Istituto di Zootecnica
Facoltà di Agraria
U.C.S.C. Piacenza

An update of nutritional factors affecting animal welfare (ruminants)

G. Bertoni

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Introduction

what do “we” want with animal welfare?

luxury or good comfortable stable?

are prevented
- **physical and mental discomfort (pain/fear)**
- **suffering (or negative feeling?)**

is favoured a positive emotional status (positive feeling)

For the 2nd one I like Webster (1994): "Absolute attainment of all five freedoms is unrealistic, indeed they are to some extent incompatible. Complete behavioural freedom, for example, is unhygienic for all us animals! In fact, all commercial husbandry systems have their strengths and weaknesses .....

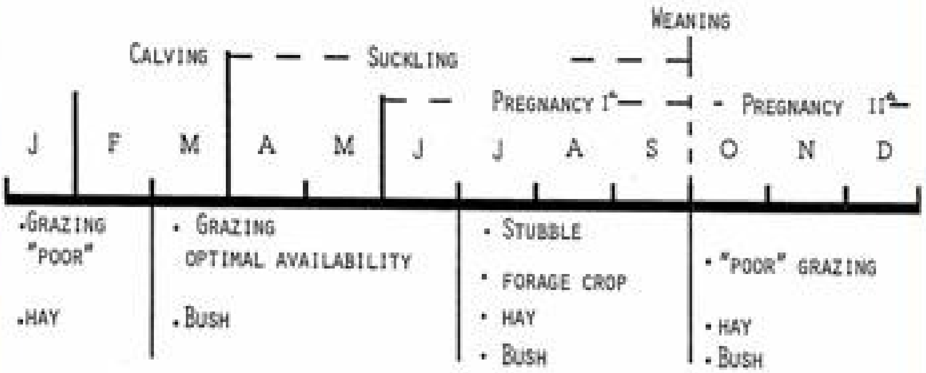


Fig. 1: Relationship between physiological stages and feeding regimen of Maremmana cattle (Bertoni et al., 1991)

Welfare of farm animals is then a "task" at different levels and aimed to reduce (-) and to increase (+)

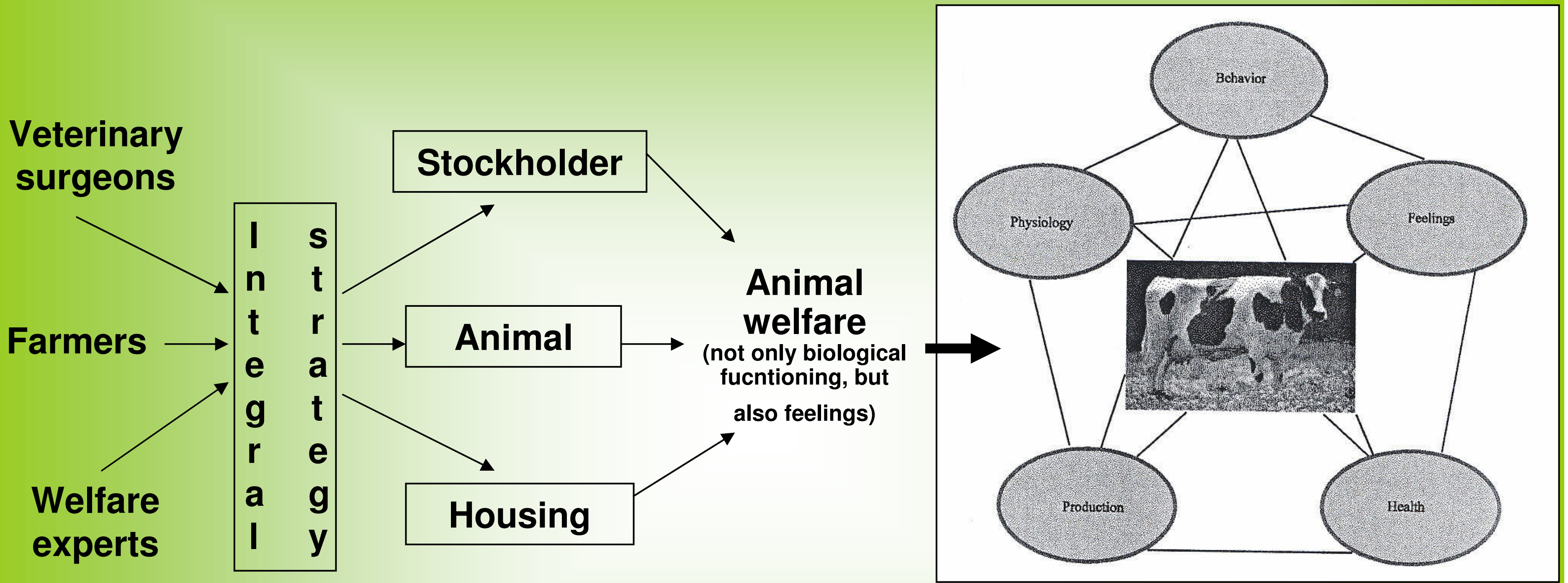
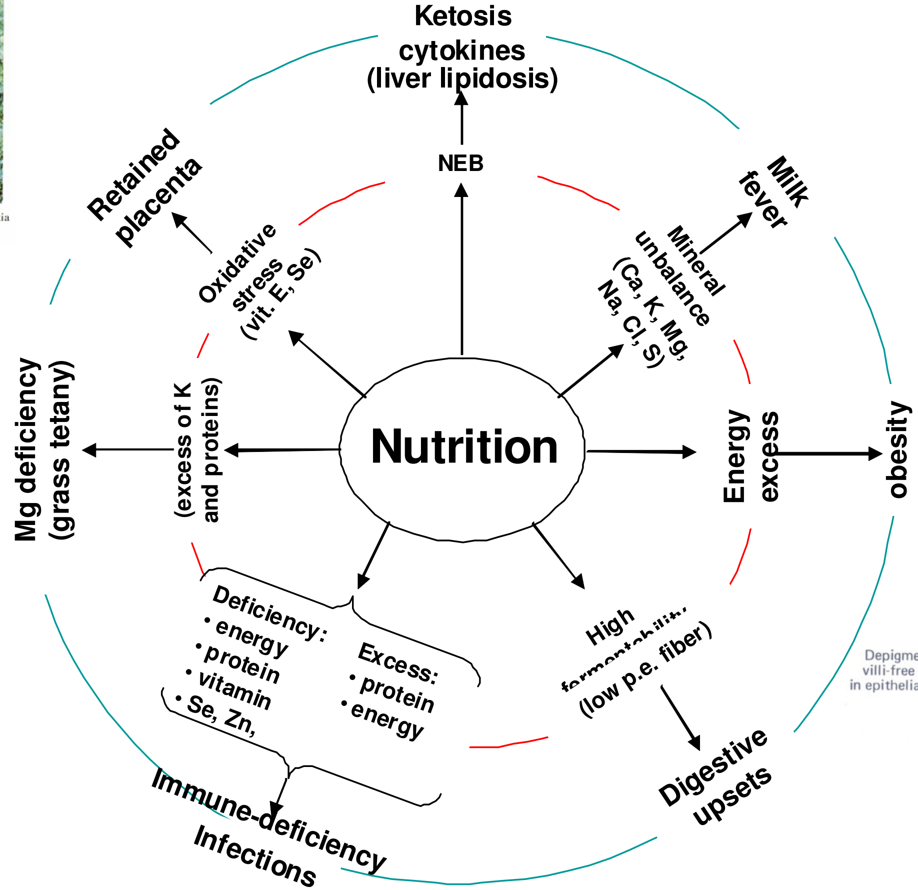


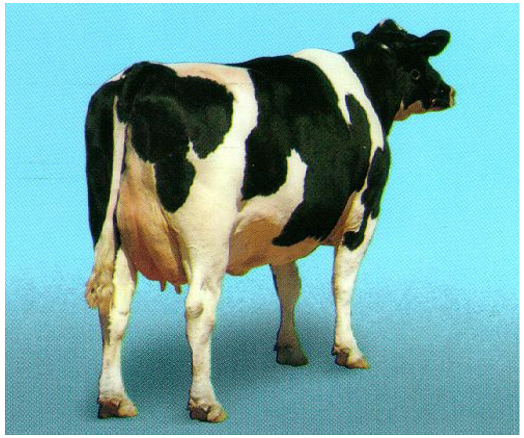
Fig. – General concept of animal welfare and how to obtain it (Sejian et al., 2011)

And Nutrition?

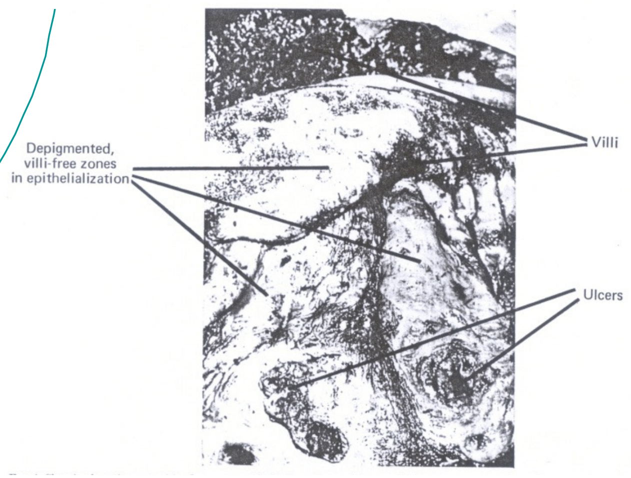
Besides pain and suffering in case of hunger and thirst ("gut filling")

Fig 2: Cu deficiency in lambs. Note the characteristic position of a lamb with enzootic ataxia or swayback.





J. Drackley courtesy

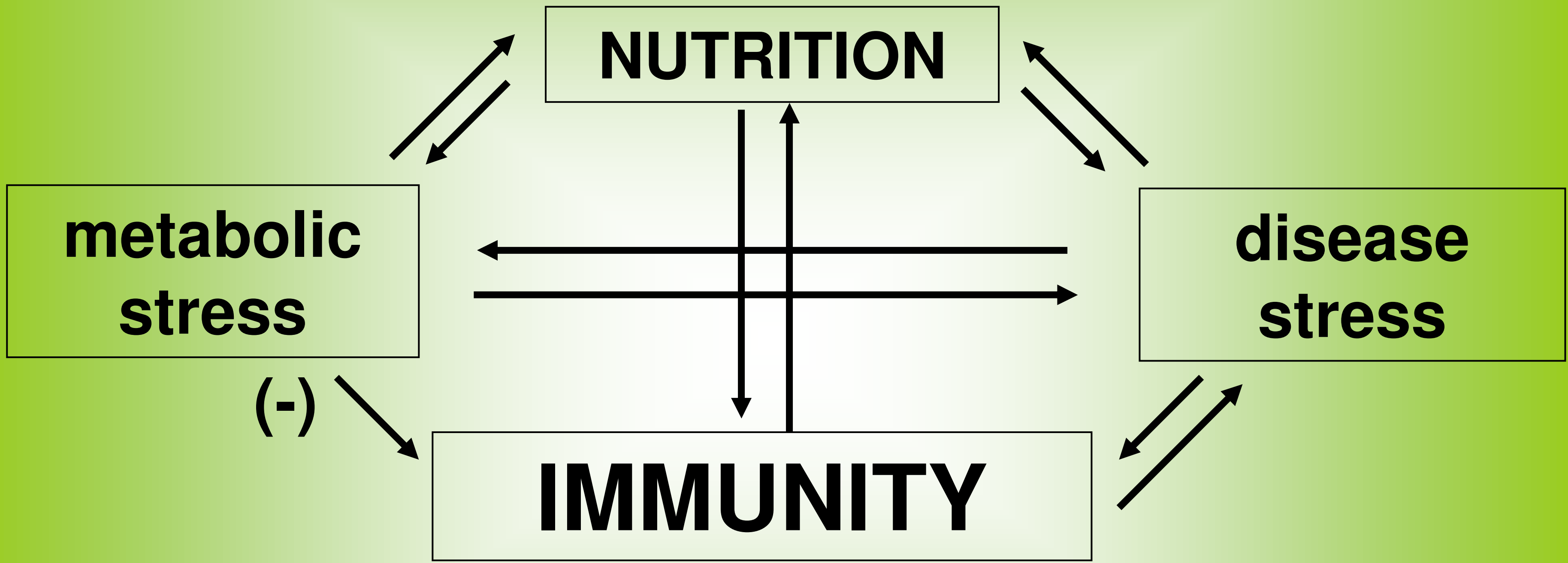


Chronic ulcerative rumenitis after severe acidosis (Dirksen, 1970)

Unsuitable diets (but also feeds in case of poisoning) cause health problems (big variety)

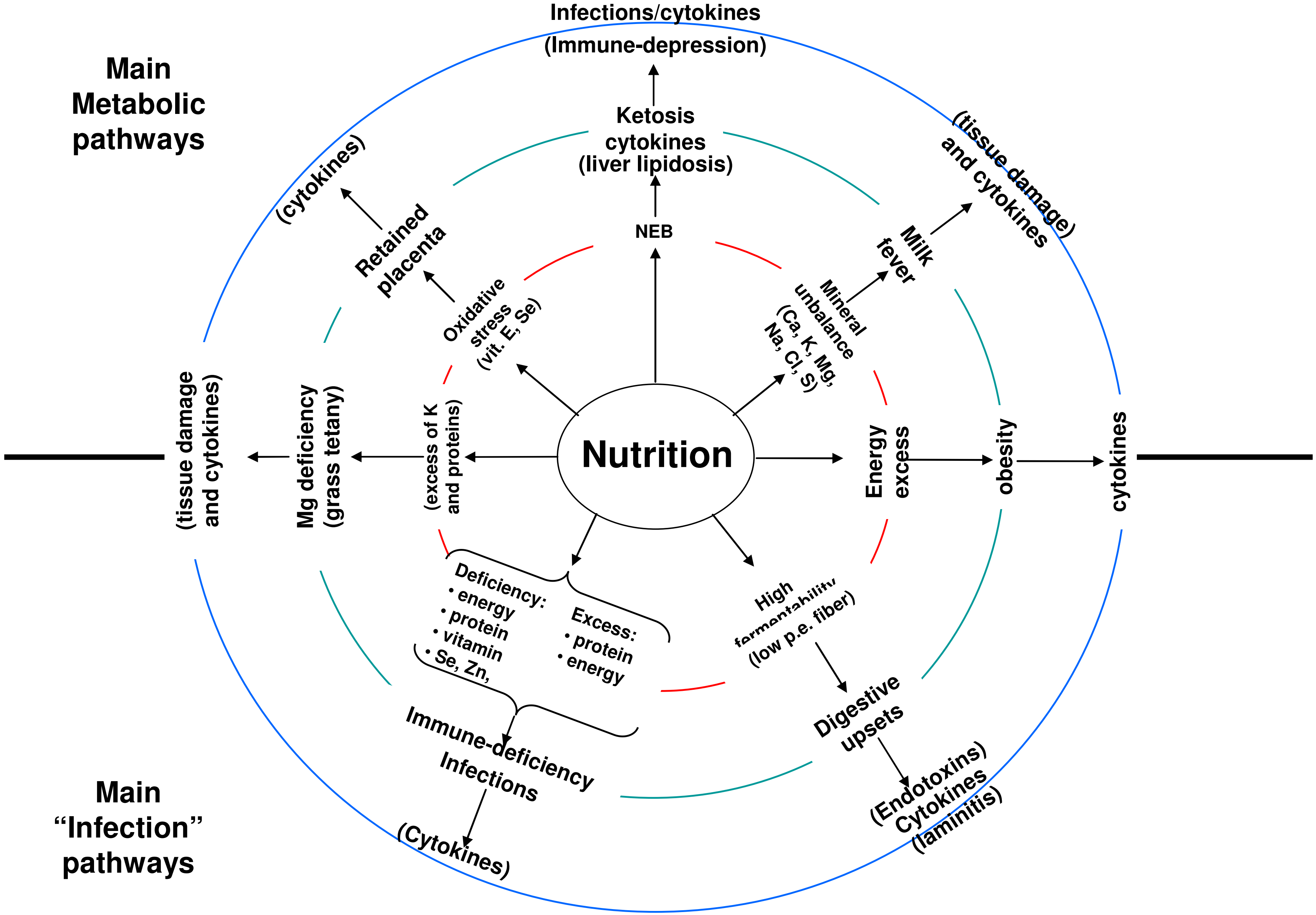
And impair health
- **↓ welfare (pain and suffering)**
- **↓ performance (body fitness)**

(Transition period), immune system and nutrition



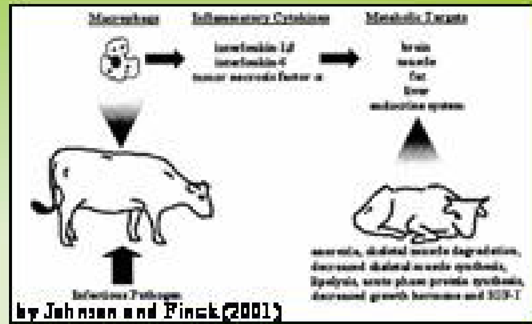
Interactions between nutrition, various stresses and immunity (vicious cycle)

Nevertheless, a big risk is from a moderate welfare impairment – for nutrition/health reasons – to serious/clinical situations (not so frequent)



Therefore it is essential to show the “common denominator” = cytokines i.e. inflammation from tissue damage (also in subclinical situations …)

Health indices

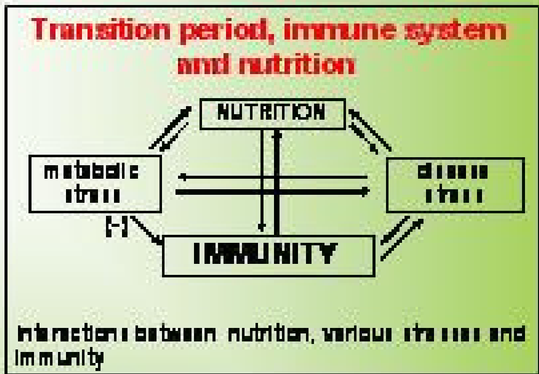


Sickness = pain and depression = low welfare

Low welfare = immune system impairment = sickness

then a

Vicious cycle can occur (Broom, 2006)



Indices of
- individual health
- herd health

In fact, not only diseases (metabolic or infections), but also subclinical conditions ("malaise") can contribute to a low welfare (or lack of pleasure?)

