Advances in Trace Mineral Nutrition

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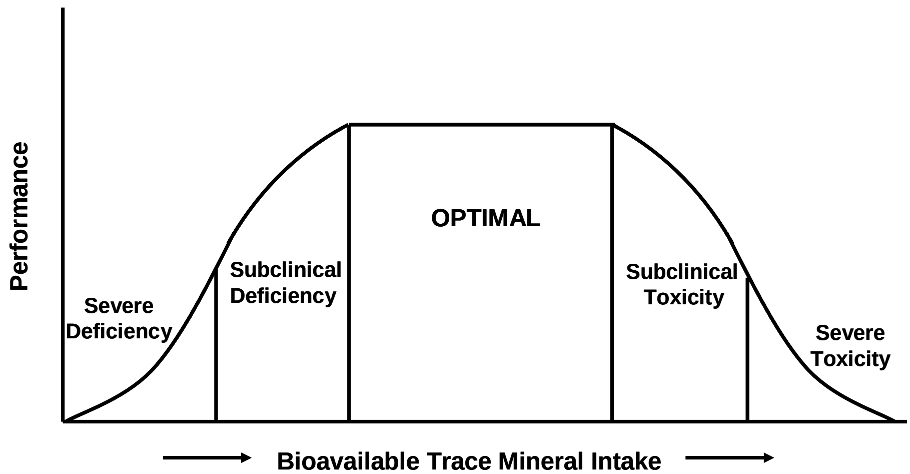
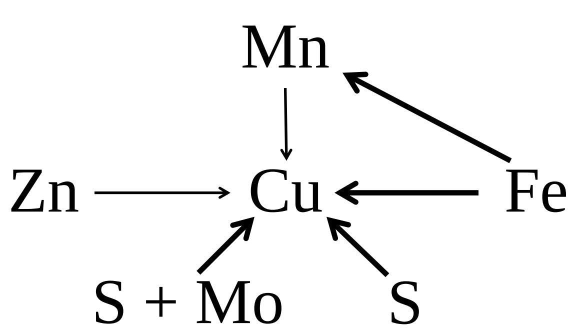
Trace Minerals – What is Important

- Provide adequate amounts of bioavailable trace minerals to meet requirements
  - Safety margin
- Avoid trace mineral toxicies (imbalances)
  - Clinical
  - Subclinical



Mineral Interactions in Ruminants



Outline of Presentation

- Chromium in dairy nutrition
- High dietary iron and possible consequences
- Manganese requirements

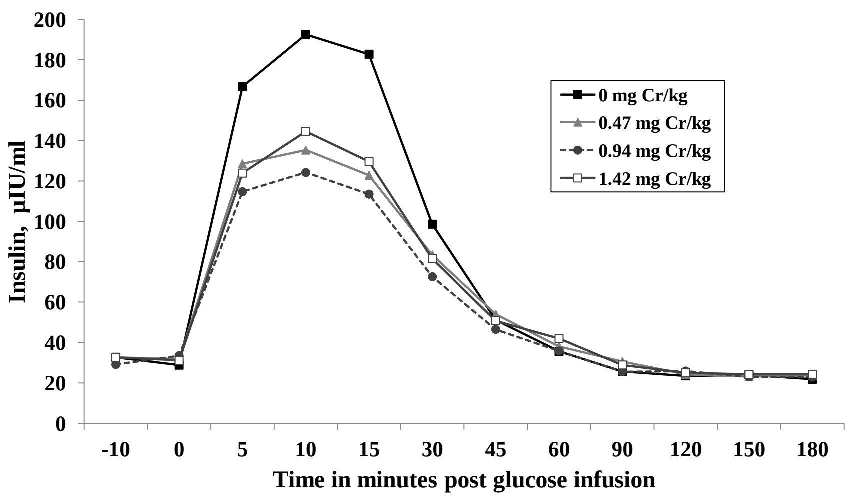
Chromium

- 1959 Schwartz and Mertz reported that trivalent chromium was a factor in brewers yeast that corrected impaired glucose metabolism in rats fed torula yeast based-diets
- 1992-present Numerous reports of responses in swine and cattle to chromium supplementation
- July 2009 FDA CVM issues a regulatory discretion letter permitting the addition of Chromium Propionate to cattle diets (0.5 mg/kg)
- First new trace mineral permitted as a supplement in cattle diets since selenium in 1979

