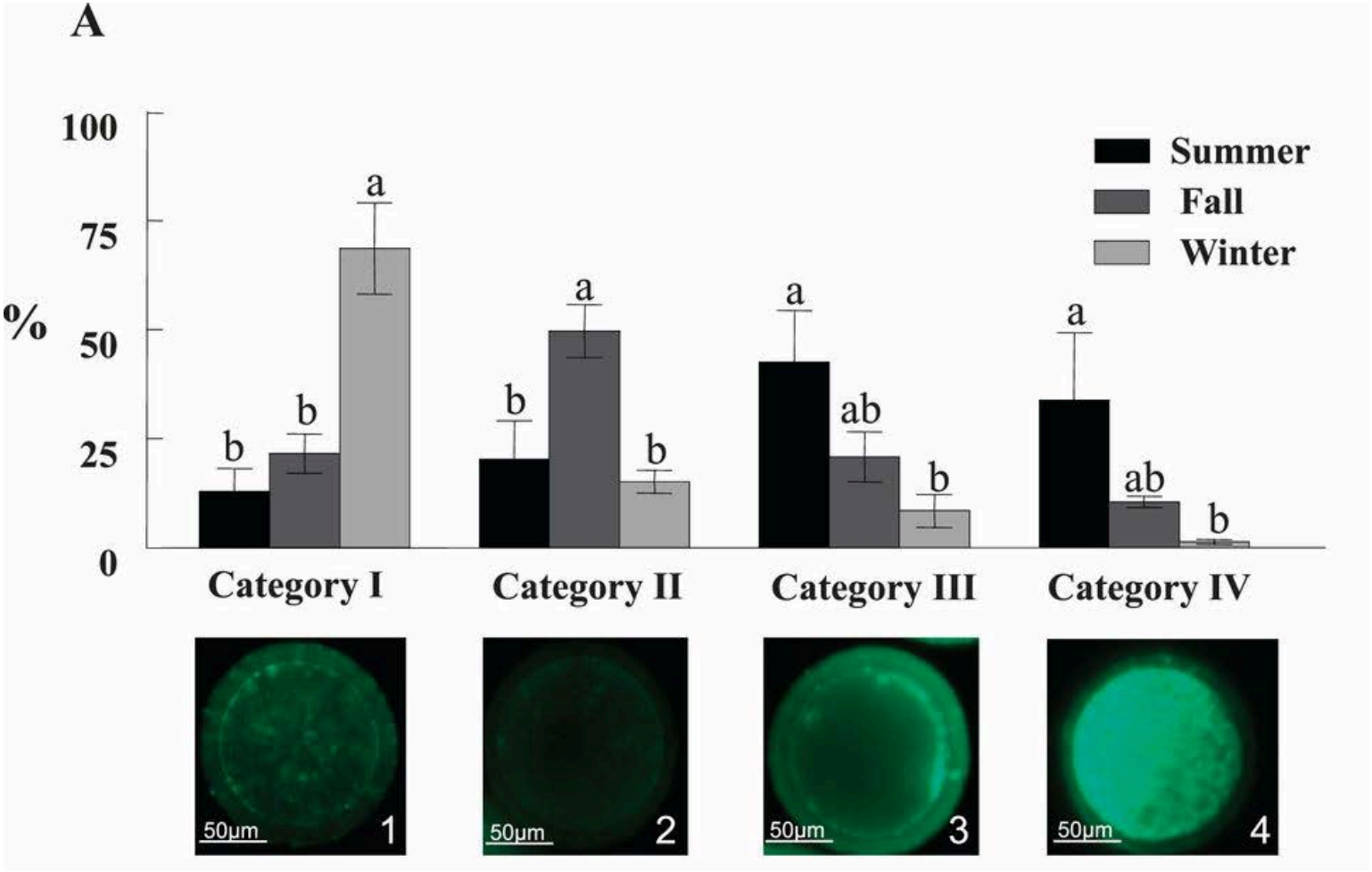
4-cell embryos



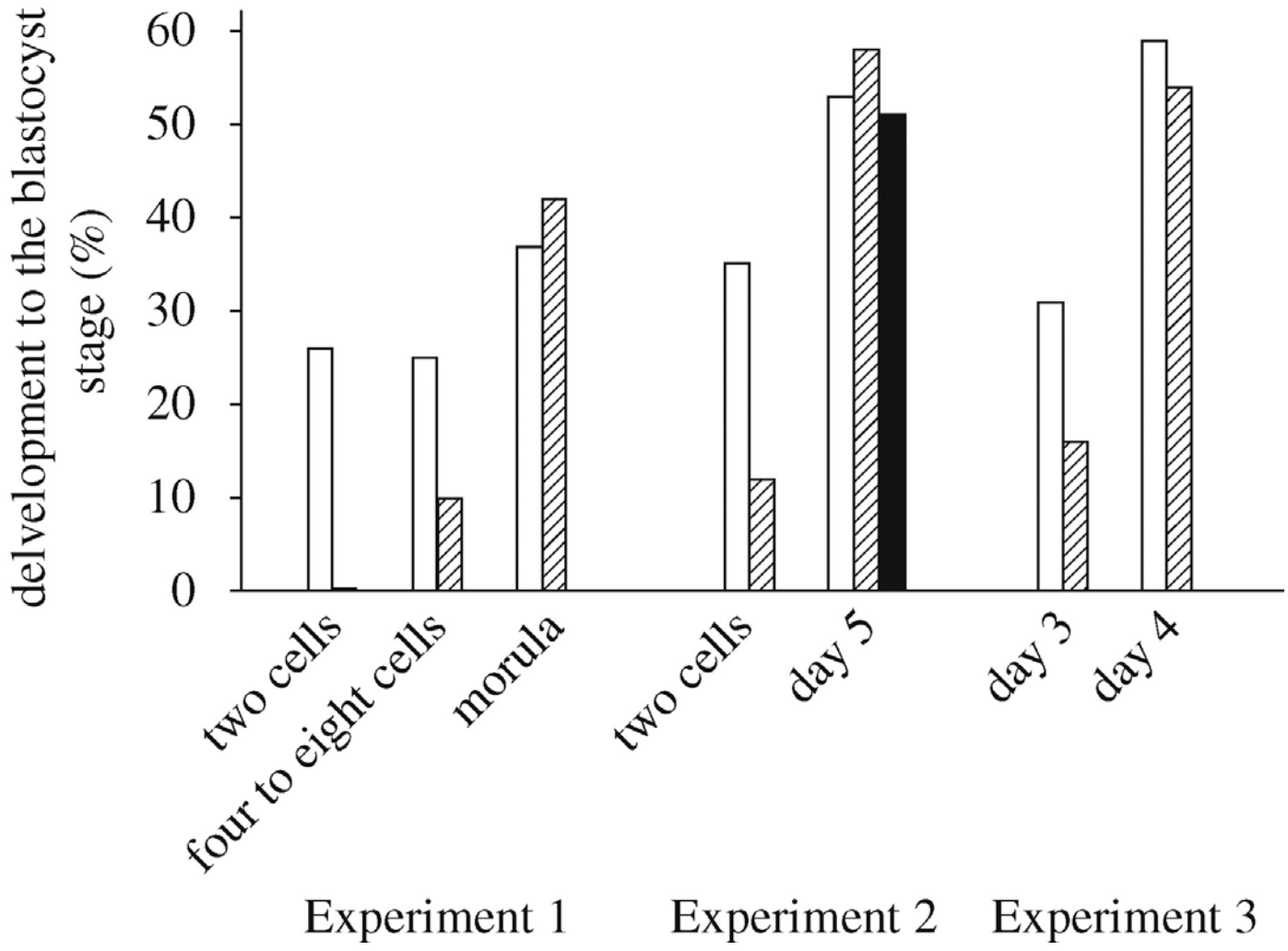
Blastocysts

Effect of season of collection on oocyte mitochondrial distribution

Gendelman and Roth, 2012