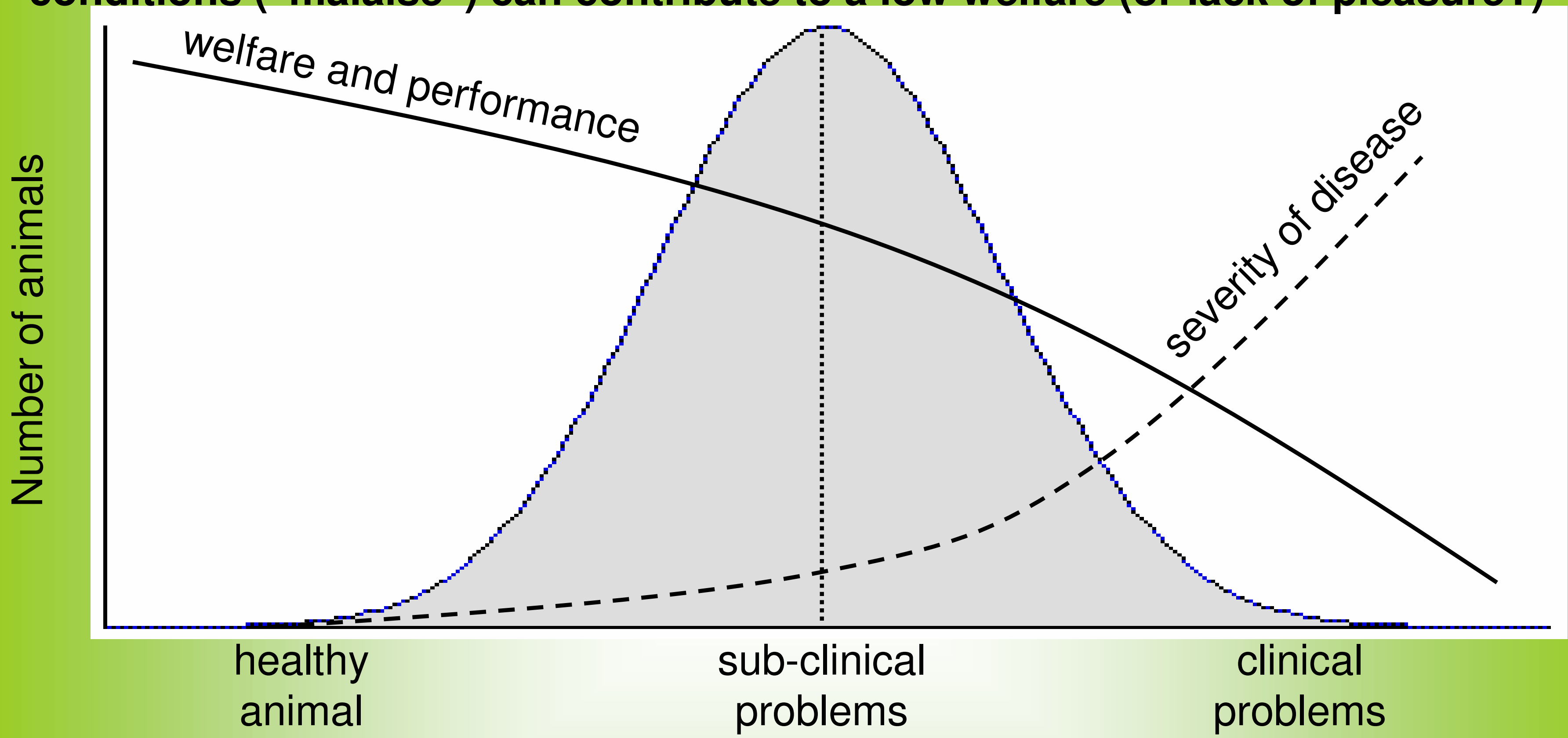


Figure – Frequency of animals according to health conditions or severity of disease. Consequences on welfare and performance (adapted from Santos, 2008)

in intensive reared animals … malaise causes lower welfare (and performance)

Objective for future: to reduce also subclinical and to have more "happy" animals?... by nutrition and …?

A useful indicator of these subclinical conditions are the PI cytokines (after tissue damage):

- released for many reasons

Parasites · **Pathogens** · **Heat stress** · **Trauma/injury** · **Oxidative stress** · **Activity excess**

Also Nutrition:
- deficiency/excesses
- poisoning (i.e. micotoxins)
- digestive disorders
- lack of anti-inflammatory nutrients (later)

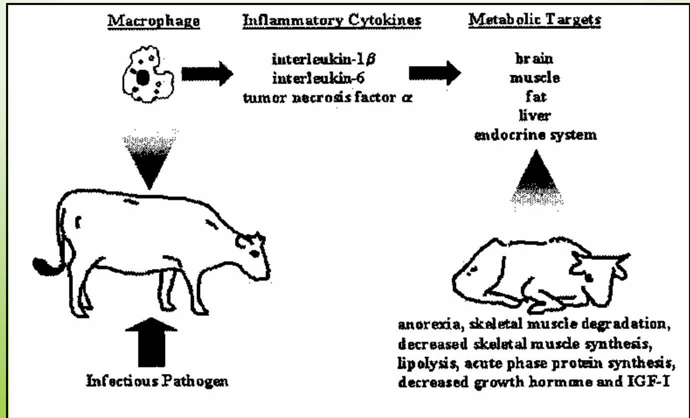
"disease"

↕

Inflammation (IL1-IL6-TNFα)

- responsible of a range of negative effects (light inflammation to disease)

Physical symptoms: fever, tissue damage, pain



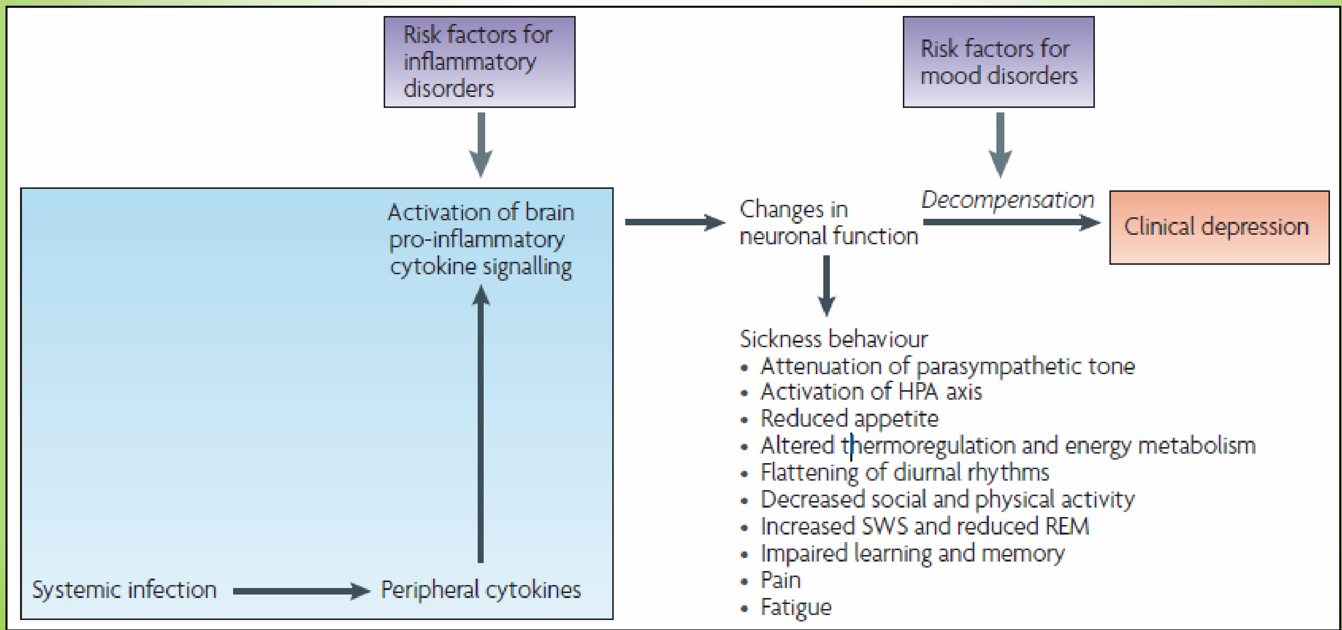
(Johnson and Finck, 2001)

Mental symptoms: loss of interest for environment, depression, irritability, mild cognitive disorders (Dantzer et al., 2008)

- as well as of either physical (pain) and mental (suffering) effects

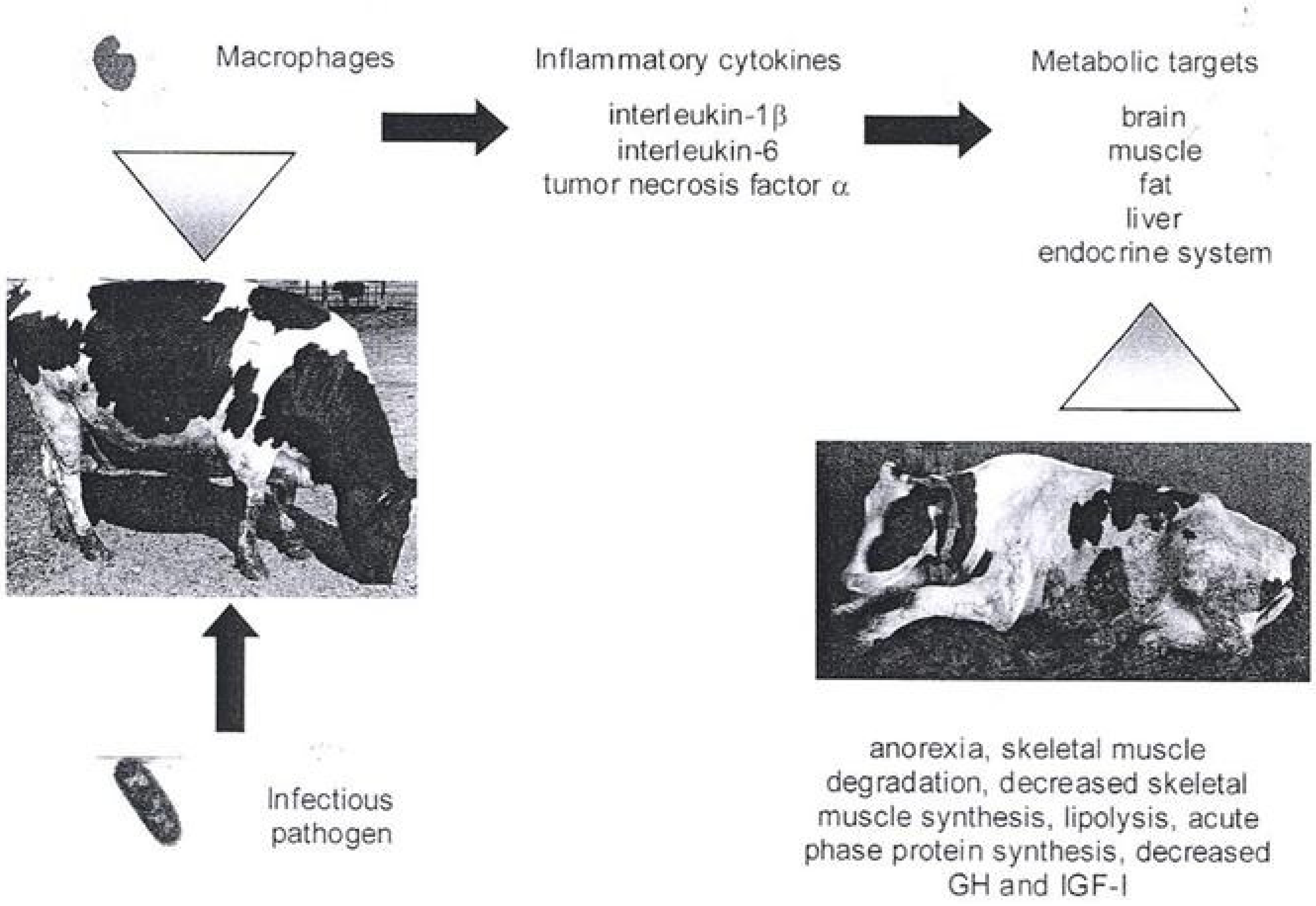
Cytokines and welfare (Eskandari et al., 2003)

1. cytokines are important factors connecting and modulating the immune and neuroendocrine systems. Cytokines and their receptors are expressed in the neuroendocrine system and exert their effects both centrally and peripherally
2. Cytokines signal the brain not only to activate the HPA axis but also to facilitate pain and induce a series of mood and behavioral responses generally termed sickness behavior

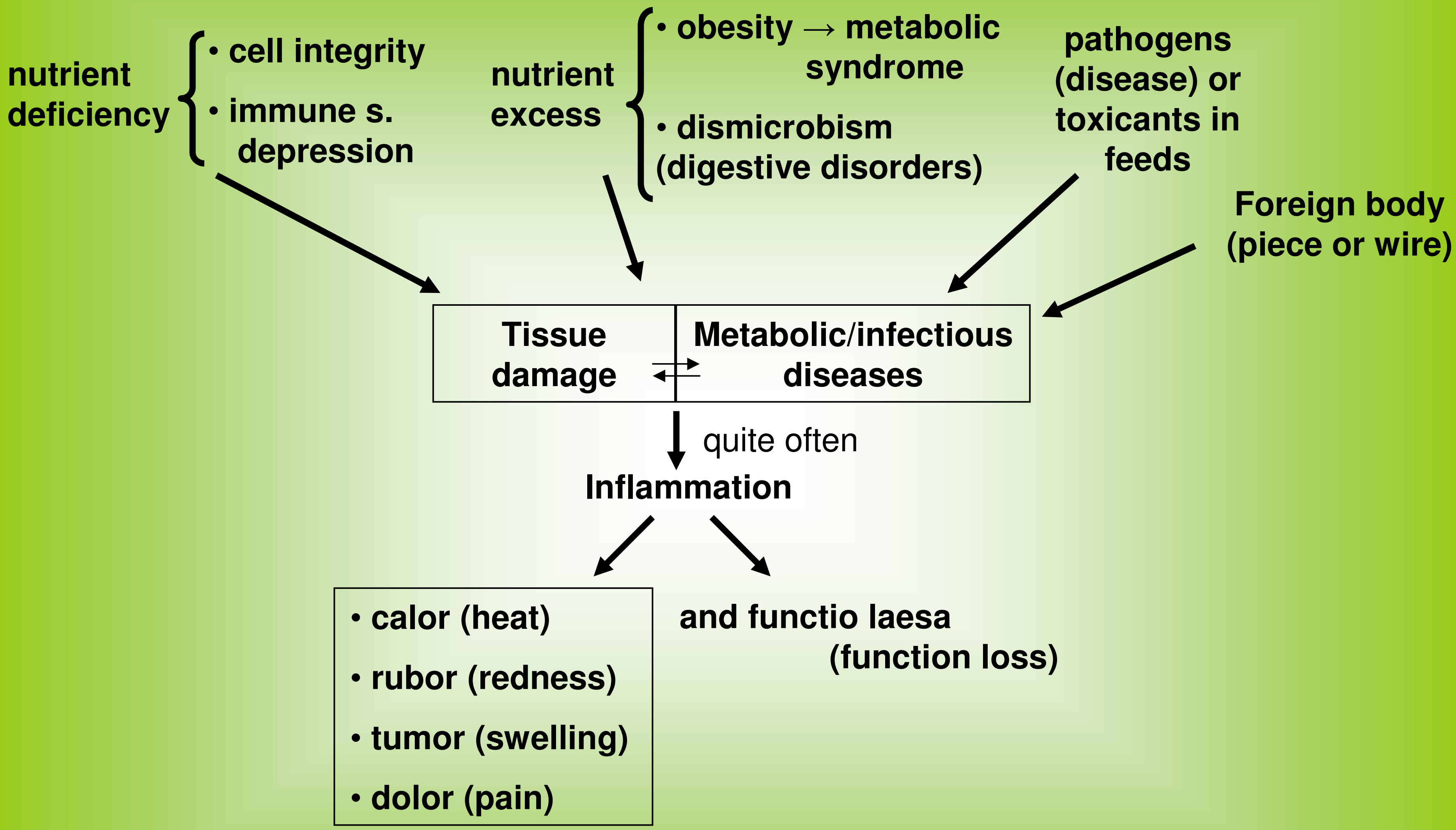


(Dantzer et al., 2008)

Figure 4. Pathogens activate immune cells, causing them to produce inflammatory cytokines. The cytokines mediate the immune response but also act on other systems and affect metabolism (adapted from Johnson and Finck, 2001). Photos by the Authors.