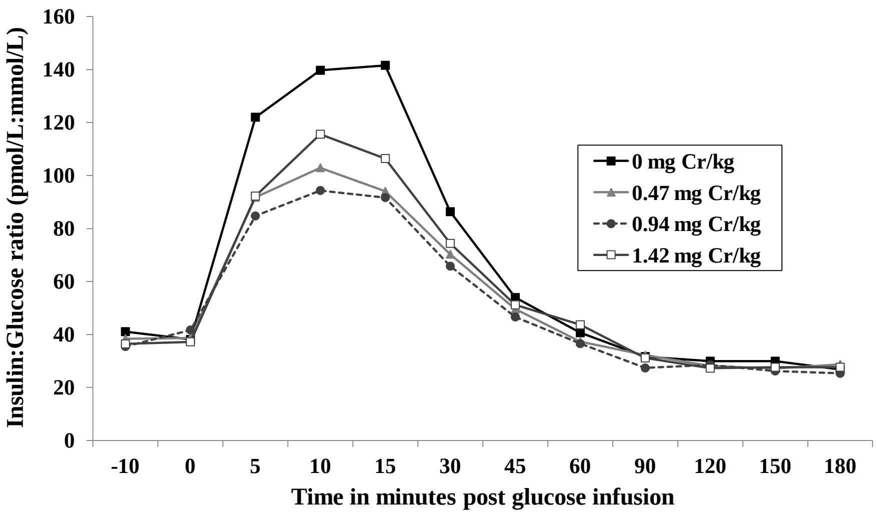
Chromium

- Functions by increasing the sensitivity of tissues to insulin
- Found in very low concentrations

Effect of Chromium Propionate on Serum Insulin in Heifers after a Glucose Tolerance Test



Effect of Dietary Chromium Propionate on Serum Insulin:Glucose Ratios in Heifers Following a Glucose Tolerance Test

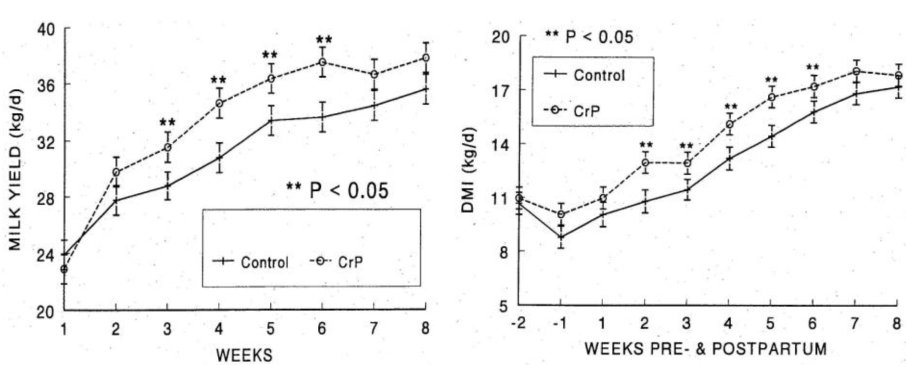


Responses to Chromium in Dairy Cattle

- Feed Intake and Milk Production
- Reproduction
- Immunity and Health

Many of the Chromium Studies with Dairy Cows have Involved Supplementation During the Transition Period

Effect of Chromium Supplementation on Intake and Milk Production



Besong, 1996

Responses of Multiparous Cows to Chromium Supplementation (0.40 – 0.50mg Cr/kg DM) During the Transition Period

		-Cr	+Cr	Δ
Hayirli et al., 2001				
	DMI, kg/d	13.8	17.2	3.4
	Milk,kg/d	33.5	38.5	5.0
McNamara and Valdez, 2005				
	DMI, kg/d	17.0	18.7	1.8
	Milk,kg/d	40.8	41.6	0.8
Smith et al., 2005				
	DMI, kg/d	18.2	19.7	1.5
	Milk,kg/d	40.3	42.8	2.5
Sadri et al., 2009				
	DMI, kg/d	17.6	18.1	0.5
	Milk,kg/d	34.6	36.5	1.9

Chromium Supplementation and Performance of Lactating Dairy Cows Under Heat Stress[a]

	Treatment	
	Control	Chromium
DMI, kg/d	**19.6[b]**	**21.2[c]**
Milk yield, kg/d	**29.9[b]**	**33.2[c]**

[a]Chromium was supplemented for 70 days beginning at 120-130 days postpartum. Average maximum temperature, 29.9 ± 2.3ºC; Average minimum temperature, 24.8 ± 2.6ºC.