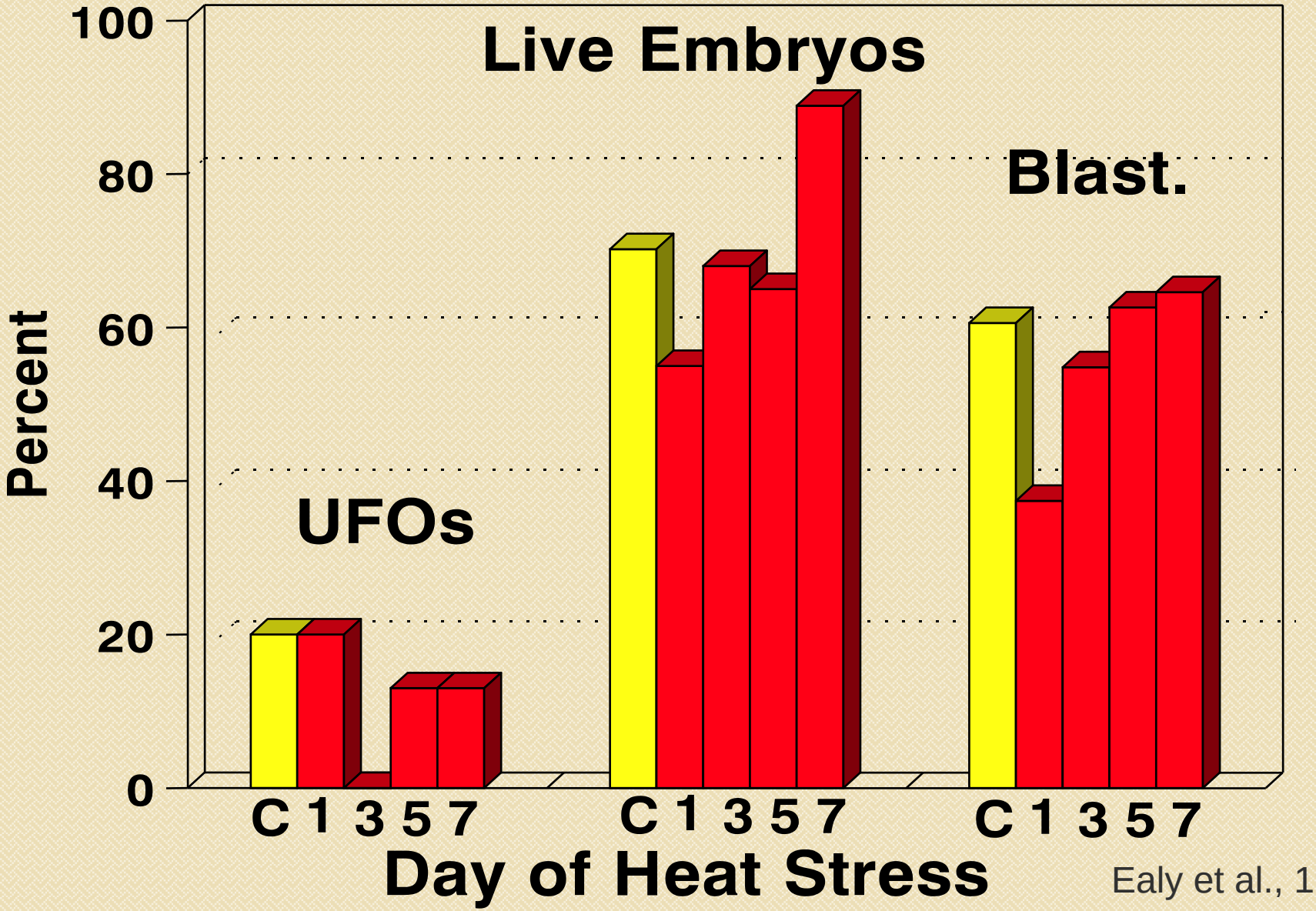


Developmental acquisition of resistance to heat shock



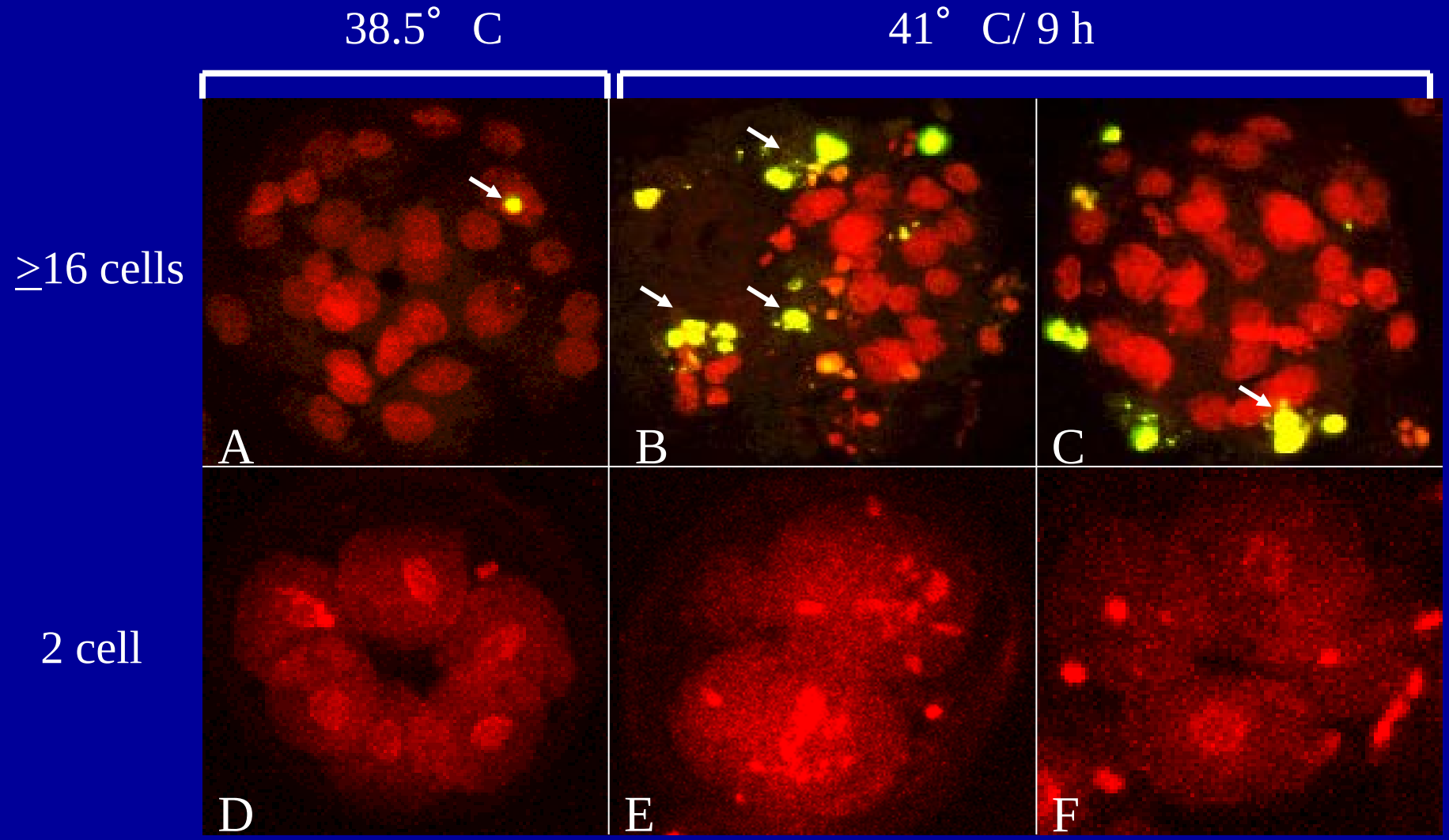
Edwards et al., 1997 Krininger et al., 2002 Ju et al., 1999