Link “malnutrition”/inflammation



but what about micro-inflammation or meta … (i.e. metabolic syndrome)?

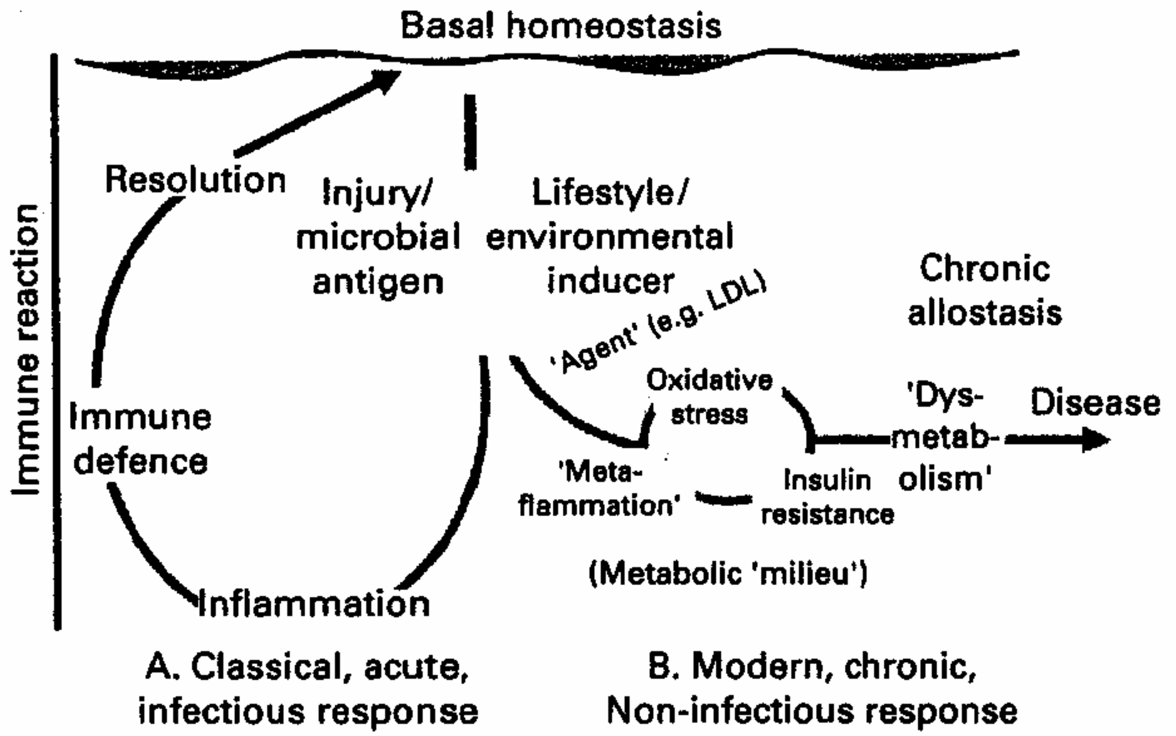


Fig. 1. A graphical representation of the difference between classical inflammation initiated by a microbial antigen or injury and metaflammation caused by lifestyle or environmental inducers. The order and other possible actions in the metabolic 'milieu' associated with metaflammation on the right-hand side of the graph are suggestive rather than definitive, but imply the mix of dysmetabolic actions associated with metaflammation. The scale of difference of immune reaction between the two forms (i.e. approximately 100-fold) is not implied. LDL, LDL-cholesterol.

Egger and Dixon (2009)

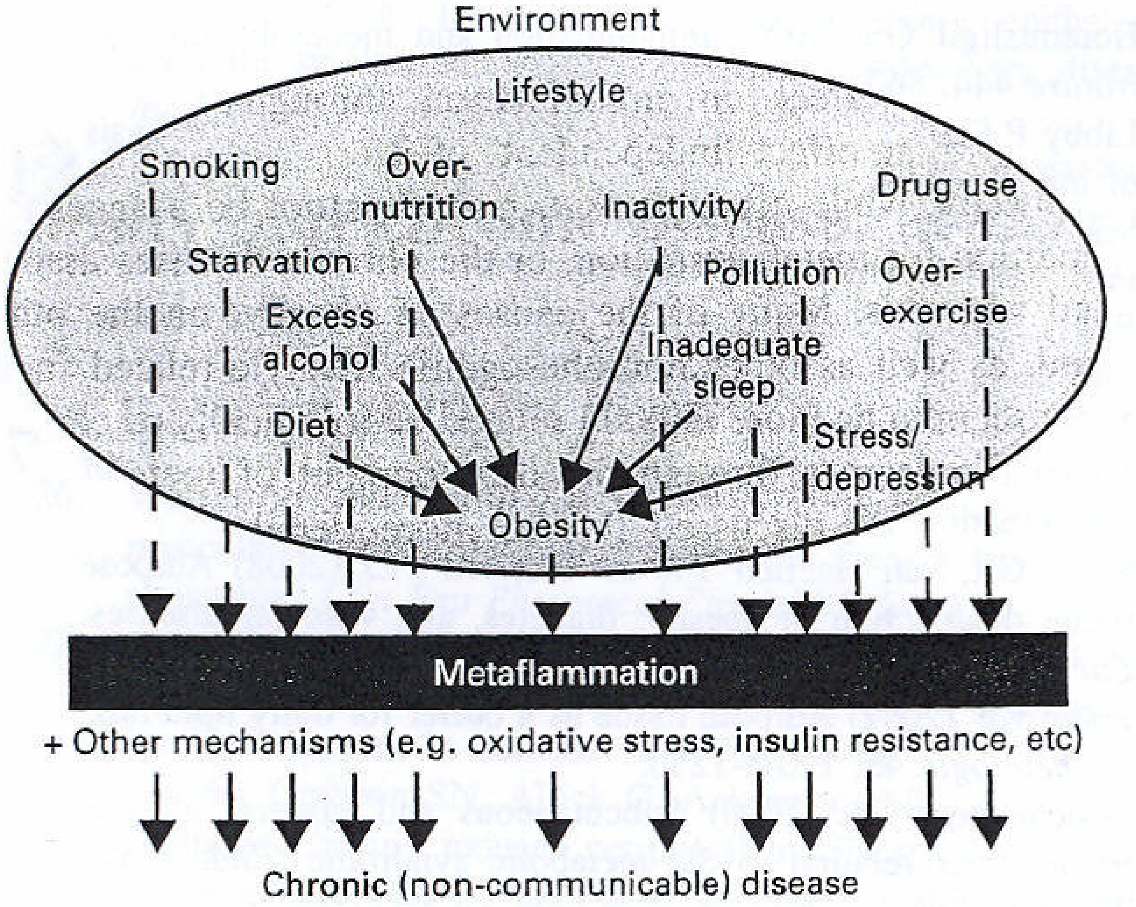


Fig. 2. Environment and lifestyle effects on the development of chronic disease through metaflammation, showing both dependent and independent effects through obesity (expanded from Wärnberg *et al.*[31]).

Egger and Dixon (2009)

Tab. 1 - Threats to food safety (Adams, 2001)

Threat	*Example*
Naturally occurring bacteria	*Listeria* in fruits and vegetables
Bacteria from intestines of animals contaminating food	*Salmonella* and *Campylobacter* in meat
Naturally occurring toxic substances	Algal toxins in shellfish, mycotoxins on fruits and cereals
Residues from medical treatment of animals	Antibiotics
Environmental contaminants	Dioxins, heavy metals
Pesticide residues	In fruits and vegetables
Food additives	Flavours, colours, preservatives

In case of animals, also physical damages are possible: reticulum peritonitis, soil/sand intake etc.

Tab. 2 - Total feed components consist of nutrients and nutricines (Adams, 2001)

Nutrients	Nutricines
Carbohydrates	Antioxidants
Fats	Colours
Minerals	Emulsifiers
Proteins	Enzymes
Vitamins	Flavours
	Non-digestible oligosaccharides
	Organic acids

Supplied (Diet) by different feeds and able (or not) to properly cover the requirements

Major examples of “malnutrition”/low welfare

Very different in
- extensive farming systems
- intensive farming systems

a) extensive: irregular availability of enough feeds (or good feeds)

- hungry feeling (shortage)
- energy (and protein) deficiency, not only hunger but also risk of pregnancy toxemia (ketosis with “malaise” and sickness … and inflammation?), at least in small ruminants at end of pregnancy.

- **mineral deficiency (i.e. Co, Se etc.) or excesses (Mo and S → Cu deficiency, K and NH3 → Mg deficiency) linked to soil properties**
- **vitamin problems (less frequent for …)**
- **toxicants in feed (poisonous plants or contaminated by fungi etc, i.e. micotoxines, fescue toxicosis = immune suppression, various symptoms**

Fig 3: Note the poorer condition of the Co deficient sheep (left) compared with the Co adequate animal (right).

(Clark et al., 1983)

less growth

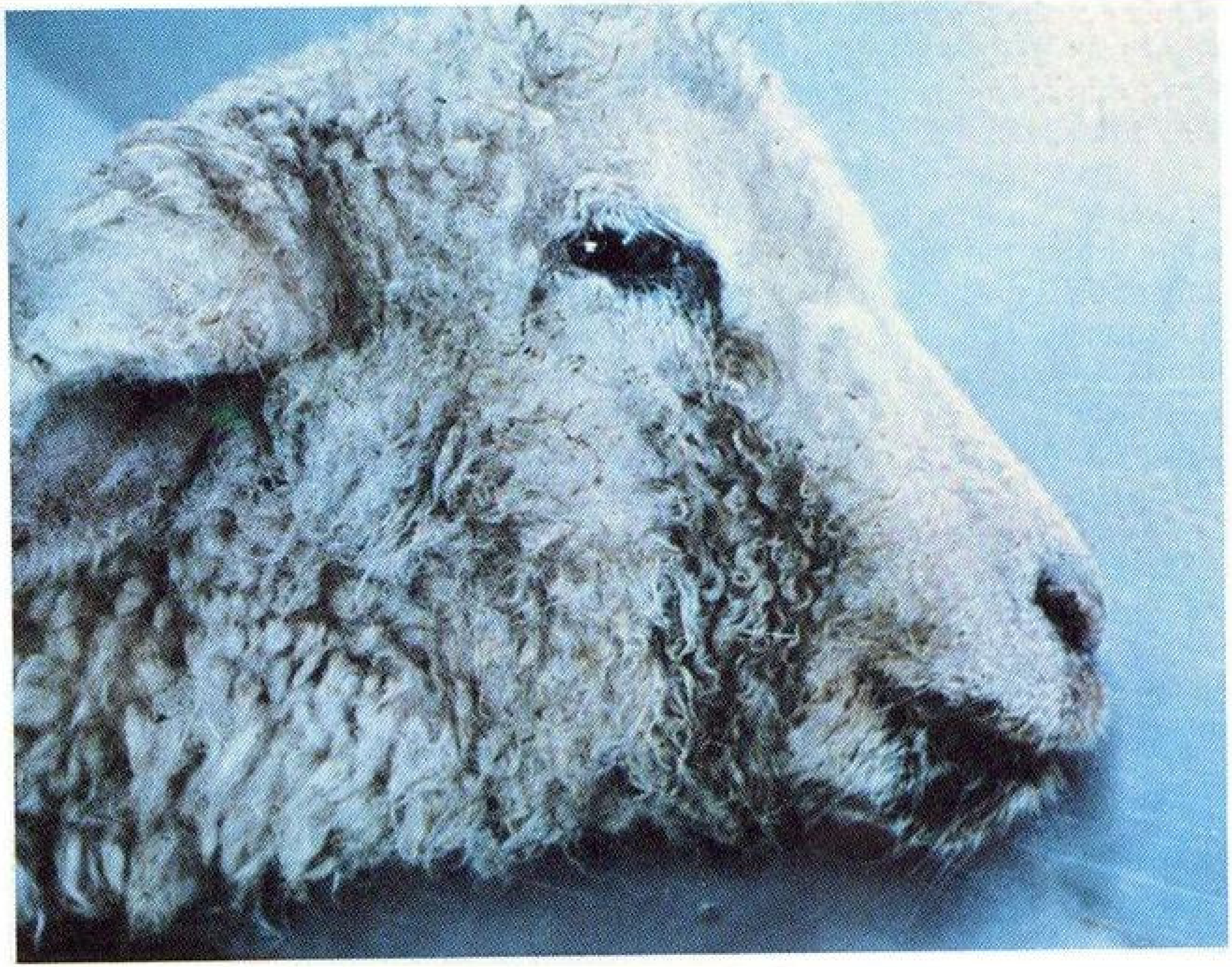


Fig 4: Co deficiency in sheep. Note the watery eye discharge.

(Clark et al., 1983)

and low welfare!

Fig 1: Se deficiency in a lamb (white muscle disease). Note the bilaterally symetrical white muscle lesions in the hind limbs.

(Millar, 1983)

↓ Se = white muscle

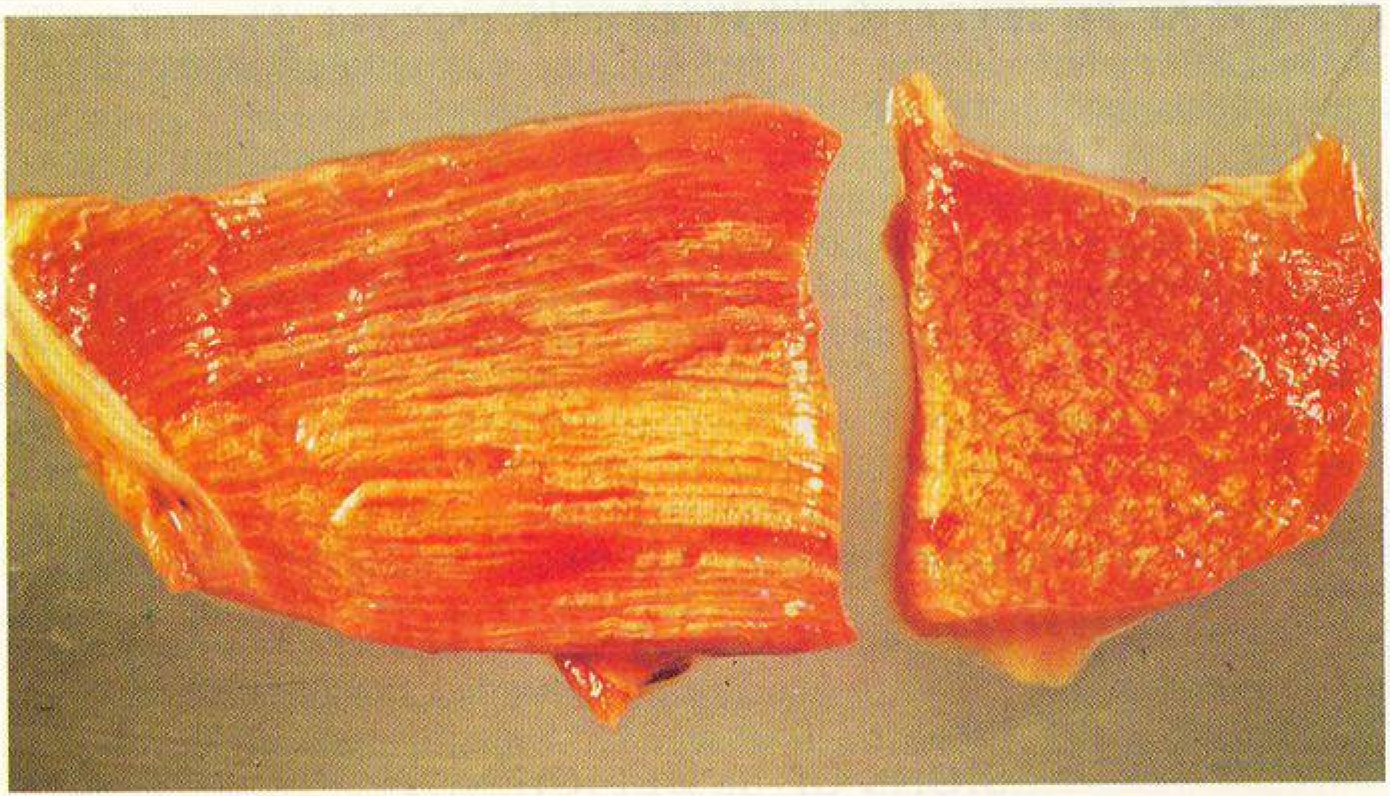


Fig 2: White muscle disease: A closer view of a muscle showing the characteristic pale streaking of necrotic tissue.