[b,c]($P < 0.01$).

Al-Saiady et al. (2004)

Effect of Chromium Supplementation on Pregnancy Rate in Primiparous Dairy Cows

	Control	Chromium	P-value
Pregnancy rate, %			
Exp 1	50(3/6)	100(6/6)	0.05
Exp 2	78(7/9)	89(8/9)	0.53

Yang et al., 1996

Effect of Providing Chromium in a Free Choice Mineral on Pregnancy Rate in Beef Cows[a]

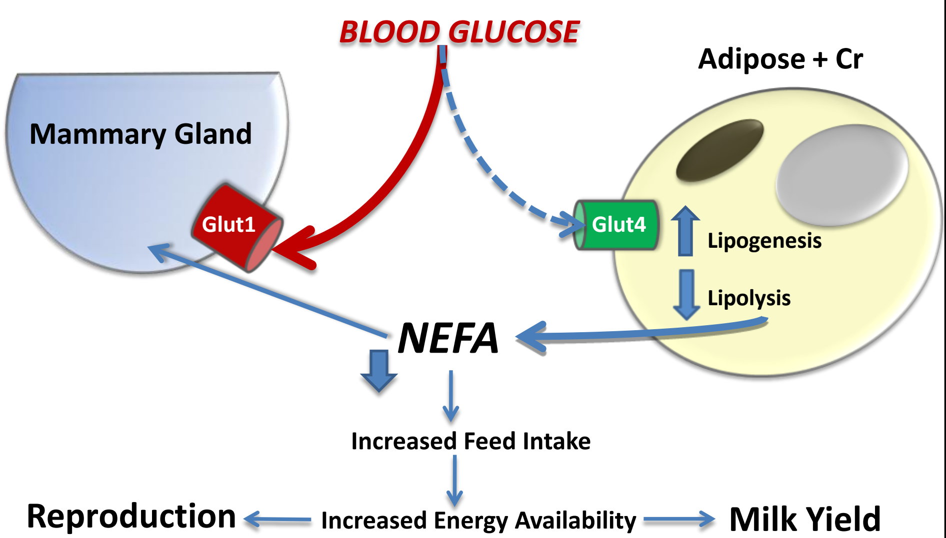
	Treatment		
	Control	Chromium	P-value
Pregnancy rate, %			
Overall	81	89	0.06
≥ 6 years of age	86(28)[b]	83(29)	0.76
4 and 5-year olds	74(19)	90(20)	0.19
2 and 3-year olds	81(26)	96(24)	0.13

[a]Study was conducted from approximately 75 d prepartum (Sept) until calves were weaned in June.
[b]Number of cows

Stahlhut et al. (2006)

Proposed Mechanism Whereby Chromium Increases Feed Intake, Milk Yield and Possibly Reproduction

Chromium appears to increase insulin sensitivity in adipose tissue during early lactation



Effect of Dietary Chromium on Performance of Early Lactation Dairy Cows

	Supplemental chromium			
	mg/cow/d	0	3.7	7.6
	mg/kg DM	0	0.20	0.39
DMI, kg/d[a]		18.2	18.9	19.7
Milk yield, kg/d[a]		40.3	40.5	42.8
Prepartum BW, kg		722	724	724
Postpartum BW, kg[a]		614	620	639

[a]Linear effect of Cr ($P < 0.05$).