Effect of Maternal Heat Stress on Embryo Survival

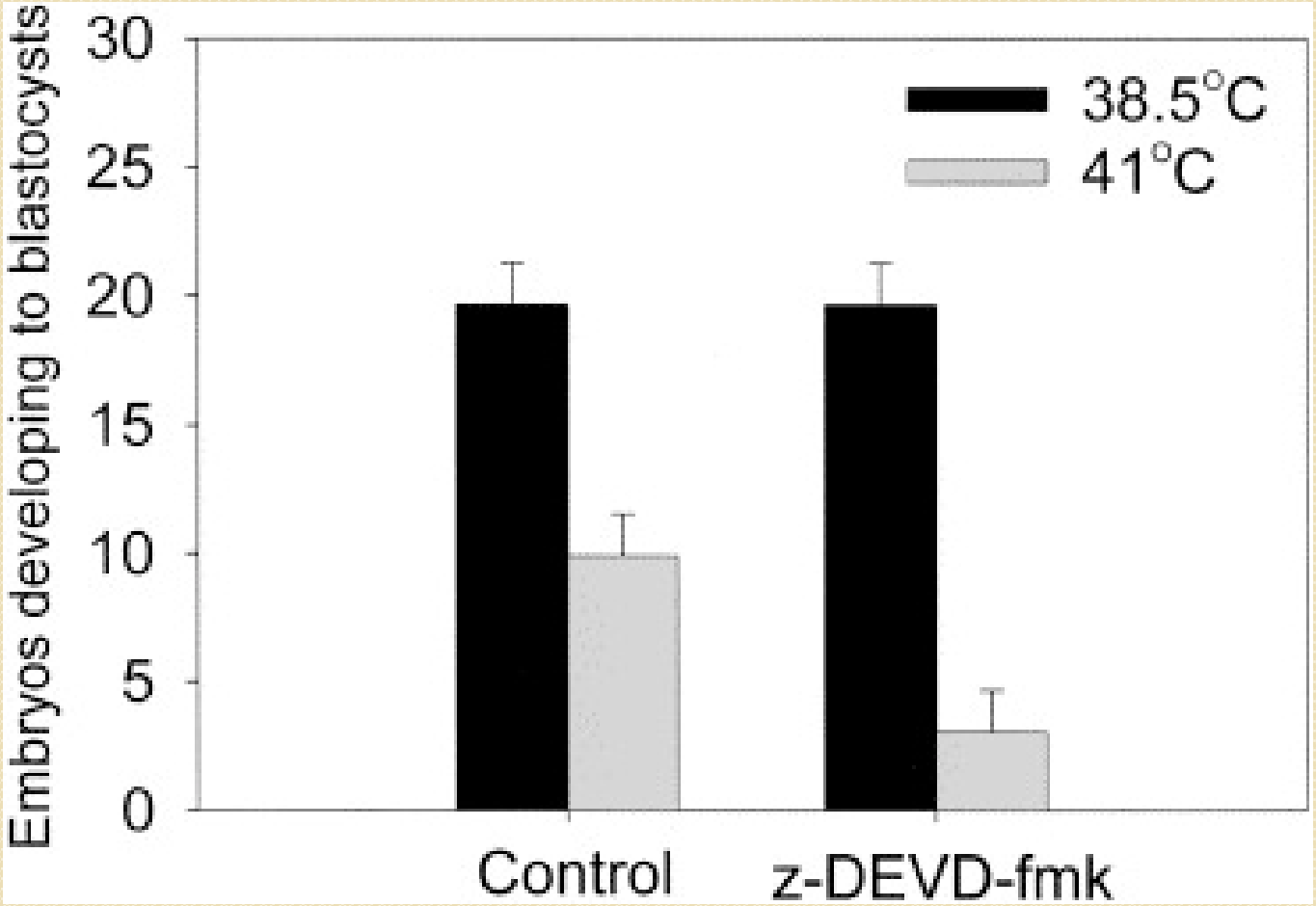


Ealy et al., 1993

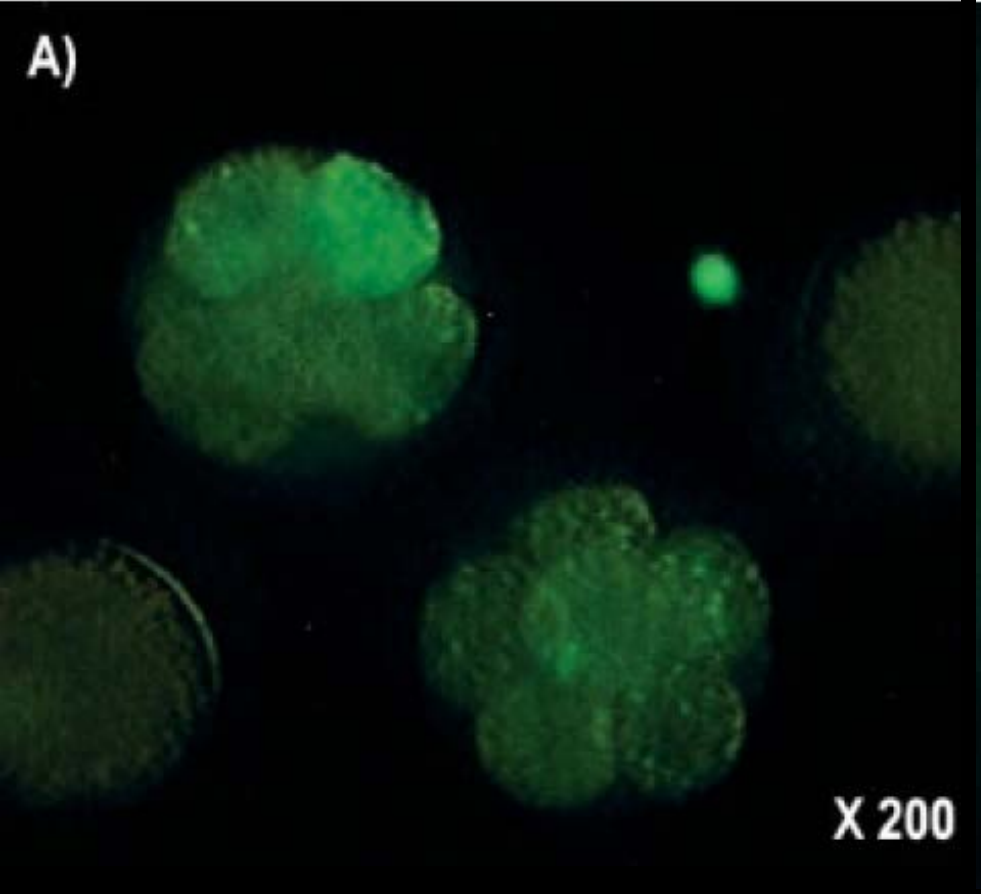
Frequency of Apoptotic Nuclei in Bovine Embryos Subjected to TUNEL