(Millar, 1983)

damaged …

b) intensive: good or excessive availability of feeds, but not always … satisfactory diets

- **dairy cows (see Fig. post partum)**

“gut filling” OK but Negative Energy Balance thus fat-protein mobilization and ↓BCS

1) ketosis – lipidosis risks
2) ↑ infection risks
} **low welfare**

but what about simple BCS changes? (see Fig. 2)

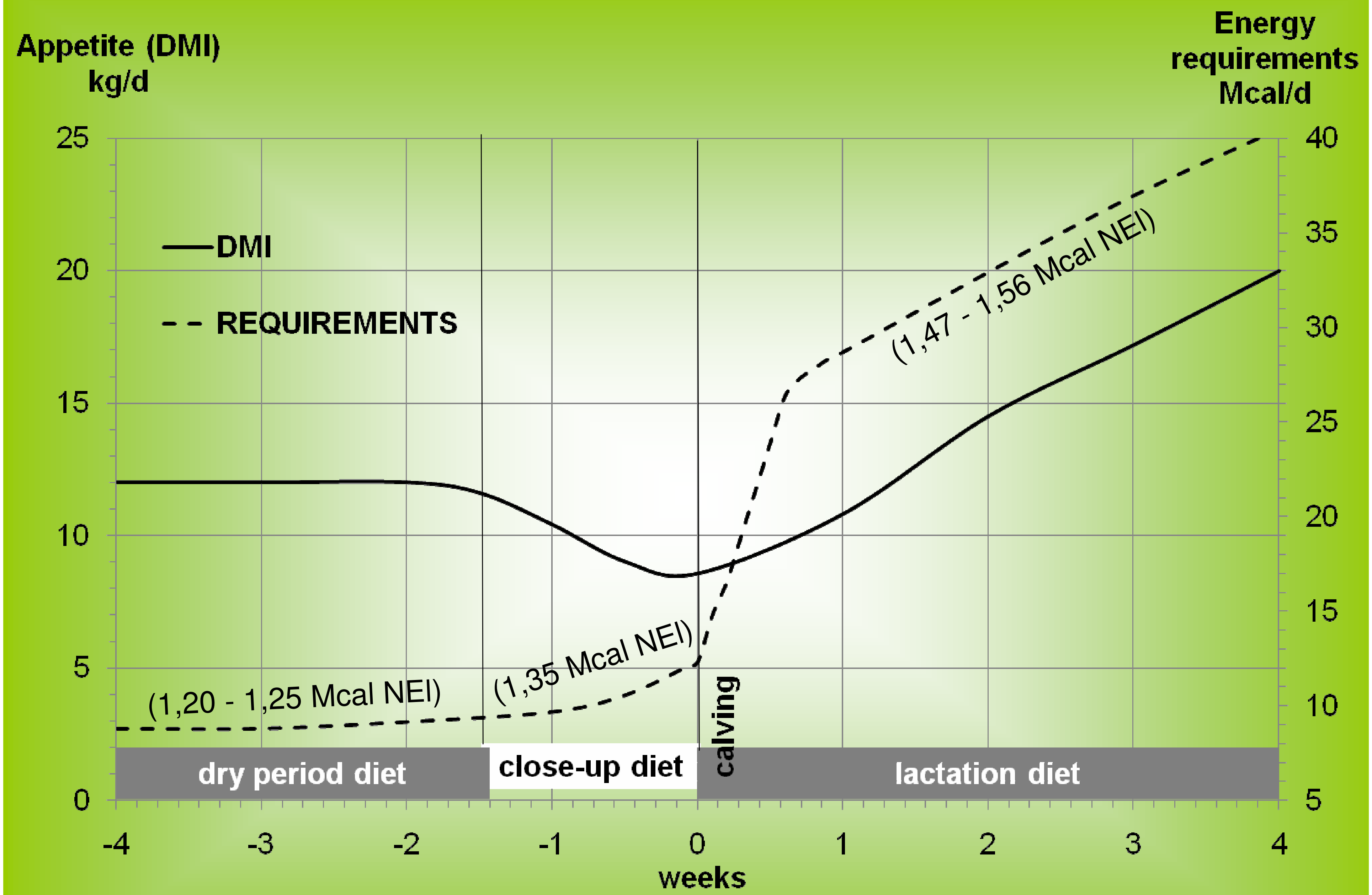


Figure 5 – Average levels of appetite and energy requirements (energy mobilization was not considered) in the transition of high yielding dairy cows. In bracket the suggested net energy for lactation (NEl) concentrations of diets.

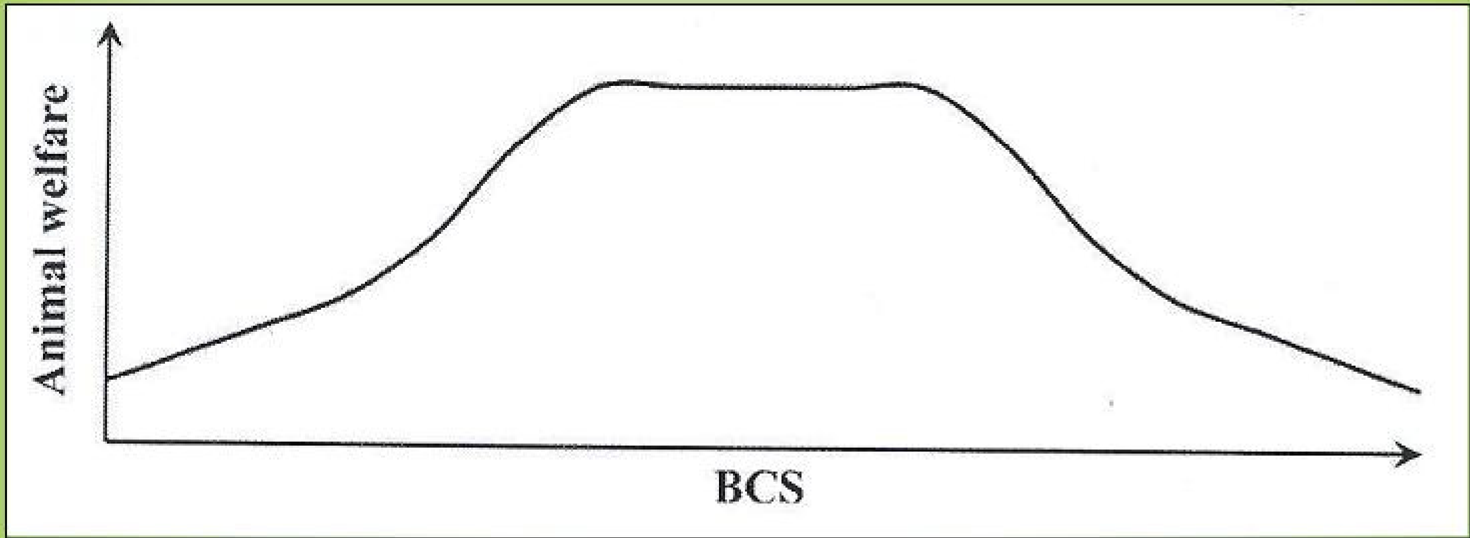


Figure 2. A stylized relationship between animal welfare and body condition score (Roche et al., 2009)

Dairy cows excesses

- **Dry period**
  - **energy → obesity (chronic (meta) inflammation)**
  - **Ca/P/K → Milk fever**

- **Transition/early lactation (too high fermentability)**
  - **Acute acidosis**
  - **SARA (sub-acute)**

You need to remember

Transition is “pivotal”

Very roughly, the peri-parturient metabolic (and infectious) diseases can be divided in:

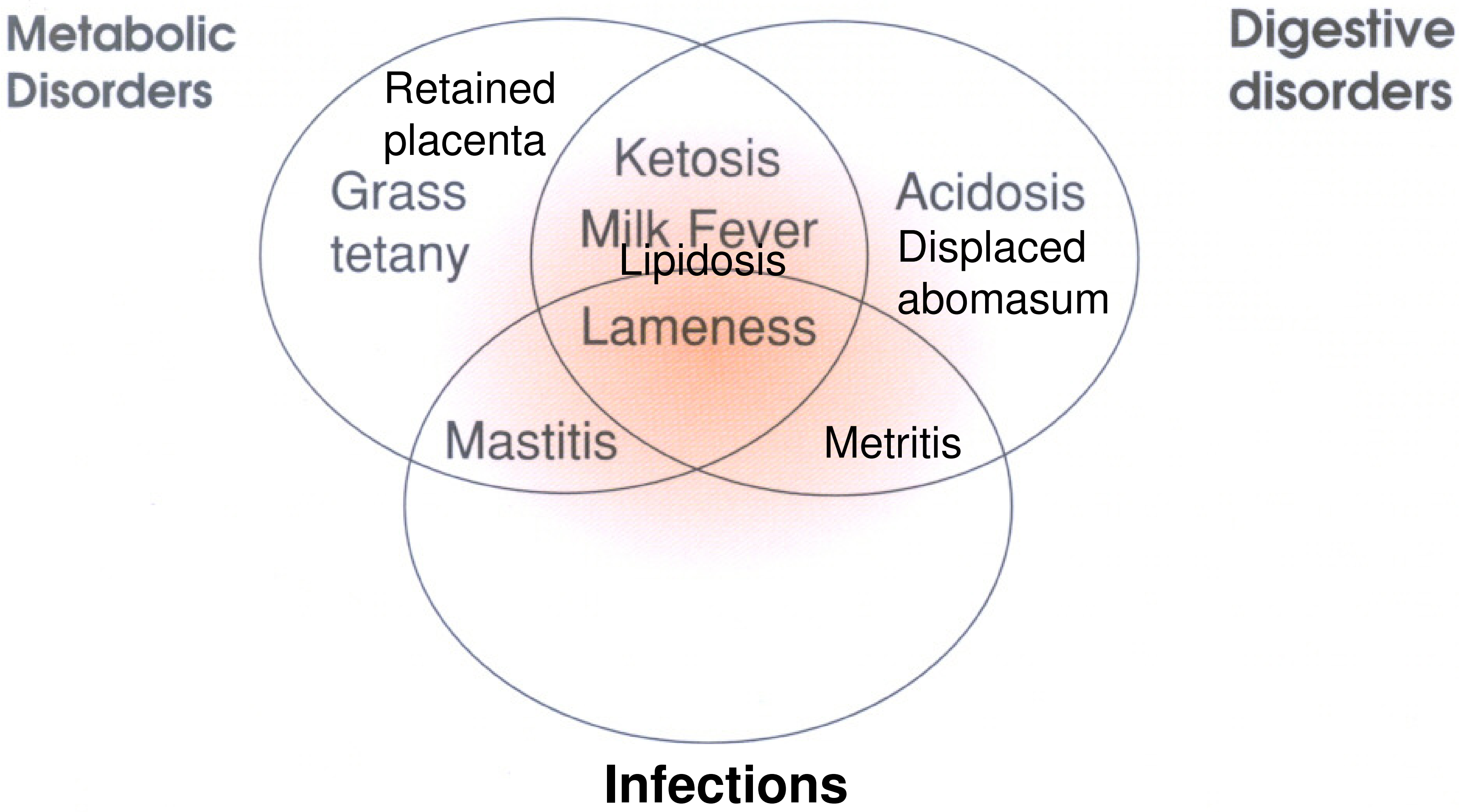
- **primary, i.e. apparently without other diseases as cause**
    - **milk fever**
    - **retained placenta**
    - **udder edema**
    - **distocya**
    - **metritis**
    - **rumen acidosis (and intestine)**
    - **displaced abomasum (*)**
    - **(mastitis and other infections) (*)**

- secondary, i.e. having other diseases as important factors of increased risk
    - ketosis
    - steatosis
    - displaced abomasum (*)
    - (mastitis and other infections) (*)

    - lameness
    - hypofertility

} occurring later but … essential

Figure 1 - Interrelationships between postparturient diseases of dairy cattle **(adapted from Reid & Little 1986)**



Milk fever → downer cow

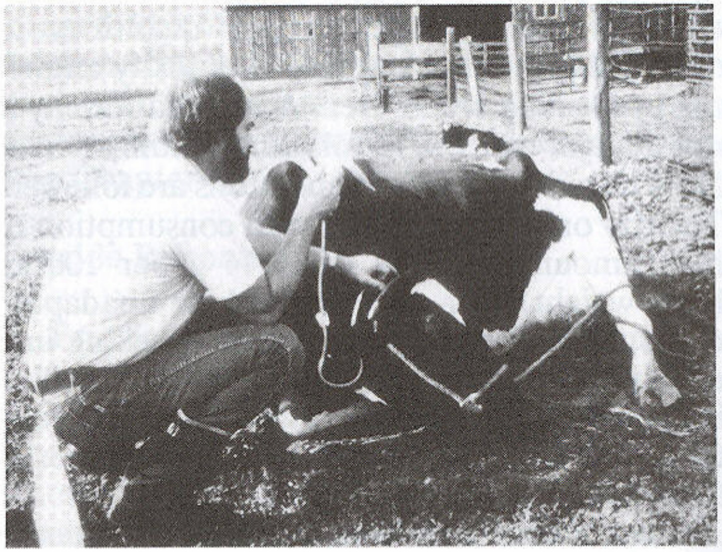


Figure 37.9. Milk fever, a common metabolic disease at time of calving, is characterized by sternal recumbency in stage two. Slow, intravenous administration of calcium borogluconate usually gives rapid recovery. In true milk fever, failure to institute treatment quickly almost assuredly results in death from cardiac arrest or respiratory failure.

Figure 37.10. Cows which fail to respond to calcium therapy should be retreated within 8 to 12 hr. Those cows which fail to respond are considered downer cows. Condition is most commonly a complication of milk fever.

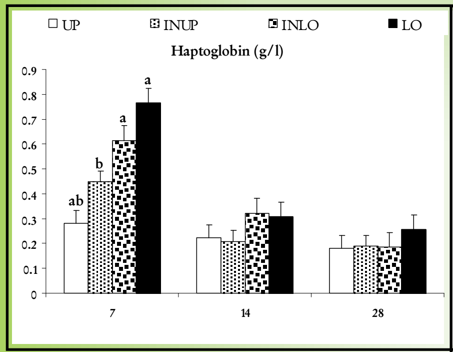
(Shearer et al., 1999)

obvious lower welfare

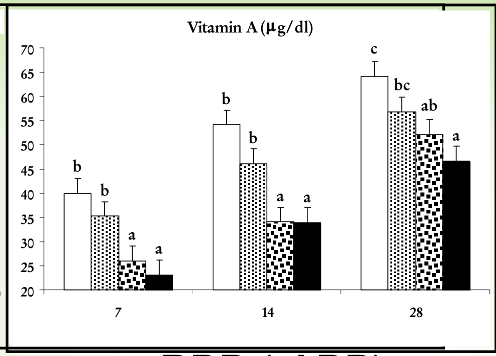
but how important could be the subclinical situation? Small T° rise, small DMI reduction to induce a "malaise"?