Smith et al., 2005

Effect of Providing Chromium in a Free Choice Mineral on Plasma Non-Esterified Fatty Acid Concentrations in Beef Cows

	Treatment		
Days postpartum	Control	Chromium	P-value
Plasma NEFA	---------- meq/dL ----------		
- 48	297	220	0.20
- 18	451	377	0.21
21	569	389	0.01
79	669	373	0.01
134	249	273	0.69
203	289	248	0.49

Stahlhut et al., 2006

Chromium and Immunity and Health

Interrelationship Between Chromium and Stress

Dietary Chromium in Receiving Diets and Performance and Morbidity of calves

	Supplemental Cr (CrY), mg/kg			
	0	0.2	0.5	1.0
n	21	21	21	21
Gain, kg/d	0.66[a]	0.84[b]	0.70[a,b]	0.84[b]
DMI, kg/d	3.99[a]	4.66[b]	3.91[a]	4.57[b]
Morbidity, %	52.4[a]	14.3[b]	33.3[a]	47.6[a]

[a,b] ($P < 0.05$)

Moonsie-Shageer and Mowat, 1993

Chromium Levels in Feedstuffs

Chromium Content of Feedstuffs

	Chromium, mg/kg	
Feedstuff	Mean	Range
Corn (13)	0.045	0.008 – 0.083
Soybean meal (5)	0.259	0.181 – 0.323
Distillers dried grain (4)	0.299	0.128 – 0.754
Wheat (1)	0.042	
Oats (1)	0.156	
Mono-dicalcium phosphate	100.0	

[a] Number of samples

Chromium Content of Ruminant Feedstuffs

	Chromium, mg/kg	
Feedstuff	Mean	Range
Corn silage (15)	0.201	0.068 – 0.453
Alfalfa hay (7)	0.466	0.200 – 0.990
Alfalfa haylage (6)	0.595	0.237 – 0.889
Soybean hulls (7)	0.574	0.262 – 1.014
Cottonseed hulls (4)	0.111	0.019 – 0.315
Cottonseed, whole (3)	0.073	0.031 – 0.155
Corn gluten (3)	0.675	0.347 – 1.282
Wheat midds (1)	0.155	
Wheat silage (1)	0.148	
Grass hay (1)	0.312	
Wheat straw (1)	0.178	
Rice hulls (1)	0.211	
Hominy feed (1)	0.0097	
Citrus pulp (1)	0.783	

How Bioavailable is Chromium Naturally Present in Feedstuffs?

Summary

- Chromium addition to cattle diets has increased insulin sensitivity
- Supplementation of chromium during the transition period has increased feed intake and milk production during early lactation
- Chromium supplementation may increase immune response
- Chromium supplementation may improve reproduction, especially in young cows

Possible Consequences of High Dietary Iron (500 mg/kg DM or greater)

High Dietary Iron (Bioavailable)

- Reduced manganese bioavailability
- Reduced copper status
- Impaired intestinal permeability
- Liver damage

Effect of dietary iron on copper status of calves[a]

	Supplemental Fe (mg/kg)	
	0	800
Plasma Cu, mg/L	0.81	0.26
Liver Cu, mg/kg DM	61.9	6.5
Liver SOD, µg/mg protein	8.3	2.7

[a]Samples were taken after diets were fed for 16 weeks.

Humphries et al., 1983

Iron Content of Selected Feedstuffs[a]

	Iron, mg/kg	SD
Corn	**54**	**53**
Barley	**70**	**60**
Soybean meal	**206**	**124**
Phosphate supplements	**10,000**	**---**
Alfalfa	**619**	**617**
Corn silage	**104**	**109**
Grass silage	**331**	**324**
Legume silage	**367**	**490**
Grass hay	**156**	**157**
Legume hay	**286**	**270**

[a]From Dairy NRC 2001.

Iron Concentrations in By-Product Feedstuffs[a]

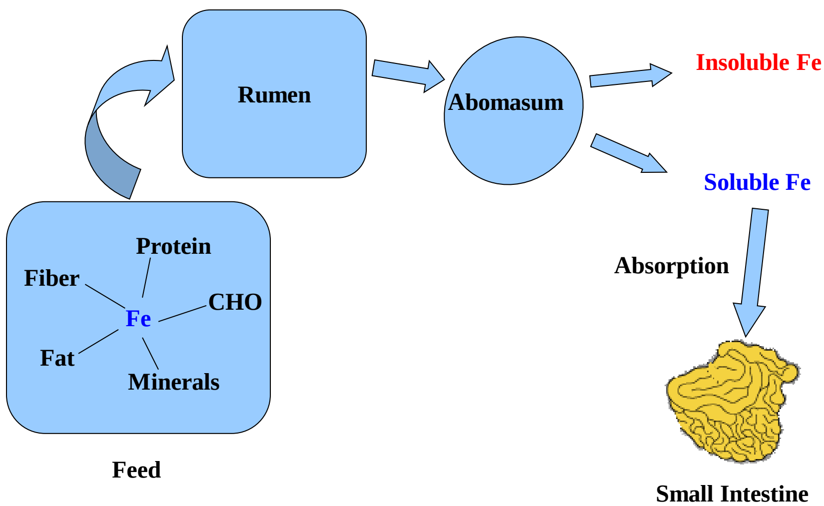
	Iron, mg/kg DM		
	Mean	Range	SD
Almond hulls	222	74-709	147
Beet pulp	290	204-447	76
Brewers grains	123	103-154	17
Canola meal	230	203-295	28
Corn gluten feed	122	80-152	24
Distillers grains	176	141-217	27
Cane molasses	171	123-277	47
Safflower meal	308	258-414	44
Soybean hulls	523	145-847	172
Wheat meal run	187	58-433	99