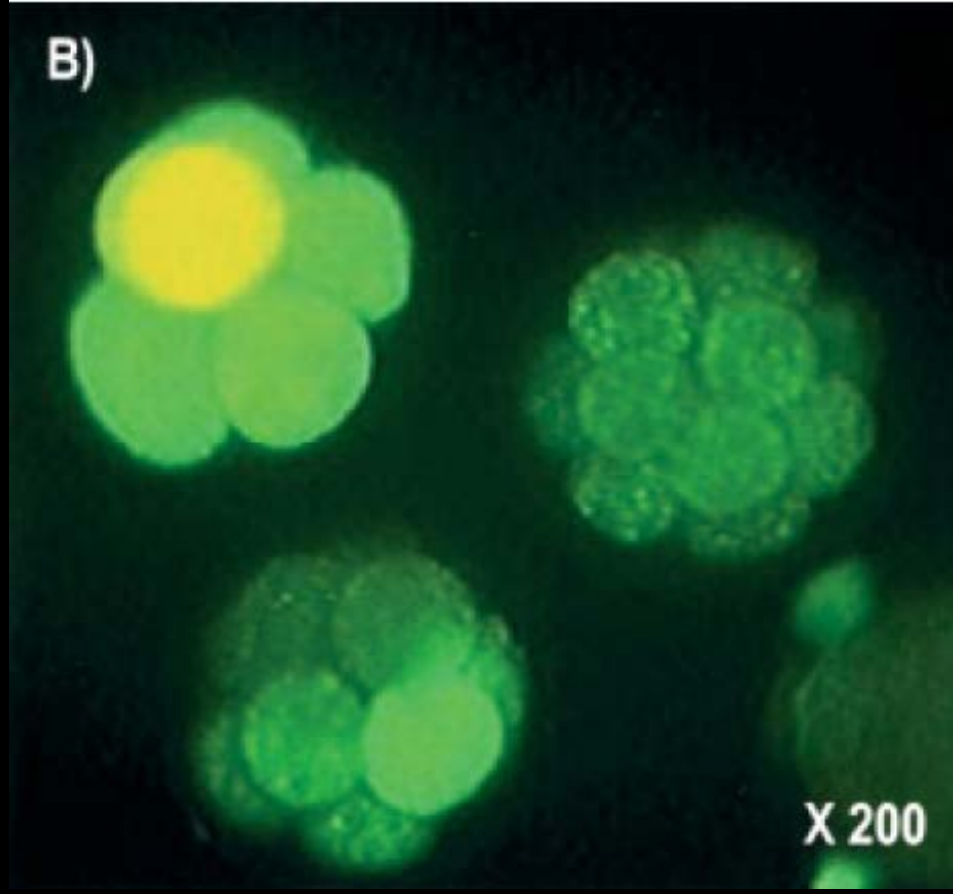


Effect of Inhibition of Apoptosis on Development Following Heat Shock



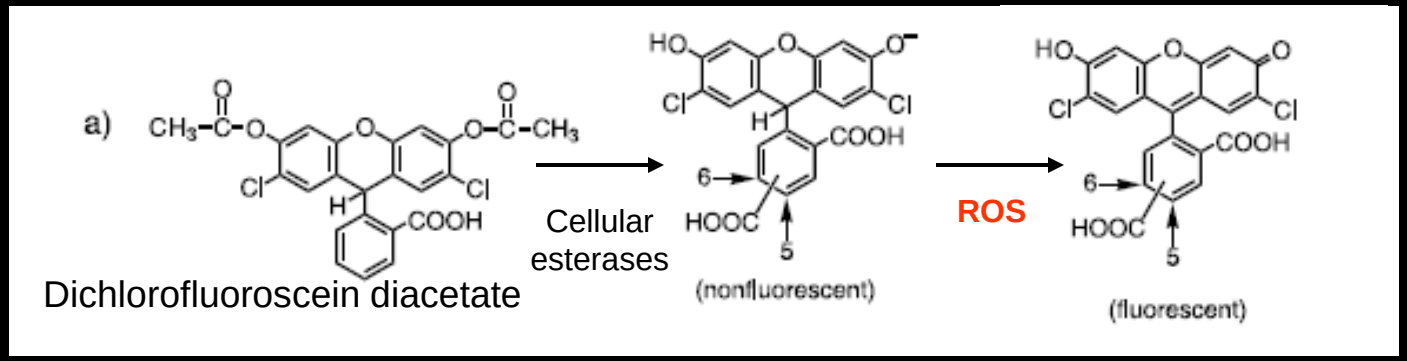
Paula-Lopes and Hansen, 2002



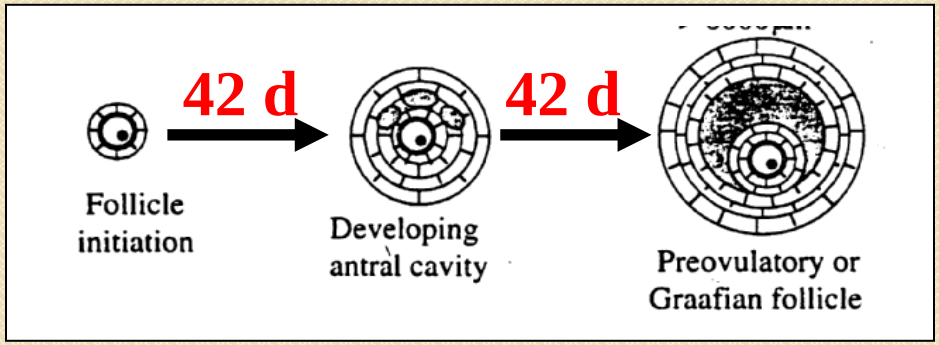


8-cell, 38.5°C

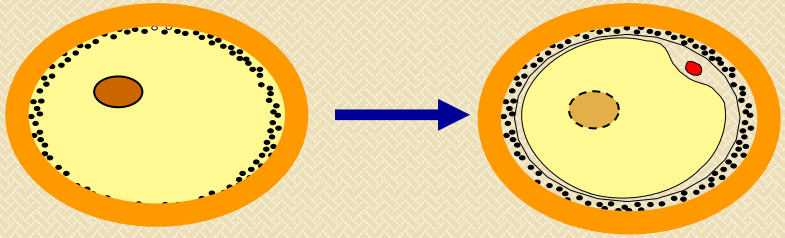
8-cell, 41°C – 6 h



Sakatani et al. Mol Reprod Dev 2004; 67:77-82

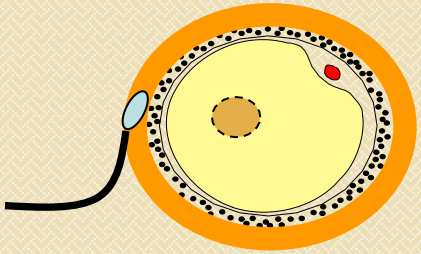


Follicular development and oocyte growth