Bertoni et al. (2008), 77 cows in transition have showed:

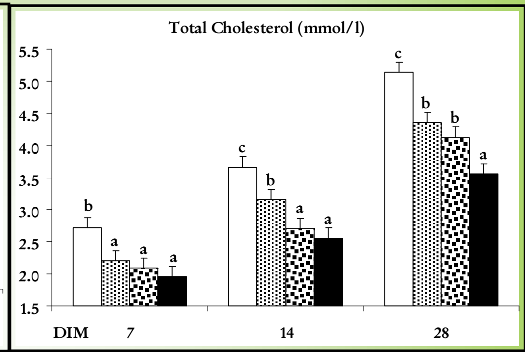
1) **More or less inflammatory conditions**



Haptoglobin (+APP)



RBP (-APP)



Lipoproteins (-APP)

2) **Not more than 45% of cows with clinical symptoms**

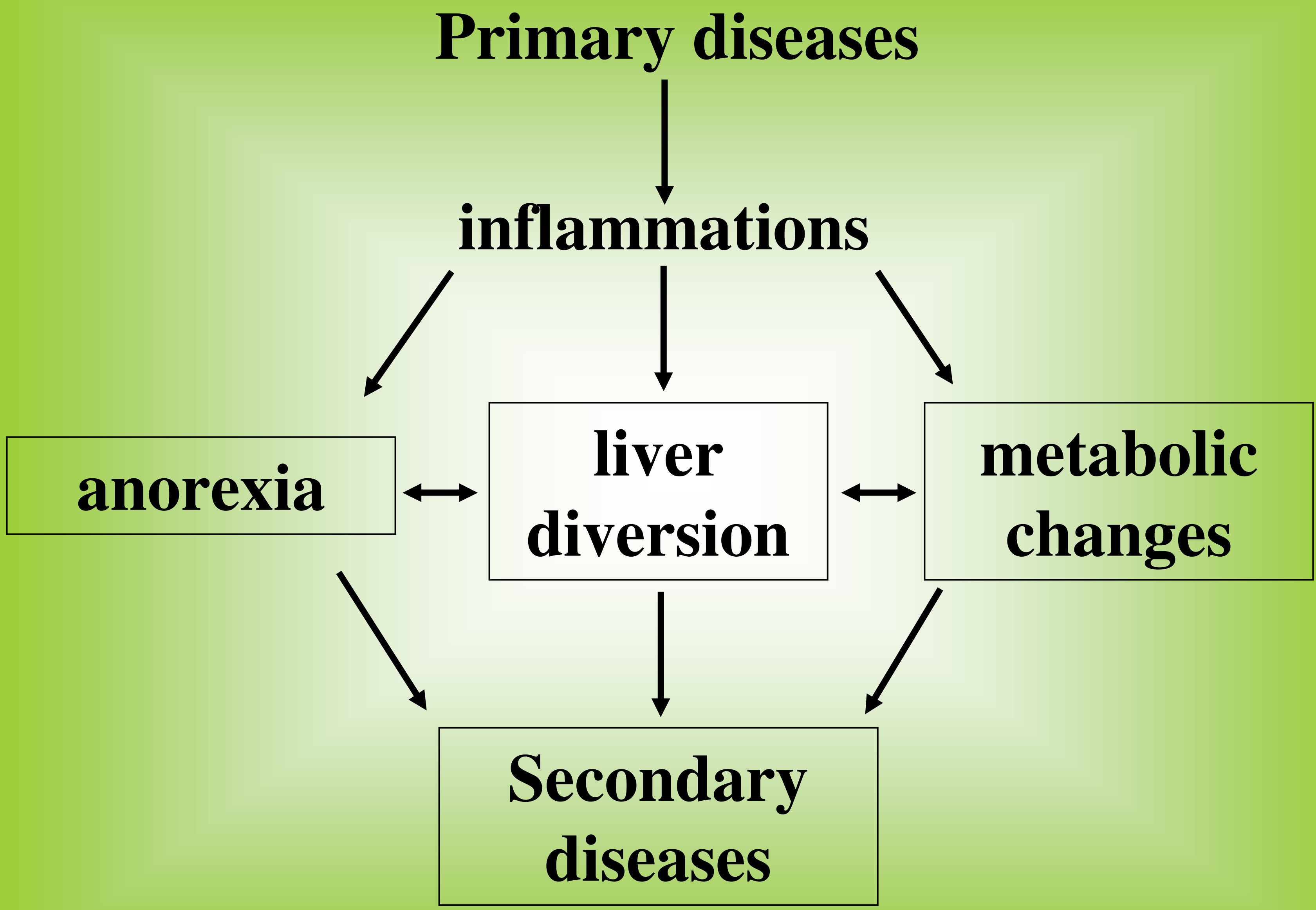
3) **PI cytokine effects are unquestionable, thus more or less prolonged "malaise" (Dantzer et al., 2008) did occur?**

Who can confirm it?

4) **Performance?**
   - **milk yield peak 37.3 vs 41.4 kg/d**
   - **days open 110 vs 93**

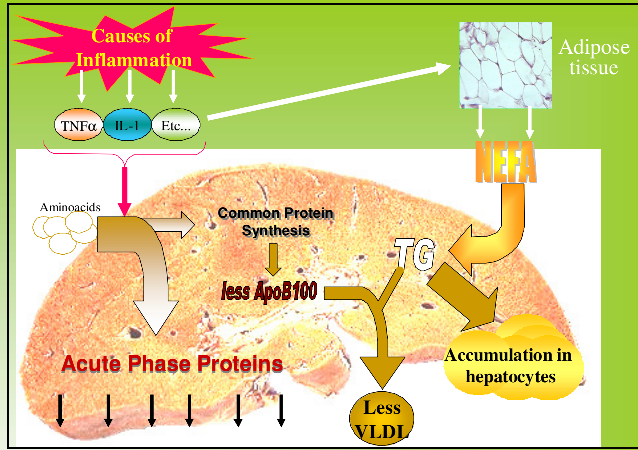
Maybe … !

As well as

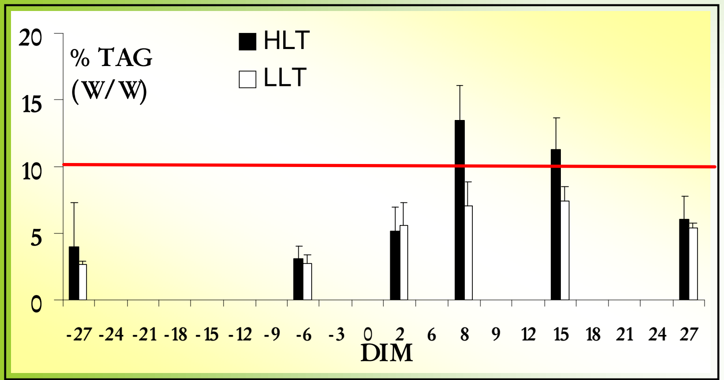


But not always and with same extent, why?

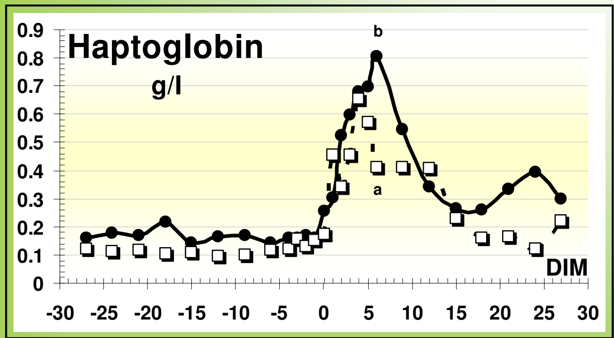
Inflammation /Liver

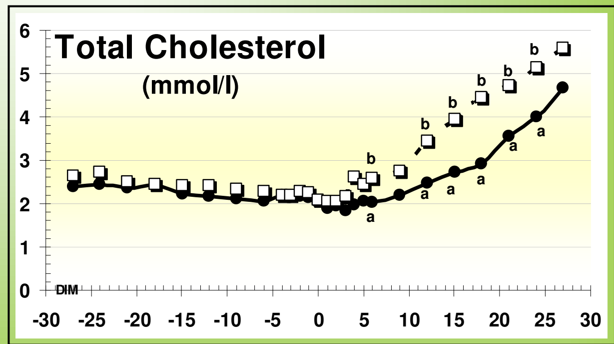


We have suggested a plausible hypotheses since several years ago



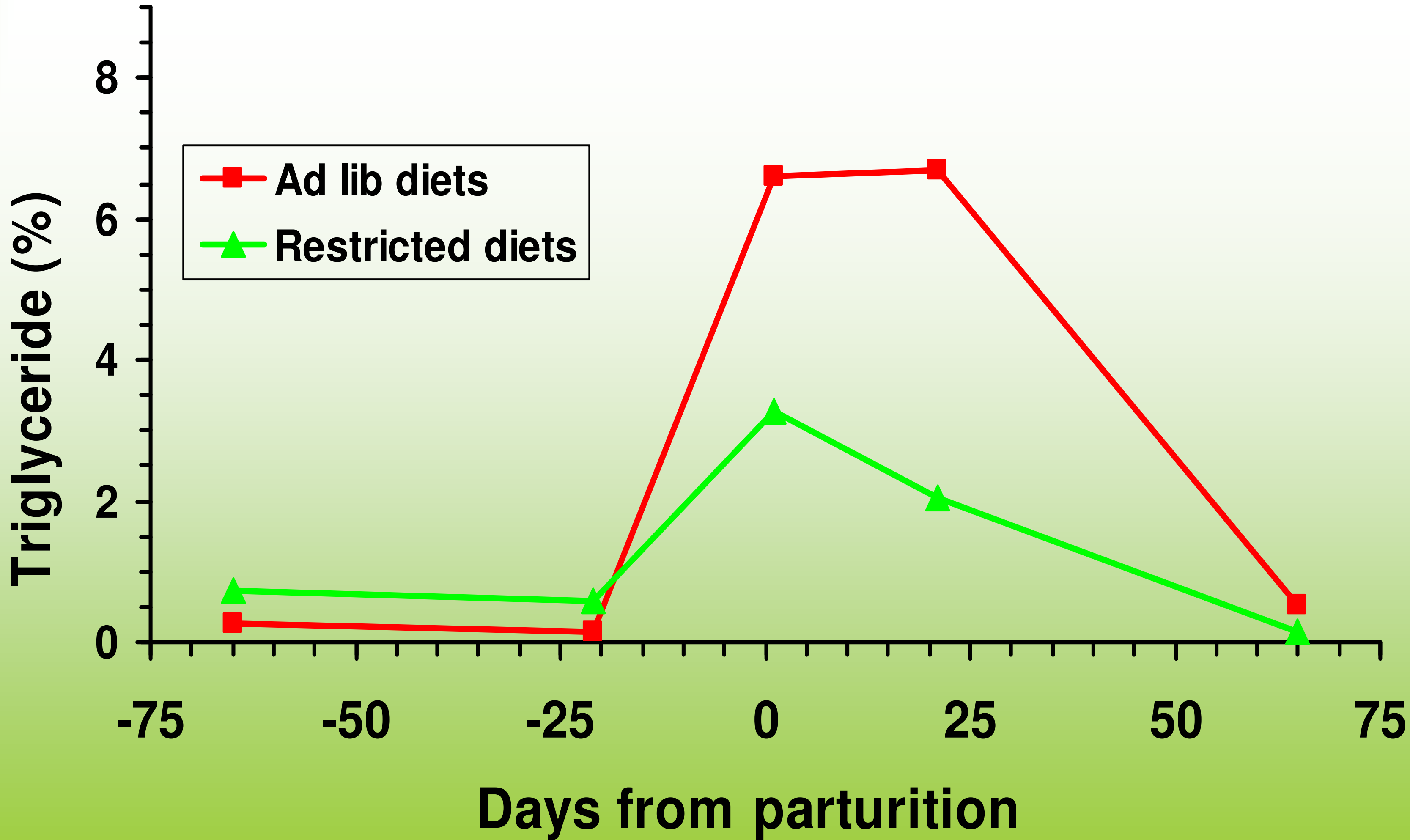
And we have partly confirmed it in cows with liver TG { **High** or **Low**



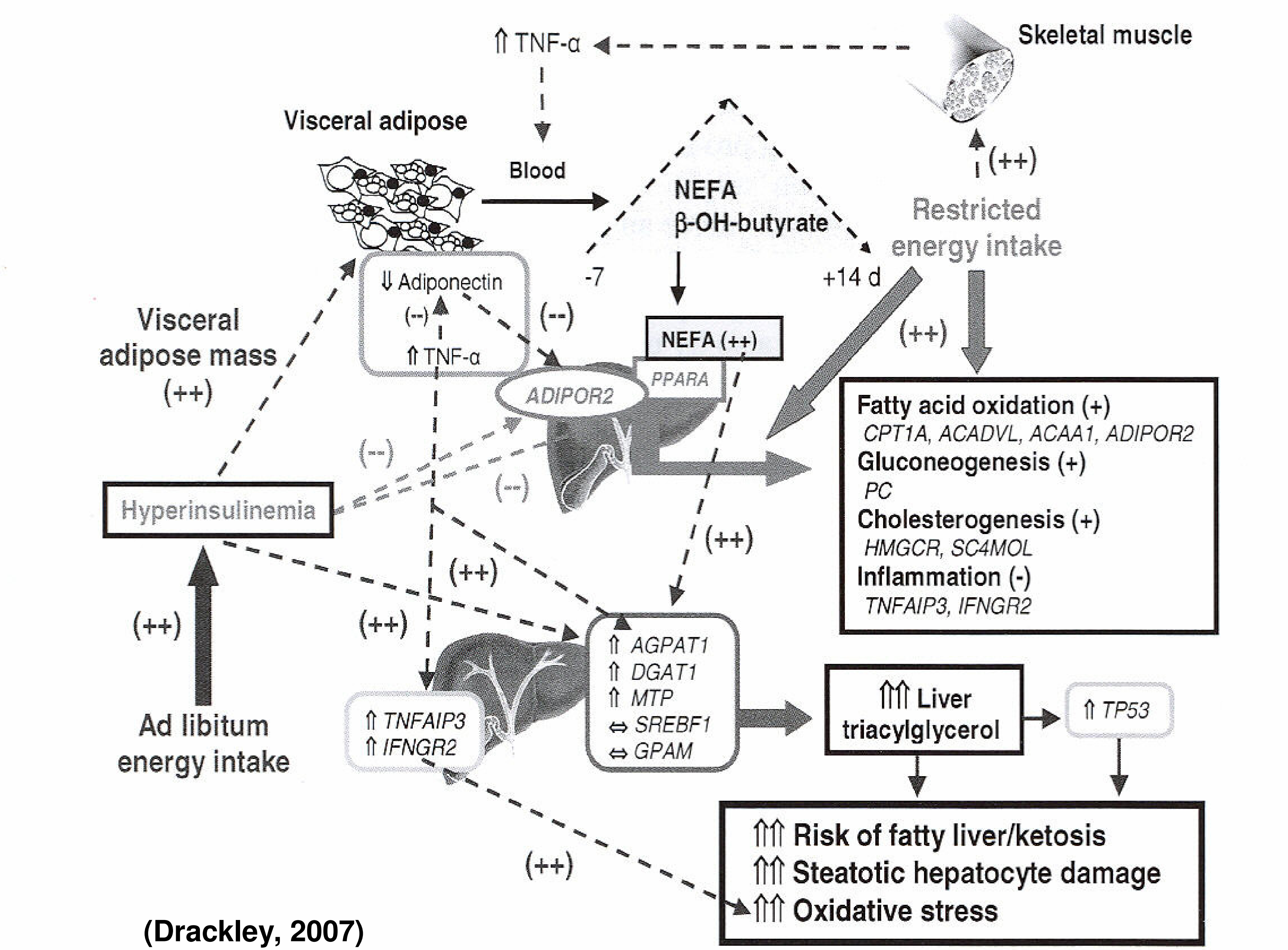


in fact higher liver TG = ↑ +APP and ↓ lipoproteins

Excess dietary energy prepartum leads to greater liver fat after calving



Douglas et al., 2006



(Drackley, 2007)

In humans:

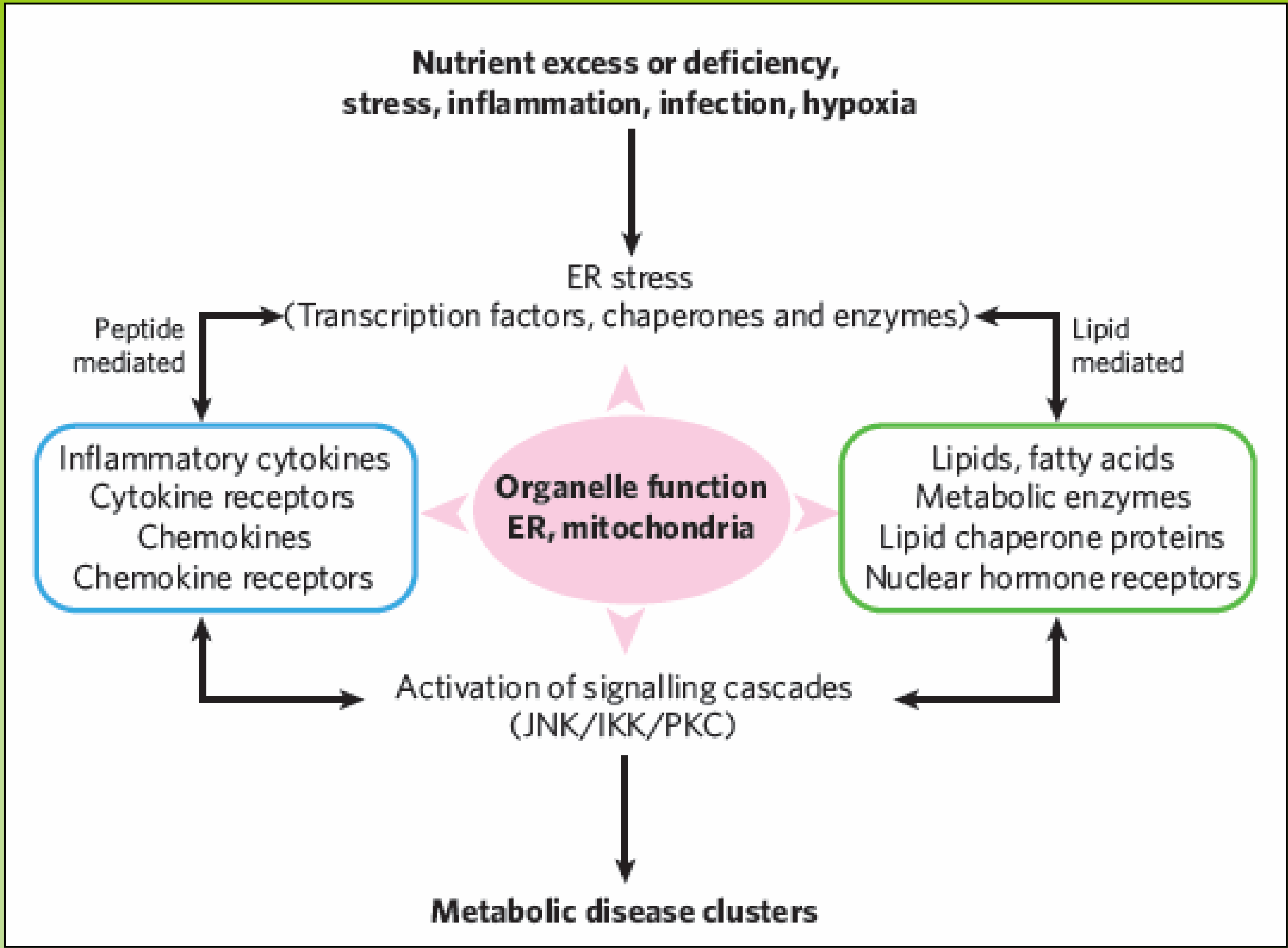


Figure xx - Therapeutic targets at the interface between metabolic and inflammatory pathways. The pathways are divided into peptide- and lipidmediated targets for practical purposes and do not represent an exhaustive list. Treating several loci involved in the disease process by targeting organelles such the ER and mitochondria represents a new approach to treating metabolic diseases (Hotamisligil, 2006).

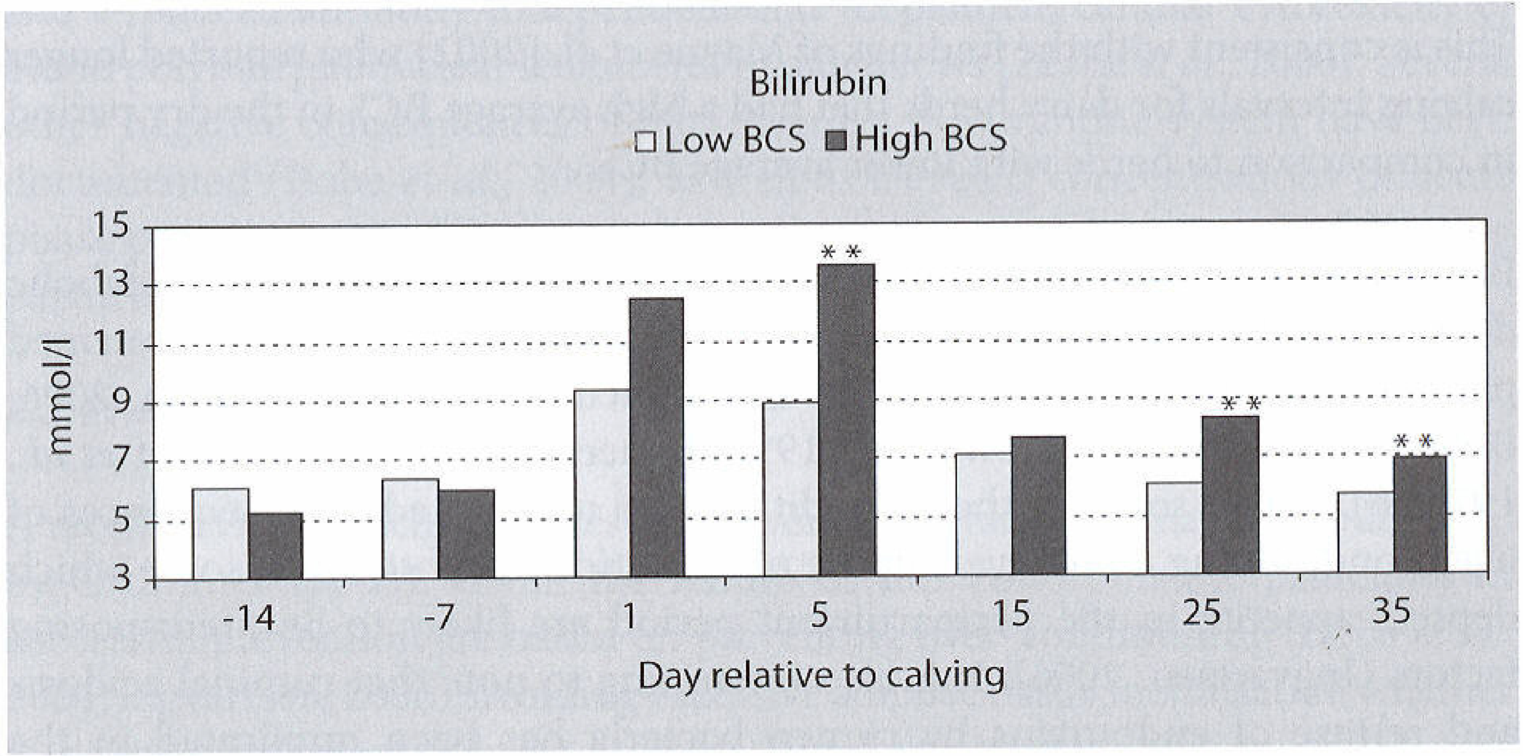


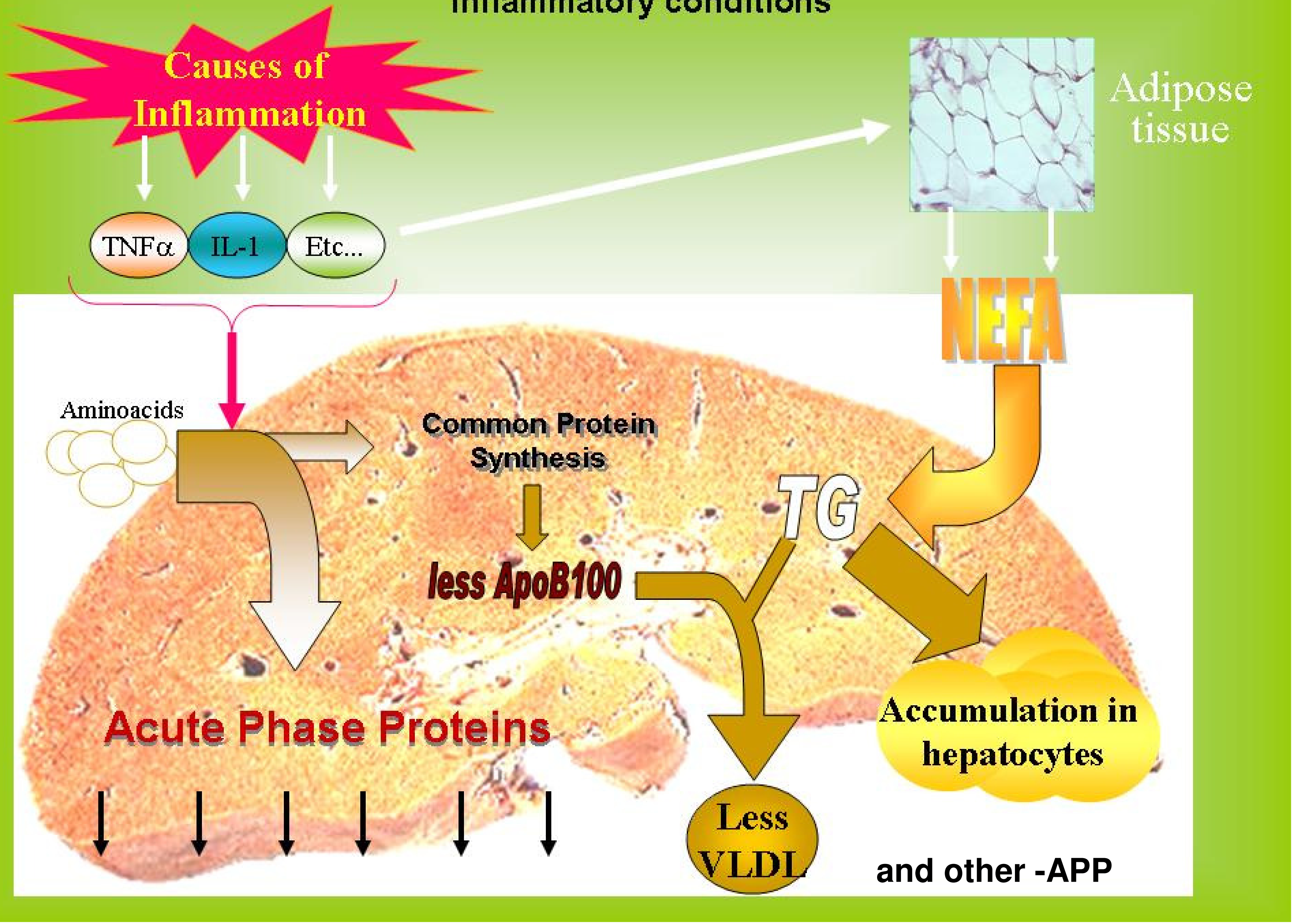
Figure 2. Bilirubin concentrations in peripheral blood of dairy cows with a high (4.0) and low (3.25) BCS at calving. **(Energy excess)**

*** Indicates significant difference between treatments at P<0.01.*

(Mulligan et al., 2009)

We observed the same dramatic increase of bilirubin in inflammatory conditions (obesity → inflammation?)

Bertoni (1996) suggested that liver lipidosis could be a consequence of inflammatory conditions



Instruction "manual" for dry period to minimize inflammations

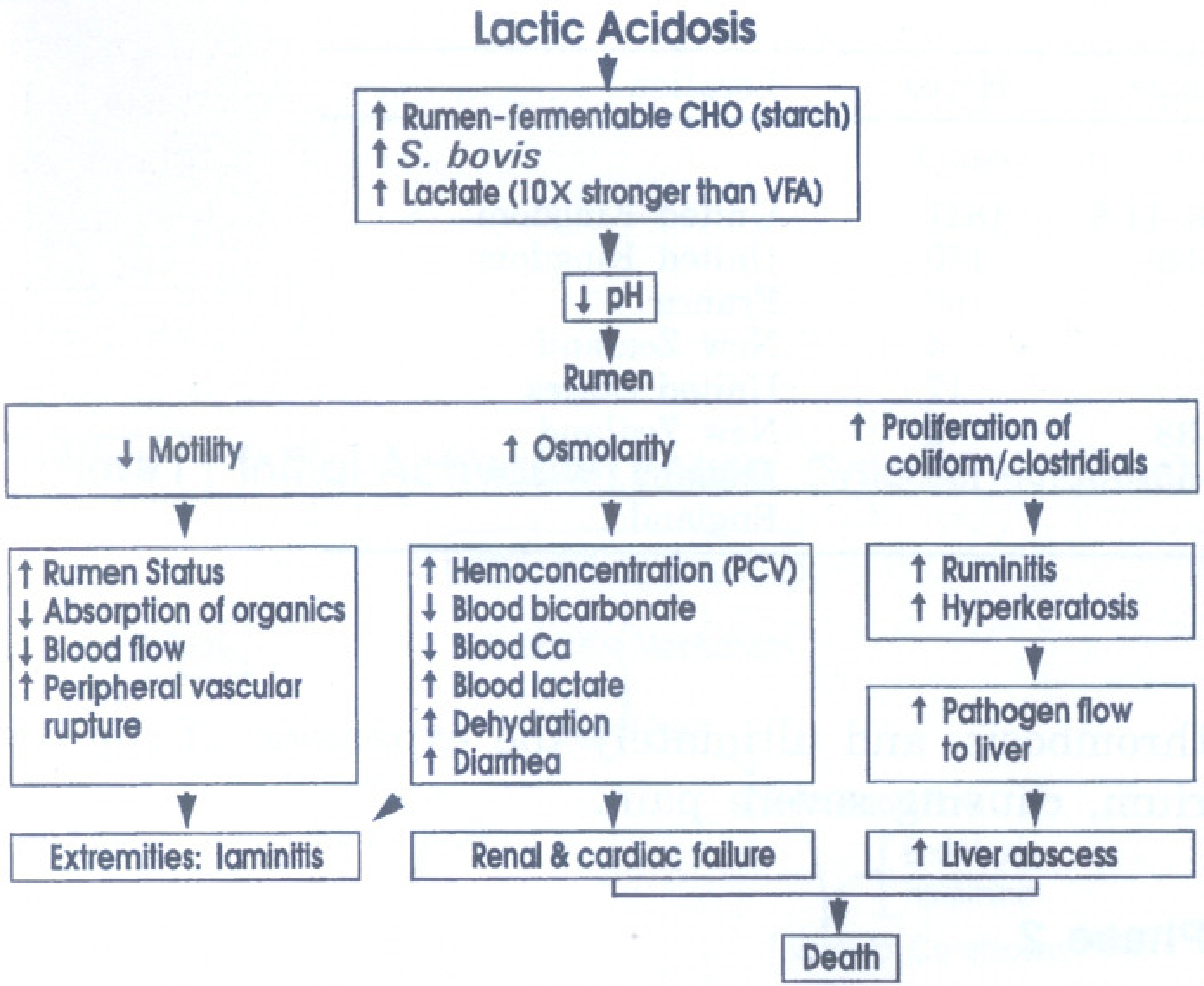
Lactation starts with 1° day … of dry period, because it allows:

- mammary gland
- feet-legs
- rumen-intestine

} recovery (specific care and feeding)

- any disease prevention (vaccinations, deworming, appropriate feeding etc.)
- to reduce stressors (housing, heat, groups management etc.)
- to avoid dystocia or difficult delivery

What about digestive disorders?



all painful and depressive

Figure 2. Progression of physiological events that link acidosis with laminitis. CHO = Carbohydrate. (Nocek, 1997)

Fig. 3. Slow sloughing of the digital horn after laminitis due to acute rumen acidosis.