[a]From DePeters et al., 2000.

How Bioavailable is Iron Found Naturally in Feeds?

- Phosphate supplements (50% relative to $FeSO_4$)
- Pasture?
- Harvested feeds (?)
- Soil (extremely low?)
  - Ensiling increases bioavailability (low pH)

Release of iron from feeds

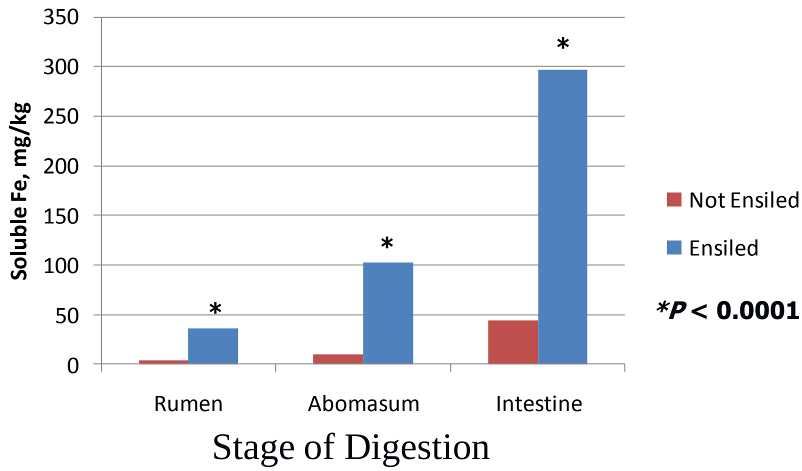


Effect of time and level of soil addition to corn silage on total and water – soluble iron concentrations

Soil Added %	Time	Total Fe µg/g DM	Water Soluble Fe µg/g DM	Water Soluble Fe %
Control (0)	------	54	8	14.7
1	Before	1591	193	12.9
1	After	1586	12	0.9
5	Before	5498	435	7.6
5	After	6830	15	0.2

Hansen and Spears, 2009

Effect of ensiling on potentially bioaccessible iron concentrations



Hansen and Spears, 2009

Ferritin is a Major Form of Iron in Soybeans and Possibly Other Legumes

- Bioavailability of iron from ferritin in soybeans has been shown to be equal to ferrous sulfate in humans

(Lonnerdal et al., 2006)

Iron Bioavailability from Common Feedstuffs

Iron released following ruminal digestion of harvested forages

			Ruminal Fe disa (%)		
Forages	**n**	**Total Fe (mg/kg)**	**3h**	**12h**	**24h**
Corn silage	**3**	**85**	**61.7**	**77.6**	**79.9**
Wheat silage	**2**	**56**	**55.4**	**72.0**	**76.9**
Alfalfa hay	**2**	**140**	**40.4**	**60.4**	**67.8**
Alfalfa haylage	**2**	**195**	**34.7**	**52.3**	**61.4**
Grass hay	**1**	**119**	**23.1**	**.**	**62.0**
Wheat straw	**1**	**634**	**30.4**	**40.5**	**40.8**
Common bermuda	**1**	**42**	**0.2**	**37.5**	**42.8**
Gamma grass	**1**	**31**	**0**	**0**	**7.3**