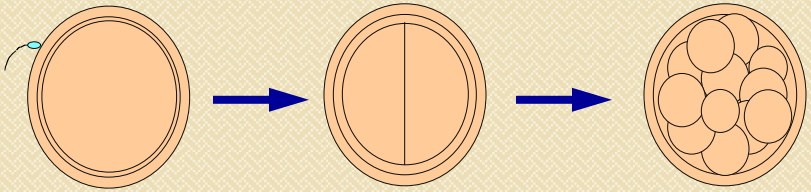


Oocyte maturation

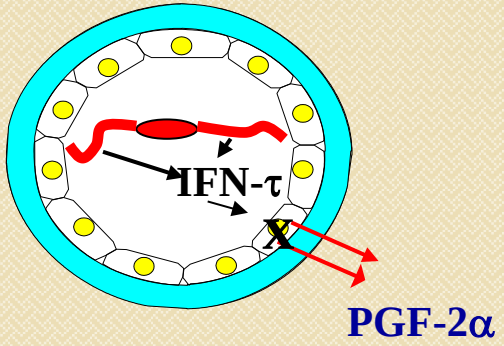
Use ET to Bypass Damage



Fertilization

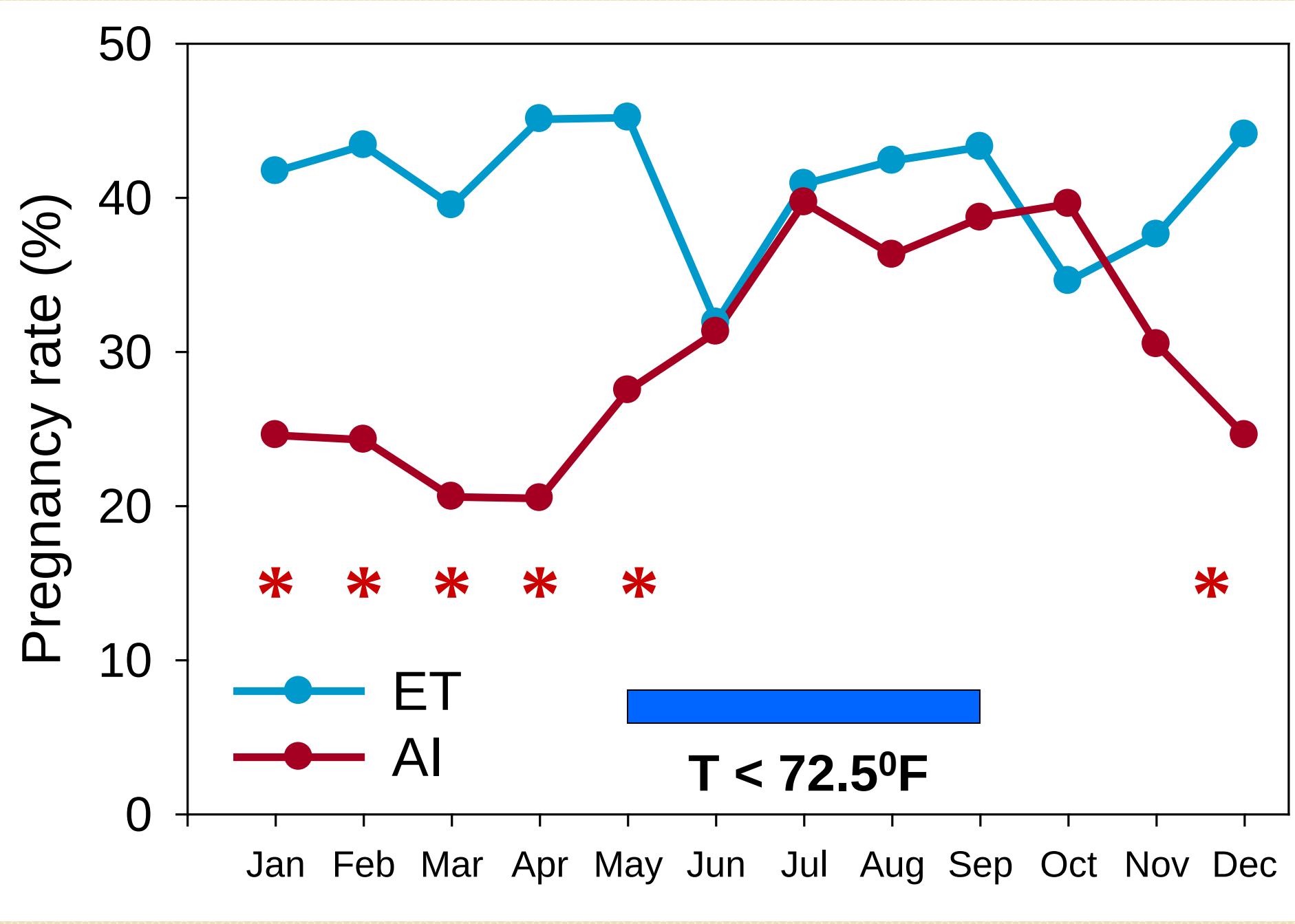


Preimplantation development



PGF-2α

Prevention of Luteolysis


Pregnancy rate (%)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
ET
AI
T < 72.5⁰F

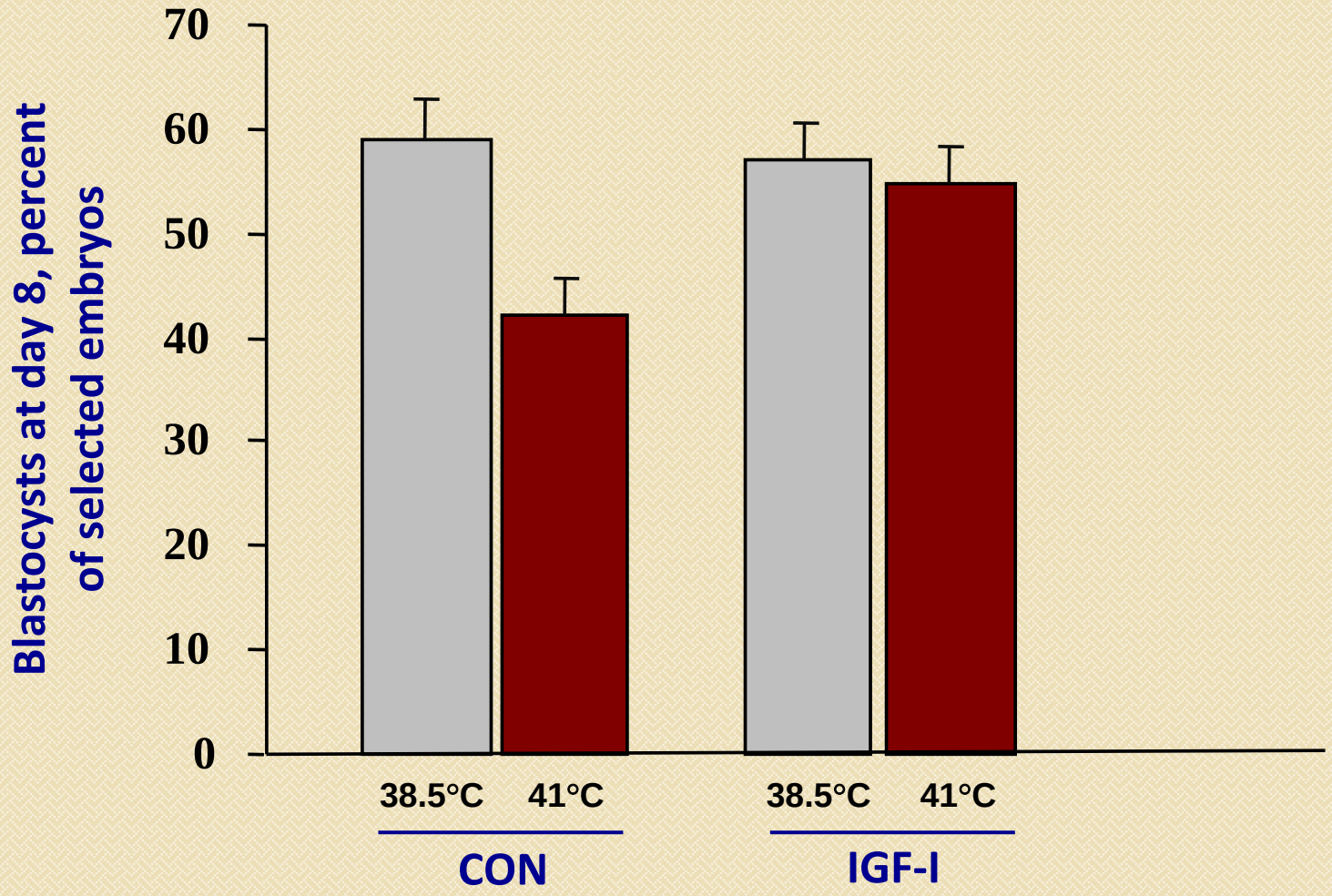
Results from Selected Embryo Transfer Experiments