(Photo: Rinderklinik Hannover) (Dirksen, 1970)

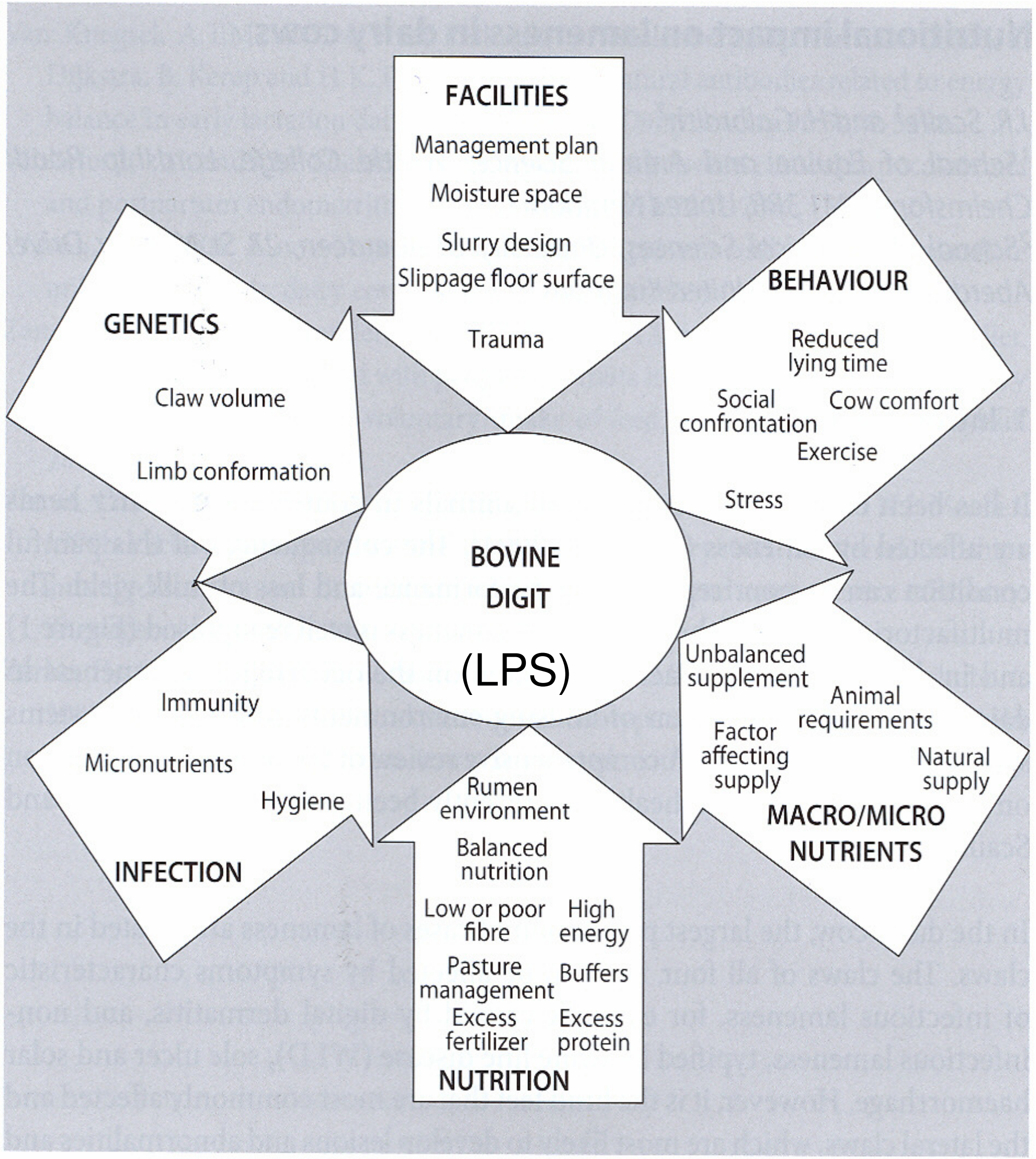


Figure 1. Multifactorial nature of the causes of lameness (Adapted from Greenough et al., *1997).* **(Scaife et al., 2009).**

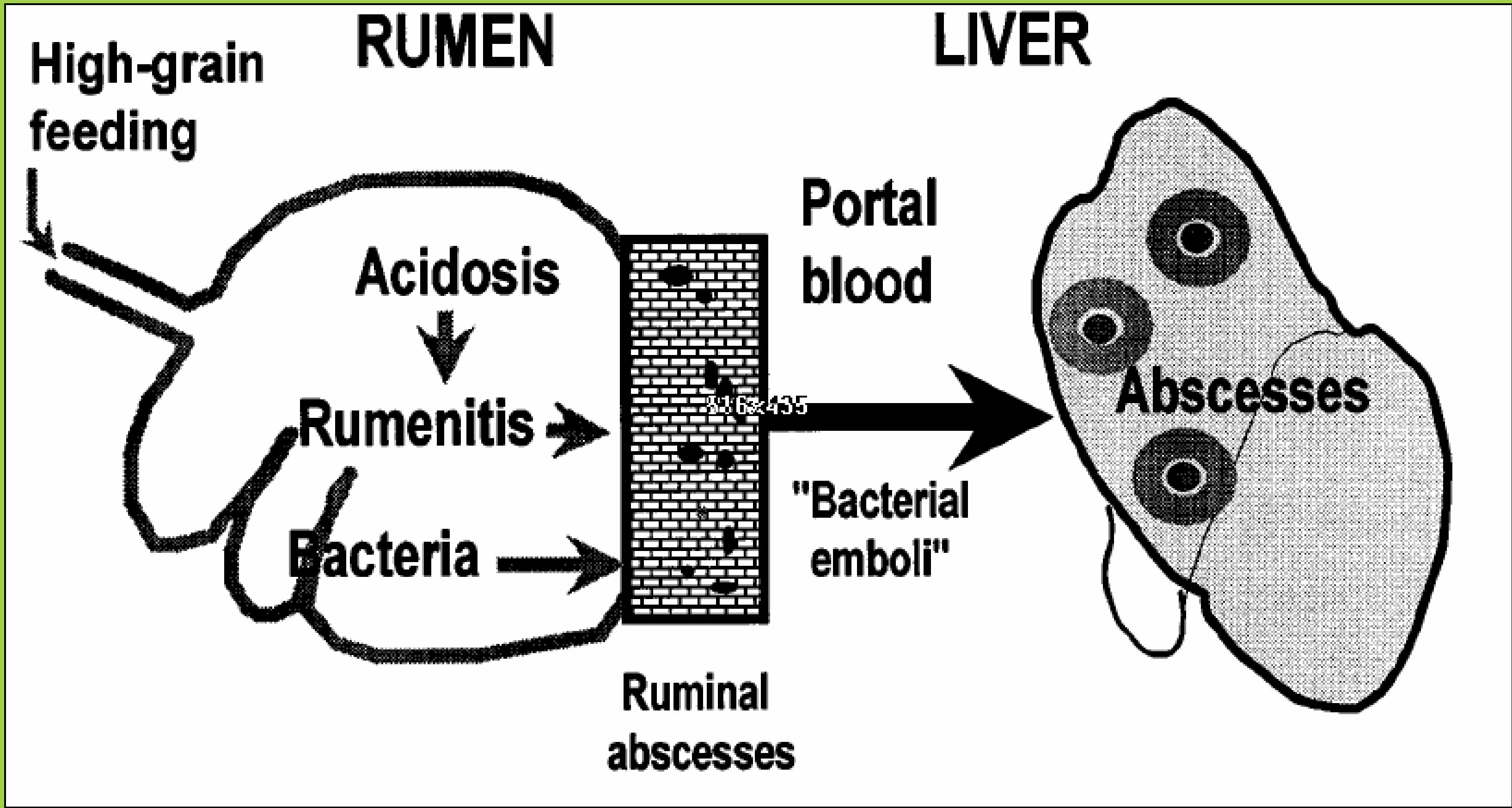


Figure x – Pathogenesis of liver abscesses in cattle fed a high-grain diet (Nagaraja e Chengappa, 1998)

not only rumen … also intestine

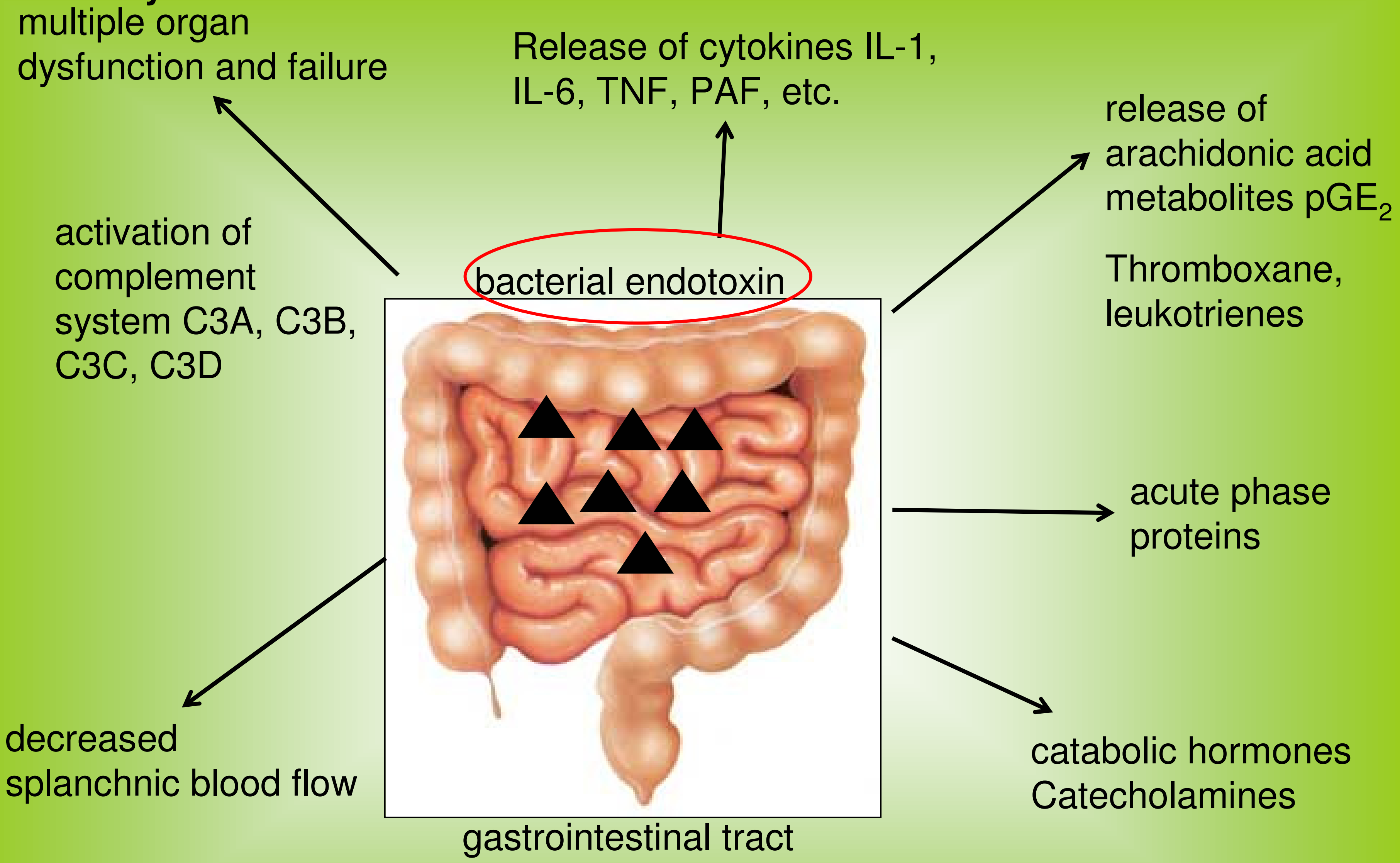


Figure xx – Various diseases lead to compromise of gut mucosal barrier function. Breakdown of local defences allows translocation of bacteria and toxin. In turn, they activate a number of systemic inflammatory cascades and release of mediators, cytokines, hormones and acute-phase proteins, which further compromise host defences. C3A-D, components of the complement system; IL, interleukin; PAF, platelet-activating factor; PG, prostaglandin; TNF, tumor necrosis factor (Rowlands JB et al., 1998)

not only diet …

INTESTINAL HEALTH

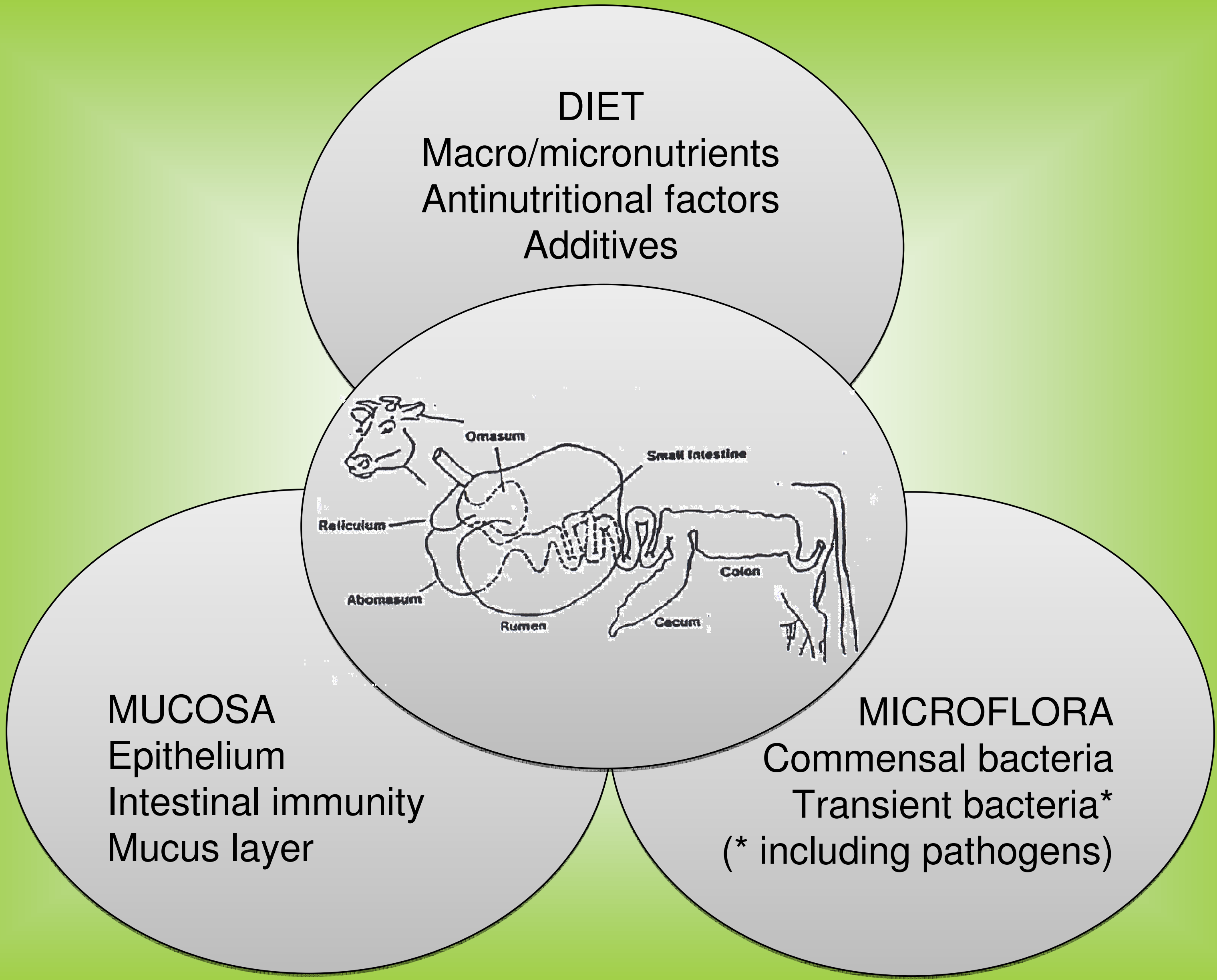
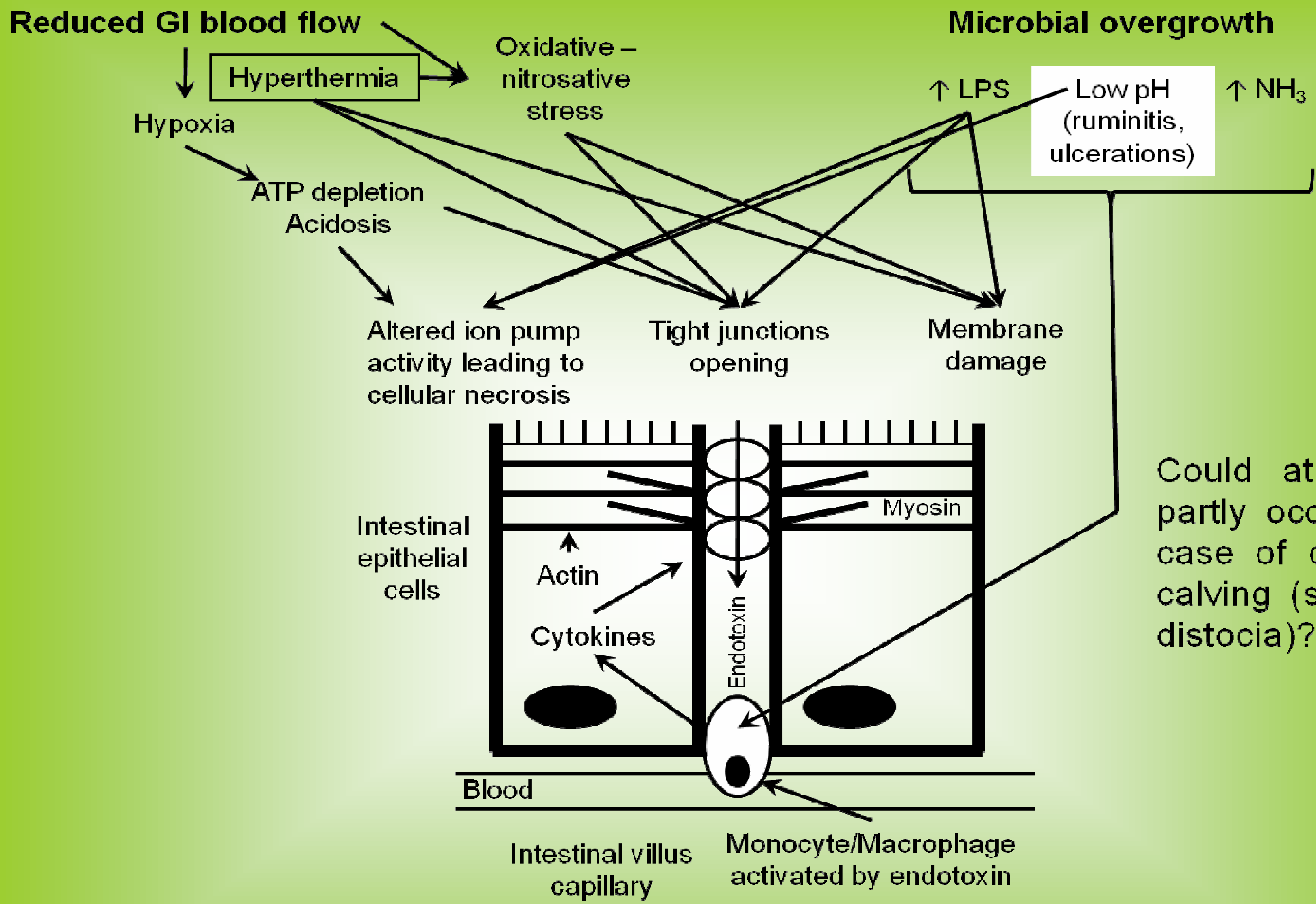


Figure xx – adapted from Santos, 2008

… also mucosa permeability (to LPS or endotoxins)



Could at least partly occurs in case of difficult calving (serious distocia)?