Iron released following ruminal digestion of concentrate and by-product

Feed stuff	n	Total Fe (mg/kg)	Ruminal Fe disa (%)		
			3h	12h	24h
Soybean hull	**2**	**373**	**75.8**	**92.4**	**96.7**
Soybean meal	**2**	**117**	**55.5**	**90.8**	**91.7**
Wheat	**1**	**28**	**27.7**	**79.8**	**85.5**
Corn gluten	**2**	**87**	**68.0**	**81.7**	**84.3**
DDGS	**2**	**72**	**51.0**	**74.1**	**80.9**
Oat	**1**	**61**	**41.5**	**63.9**	**69.6**
Corn	**2**	**33**	**33.5**	**57.9**	**63.8**

Summary

- High dietary iron in animal diets may be a practical problem in certain situations
- Little is known regarding bioavailability of iron from animal feeds
- Ensiling seems to increase bioavailability of iron from soil contamination
- Legumes may provide highly available iron in the ferritin form

Manganese Requirements

- Manganese recommendations in the Dairy NRC appear to underestimate requirements
  - * Lactating cows 12 – 14 mg/kg DM
  - * Late gestation 16 – 24 mg/kg DM

Effects of Dietary Manganese on Growth and Reproductive Performance of Beef Heifers[a,b]

	Supplemental Mn, mg/kg			
	0	10	30	50
Gain, kg/d	0.98	0.97	0.98	1.01
DM intake, kg/d	10.2	9.8	10.2	10.4
Gain:feed	0.11	0.11	0.11	0.11
Average age at conception, d	431	436	432	432
Pregnancy rate, %	60	50	67	75
	(12/20)	(10/20)	(13/19)	(15/20)

[a]196-day study.
[b]Control diet analyzed 15.8 mg Mn/kg DM.

Hansen et al., 2006

Effect of dietary manganese concentration fed to beef heifers on performance of their offspring

	Supplemental Mn, mg/kg	
Item	0	50
Birth weight, kg[a]	31.54	38.51
ADG, kg[b]	0.81	0.84

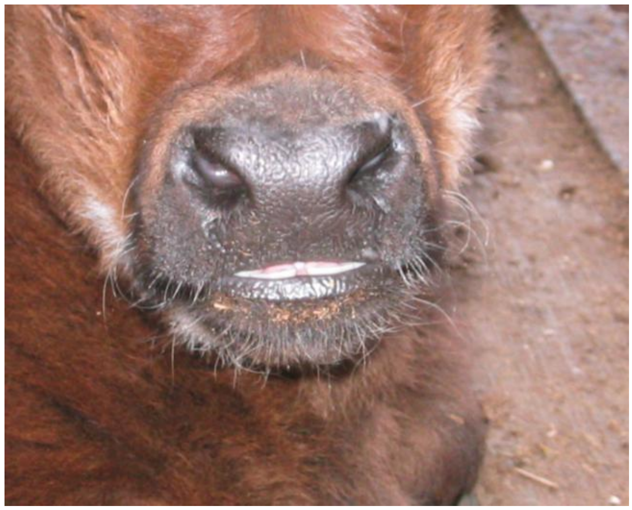
[a]P < 0.05.
[b]Average calf age 67 d at final weight.

Observed signs of manganese deficiency in calves born to heifers fed low manganese diets

	Supplemental Mn, mg/kg		
Observed Sign[a]	0	50	*P*
Disproportionate dwarfism[b]	3/7	0/6	0.08
Unsteadiness/weakness at birth[c]	3/7	0/6	0.08
Superior brachygnathism[d]	5/7	0/6	0.005

[a]Data were pooled for calves across breeds.
[b]Defined as calves that were smaller in stature when compared to their age and breed matched supplemented counterparts.
[c]Defined as calves that trembled or shook when walking and could be put off balance by a push of the hand.
[d]Defined as calves that had an extended lower jaw due to shortened nasomaxillary bones.

Control Calf



Lameness, Suspected Mn Deficiency

What factors may increase manganese requirements?

- Iron
- Calcium and Phosphorus

Congenital Joint Laxity and Dwarfism

- Field observations of Mn deficiency in Canada from late 1980's to 1990's
- Signs included joint laxity, dwarfism, domed foreheads, and superior brachygnathism
- Abnormal calves born to cows fed grass or red clover silage over winter
- Diets contained 50-60 mg Mn/kg DM
- Cows supplemented with hay produced no CJLD calves

Ribble et al., 1989
Hidiroglou et al., 1990

Conclusions