Location	Treatment [a]	Pregnancy diagnosis (days)	Pregnancy rate (%)[b]	Reference
Florida	AI	45-60	14	Putney et al., 1989
	MOET-Fresh		29	
Florida	AI	42	21	Drost et al., 1999
	MOET-Cryo		35	
	ET-IVP-Cryo		19	
Florida	TAI	45-52	5	Ambrose et al., 1999
	TET-IVP-Fresh		14	
	TET-IVP-Cryo		5	
Florida	TAI	45	6	Al-Katanani et al., 2002
	TET-IVP-Fresh		19	
	TET-IVP-Cryo		7	
Texas	TAI	97	17	Stewart et al., 2011
	TET-IVP-Fresh		36	
	TRT-IVP-Cryo		26	

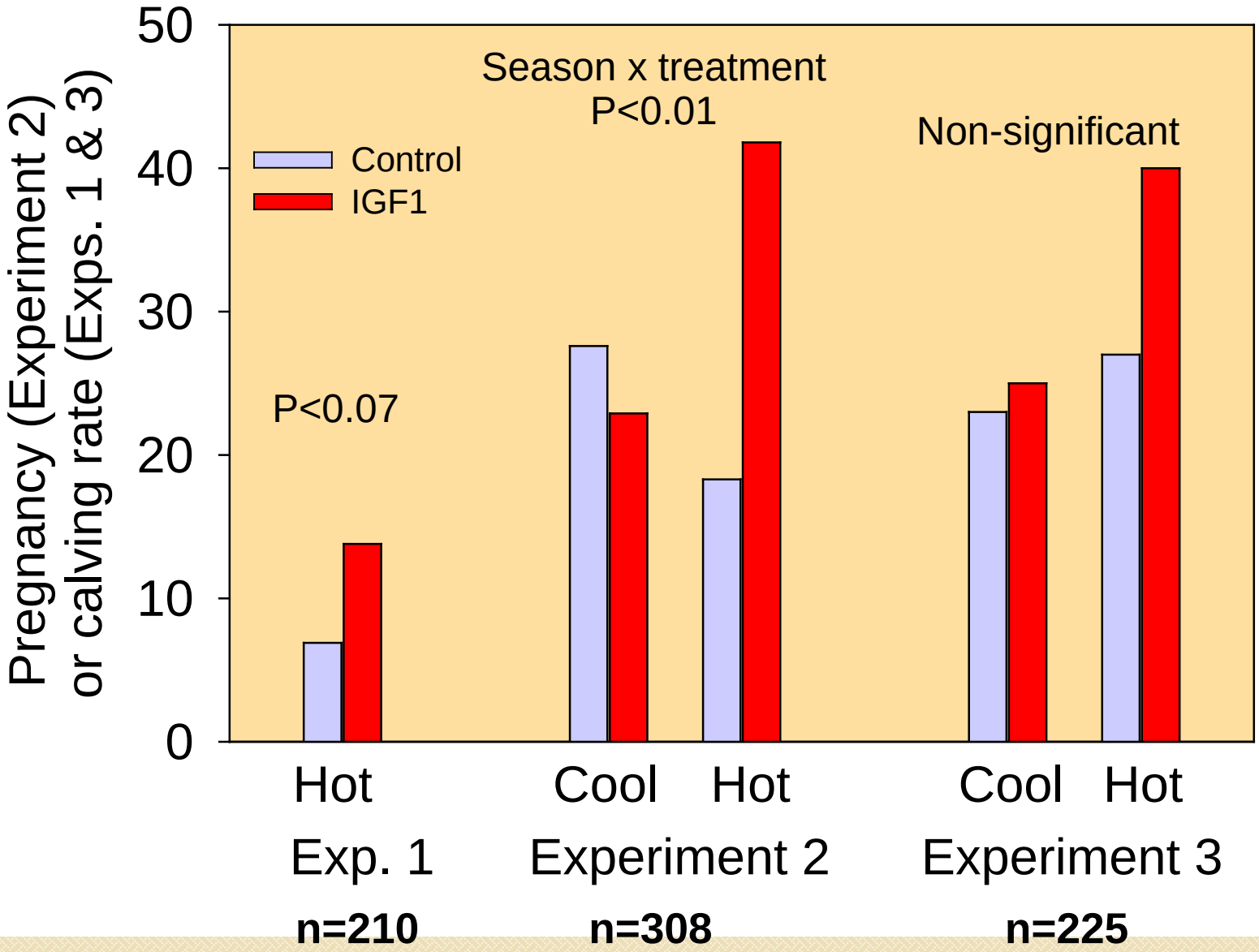
[a] Abbreviations are as follows: AI, artificial insemination; Cryo, cryopreserved; ET, embryo transfer; IVP, in vitro produced embryo; MOET, multiple ovulation embryo transfer; TAI, timed artificial insemination; TET, timed embryo transfer. Embryos were either transferred fresh or after cryopreservation.

[b] Percent of cows that were inseminated or received an embryo that were diagnosed pregnant.

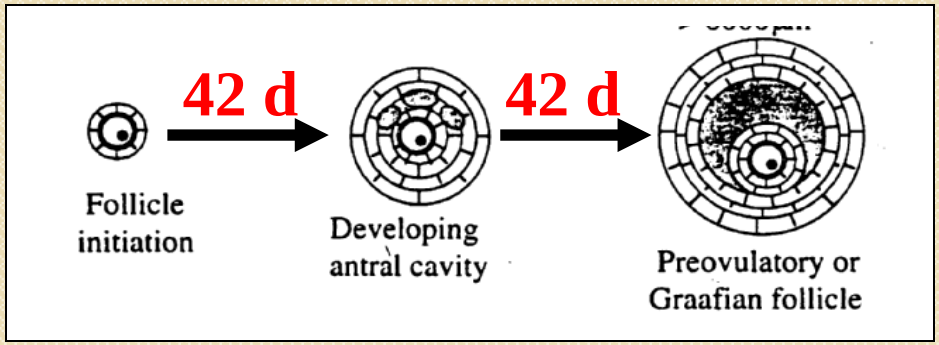
IGF-I prevents the reduction in blastocyst development caused by heat shock



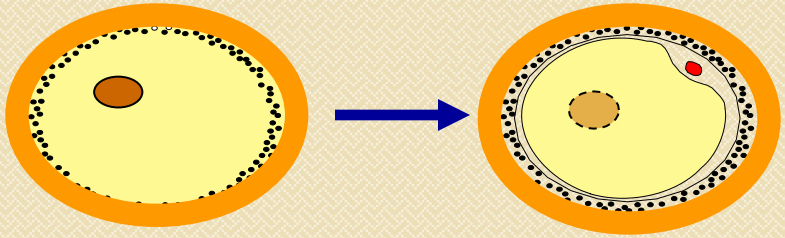
Seasonal effects on actions of IGF-1 during culture on embryo competence after transfer into lactating Holsteins



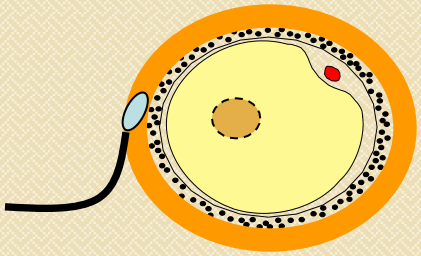
Manipulate the Genome to Increase Cellular Thermotolerance



Follicular development and oocyte growth



Oocyte maturation



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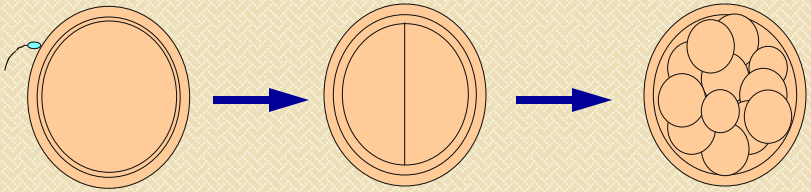
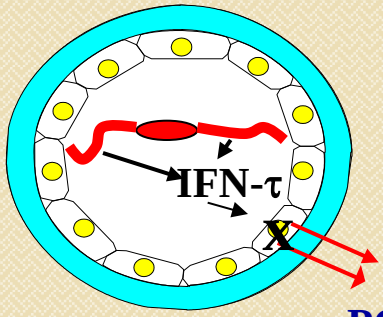
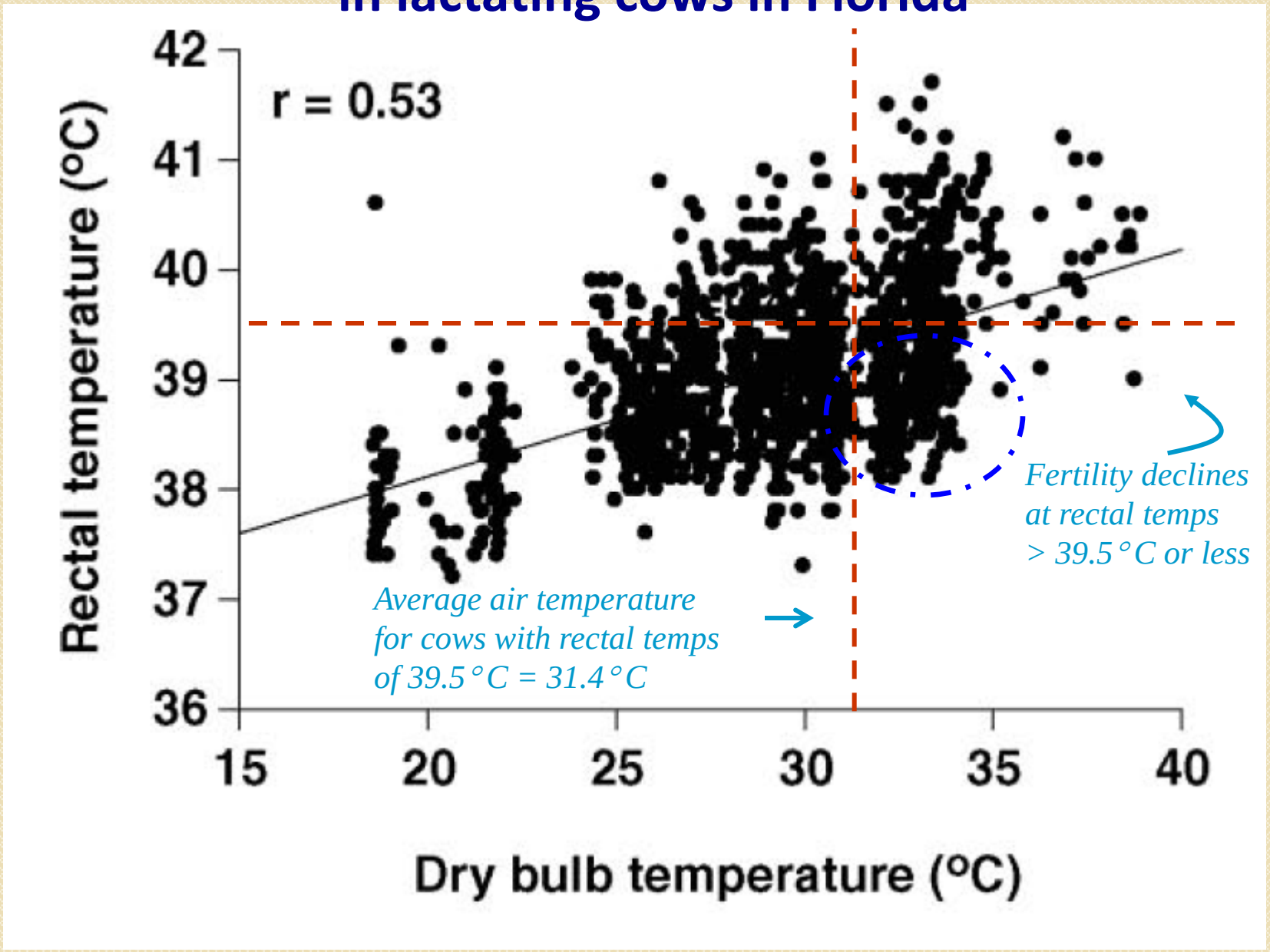


Preimplantation development

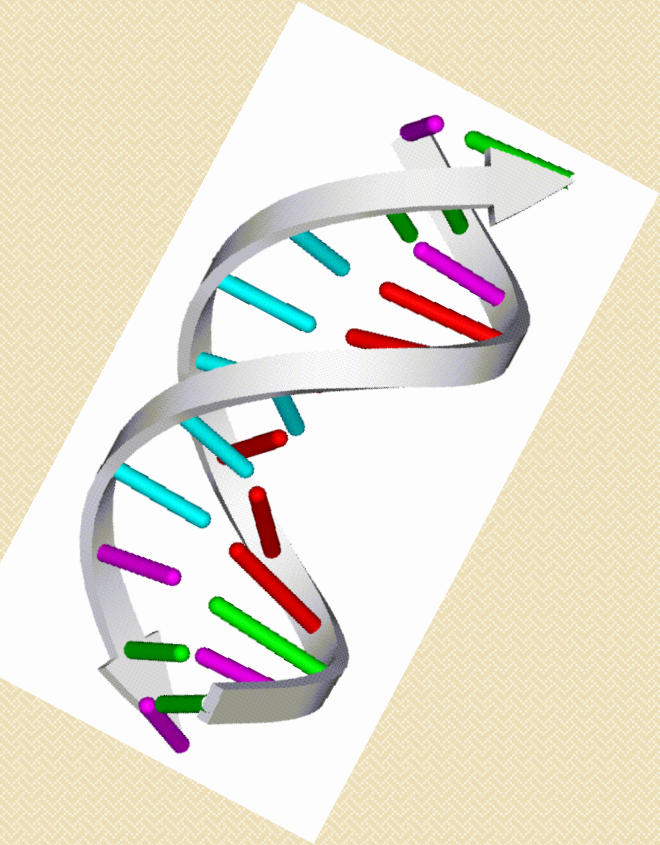


Prevention of Luteolysis

Relationship between air temperature and rectal temperature in lactating cows in Florida



Strategies to Increase Genetic Resistance to Heat Stress



Within a Breed

-conventional selection

-marker assisted selection
--SNP50 Chip

From Other Breeds or Species

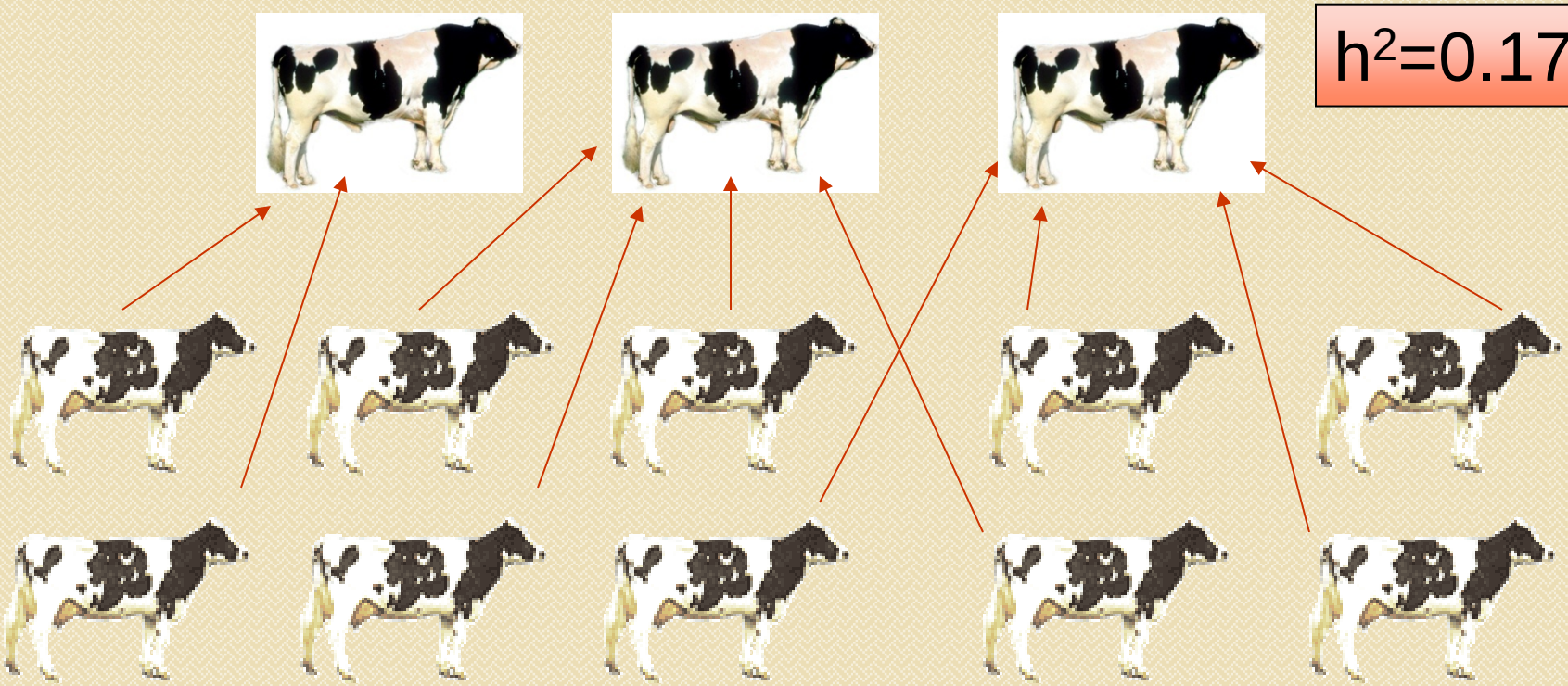
-introgression (crossbreeding & upgrade while selecting for gene of interest)

-transgenics

ESTIMATION OF HERITABILITY FOR RECTAL TEMPERATURE DURING HEAT STRESS

Related data to 509 proven sires to estimate heritability
(percent of variation in rectal temperature is due to genetics)

$h^2=0.17$



Measured rectal temperature between 3 and 5 PM
on 1695 cows on three free-stall dairies
June – September

Mol Biol Rep
DOI 10.1007/s11033-010-0080-8

A novel SNP of the *ATP1A1* gene is associated with heat tolerance traits in dairy cows

Yanxin Liu · Daqi Li · Huixia Li · Xuan Zhou · Genlin Wang

Online supplementary data

Table 1 Least-squares means and Standard error for heat tolerance traits of different genotypic heat-stressed cows

locus	Genotype	N	HTC	RR	Daily milk yield in summer	305d milk yields
P17	CC	121	79.59±2.78**	83.75±3.76*	27.89±1.65**	8579.60±110.43*
	CA	34	72.37±2.52	92.60±4.20	18.06±1.39	8162.25±98.92

** Means in a column with difference superscripts differ significantly ($P<0.01$); * ($P<0.05$), N-Number of sample group.

HTC = 100-10 (ART –38.3), where ART = average rectal temperature before and after 3 h exposure to solar radiation for three consecutive days and 38.3C is the average normal rectal temperature of cow.

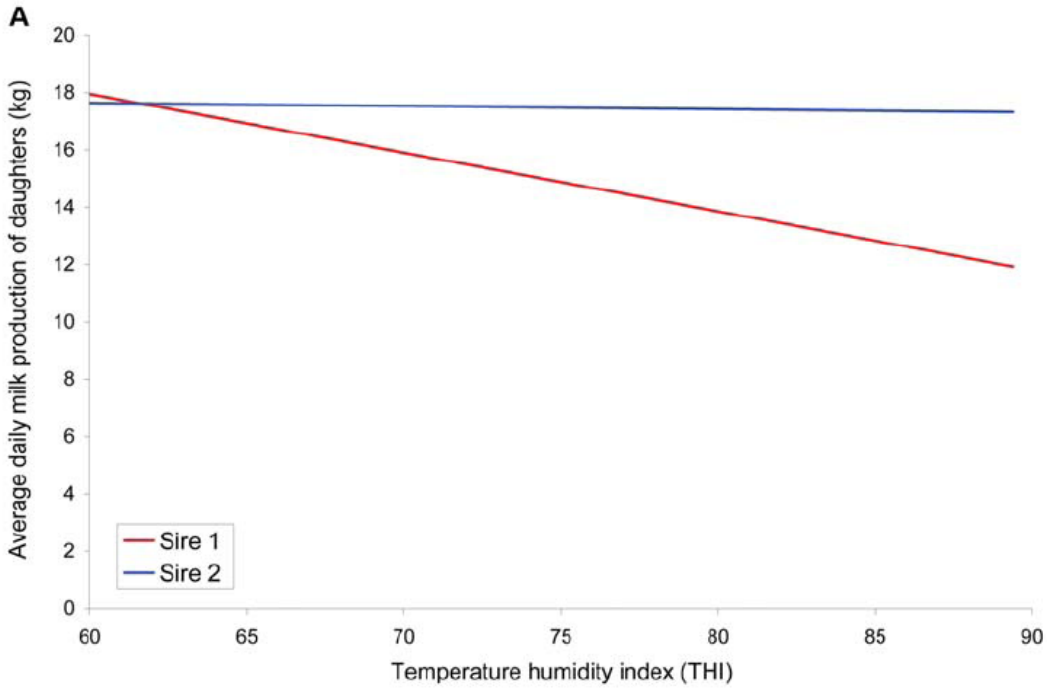
OPEN ACCESS Freely available online

PLoS one

A Validated Genome Wide Association Study to Breed Cattle Adapted to an Environment Altered by Climate Change

Ben J. Hayes[1]*, Phil J. Bowman[1], Amanda J. Chamberlain[1], Keith Savin[1], Curt P. van Tassell[2], Tad S. Sonstegard[2], Mike E. Goddard[1,3]

1 Biosciences Research Division, Department of Primary Industries Victoria, Melbourne, Victoria, Australia, **2** United States Department of Agriculture, Agricultural Research Service, Bovine Functional Genomics Laboratory, Beltsville, Maryland, United States of America, **3** Faculty of Land and Food Resources, University of Melbourne, Melbourne, Victoria, Australia



Using SNP50 Chip, significant SNP related to slope of change in milk yield on chromosome 29, near *FGF4*

Thank you for your attention

People in the Hansen Lab
Yaser Al-Katanani
Carlos Aréchiga
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Fabiola Paula-Lopes
Jeremy Block
Luciano Bonilla

UF Faculty
Jeremy Block
Albert de Vries
Tim Olson
Bill Thatcher
Dan Webb

Colleagues Outside UF
Joel Hernández-Cerón - UNAM
Ciro Barros – UNESP-Botucatu
Todd Bilby - Texas A&M
John Cole – USDA-ARS
Serdal Dikmen – Uludag Univ.

Dairies
Larson Dairy
Levy Co. Dairy
McArthur Dairy
UF Dairy Unit

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

#2010-85122-20623

Southeast Milk, Inc. Dairy Check-Off

Heritability Estimates

S. Dikmen, J. B. Cole, D. J. Null and P. J. Hansen

Trait	h^2
Rectal temperature	0.17
305-d actual milk yield	0.36
305-d actual fat yield	0.29
305-d actual protein yield	0.33
305-d actual somatic cell score	0.12
Productive life	0.08
Daughter pregnancy rate	0.04

Average dry bulb temperatures experienced by cows at various rectal temperatures – Florida

(Dikmen and Hansen, 2009)