(Lambert, 2009)

in human heavy exercise (or heat stress)

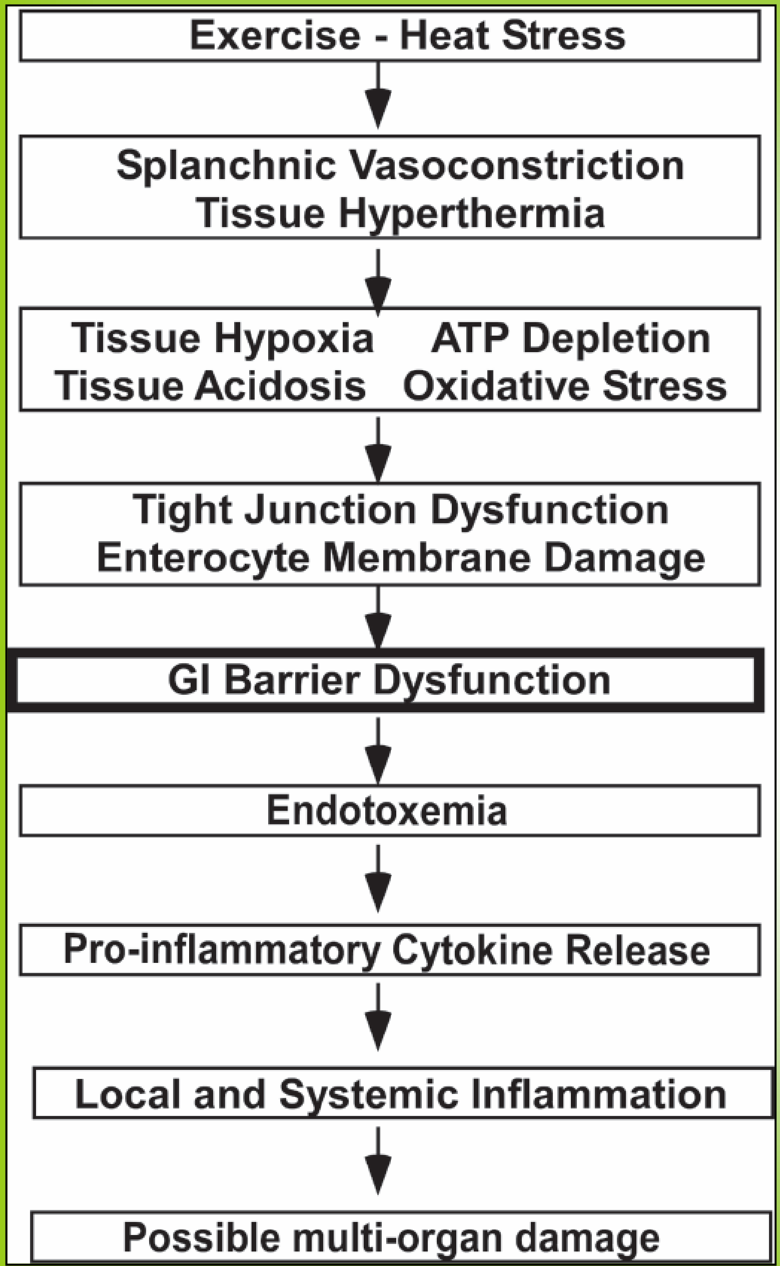


Figure xx - Causes and possible consequences of gastrointestinal (GI) barrier dysfunction with exercise-heat stress. Lambert, 2009; reprinted fromLambert (2004) with permission (copyright 2004, American College of Sports Medicine).

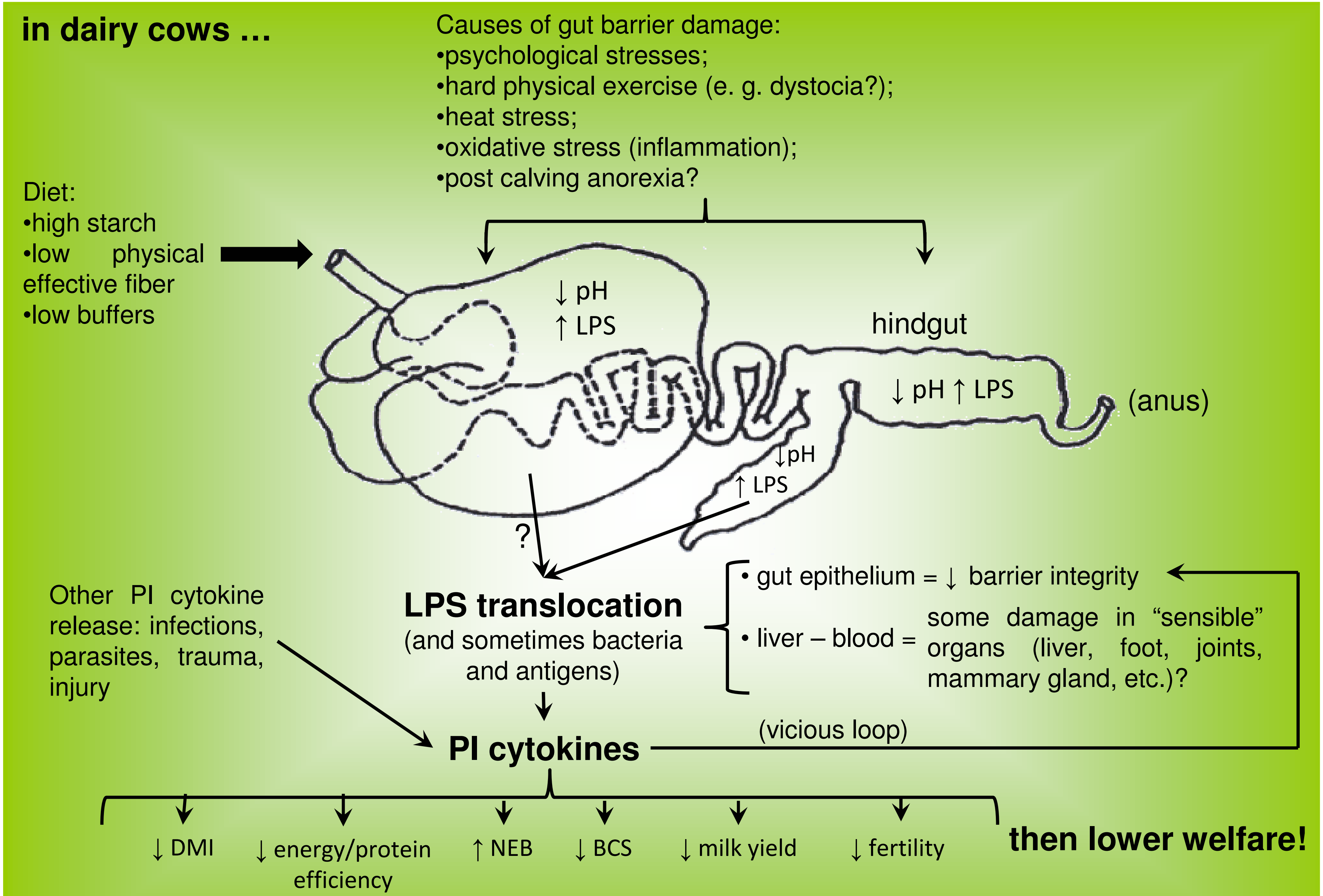
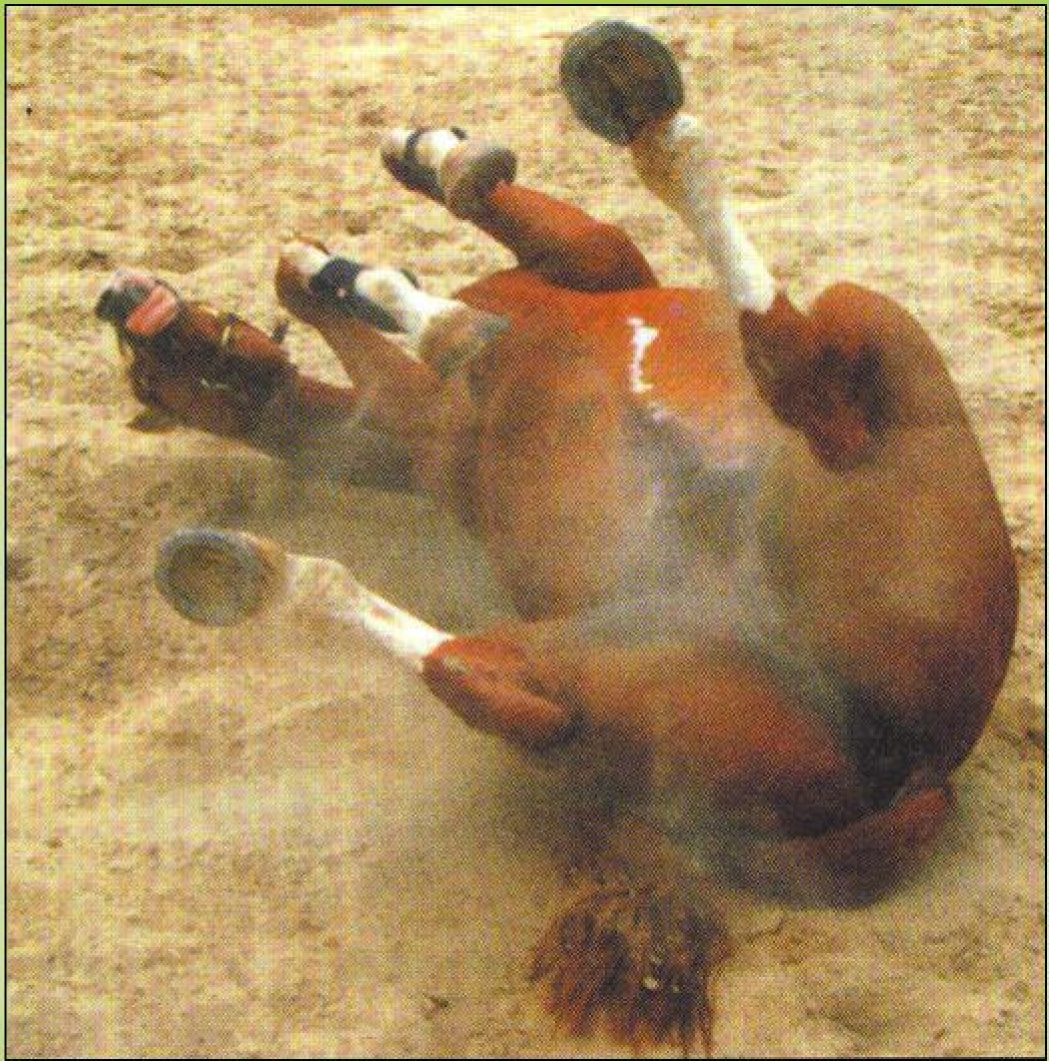


Fig. 7 – Factors of digestive disorders and of gut permeability increase in periparturient dairy cows: possible consequences. LPS, endotoxin; DMI, dry matter intake; NEB, negative energy balance; BCS, body condition score; PI, pro-inflammatory.

Horse with caecum colics



Some time in cattle too (i.e. JHS?)

Veal calves

(milk feeding for 6 months)

- severe anemia (infectious disease)
- stereotipies and/or rumen problems
  (lack of material to chew)

EU directory: not less of 250g DM as "roughage"

↑ hemoglobin (pink meat)

↓ lameness and better coat

↑ gain and efficiency
(better welfare and performances)

Nutrition and welfare improvement

Beyond the correct amount of nutrients, feeds car contribute to:

- **modulation of immune system (nutraceuticals)**
- **reduction of inflammation response (nutraceuticals)**

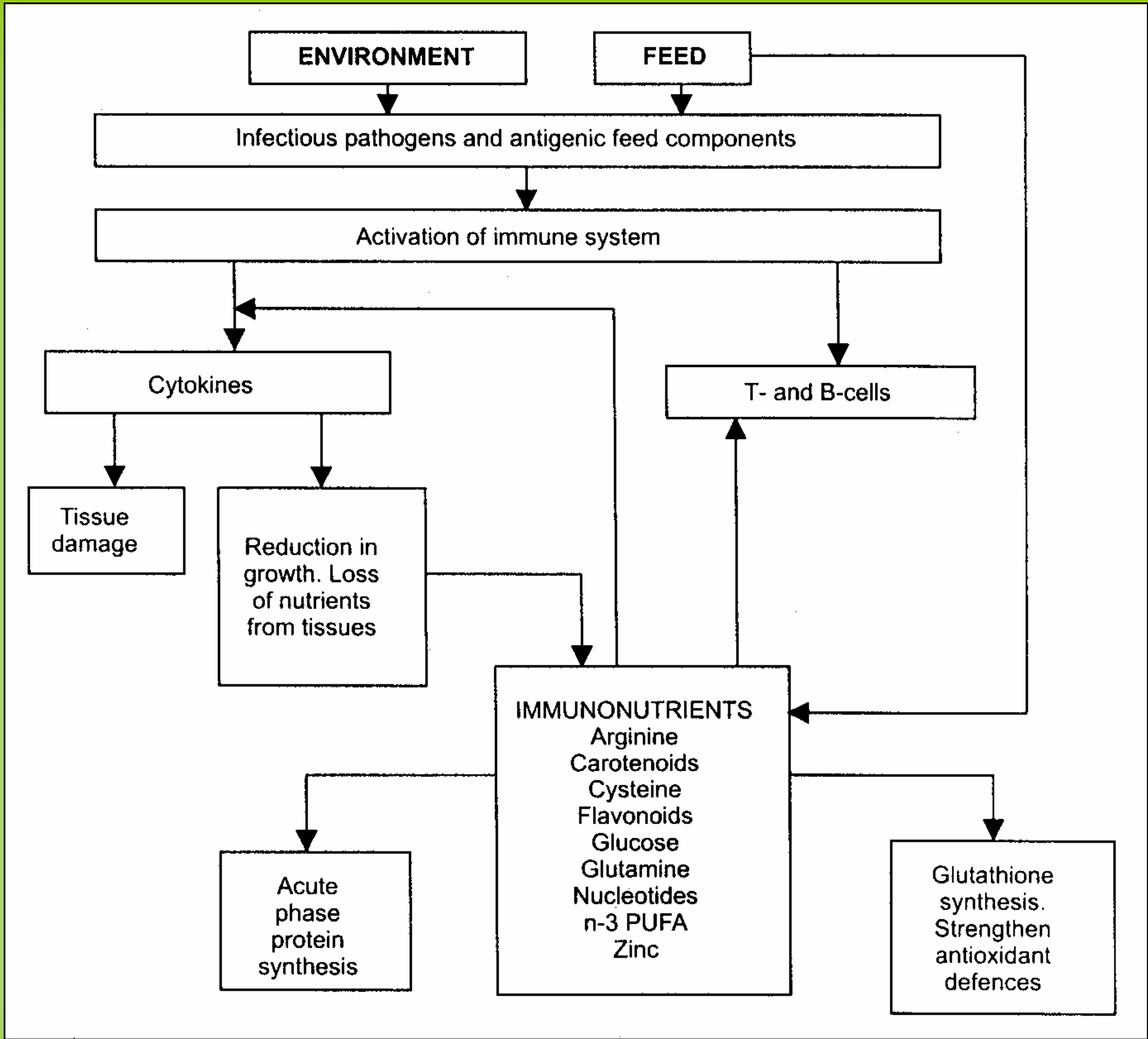


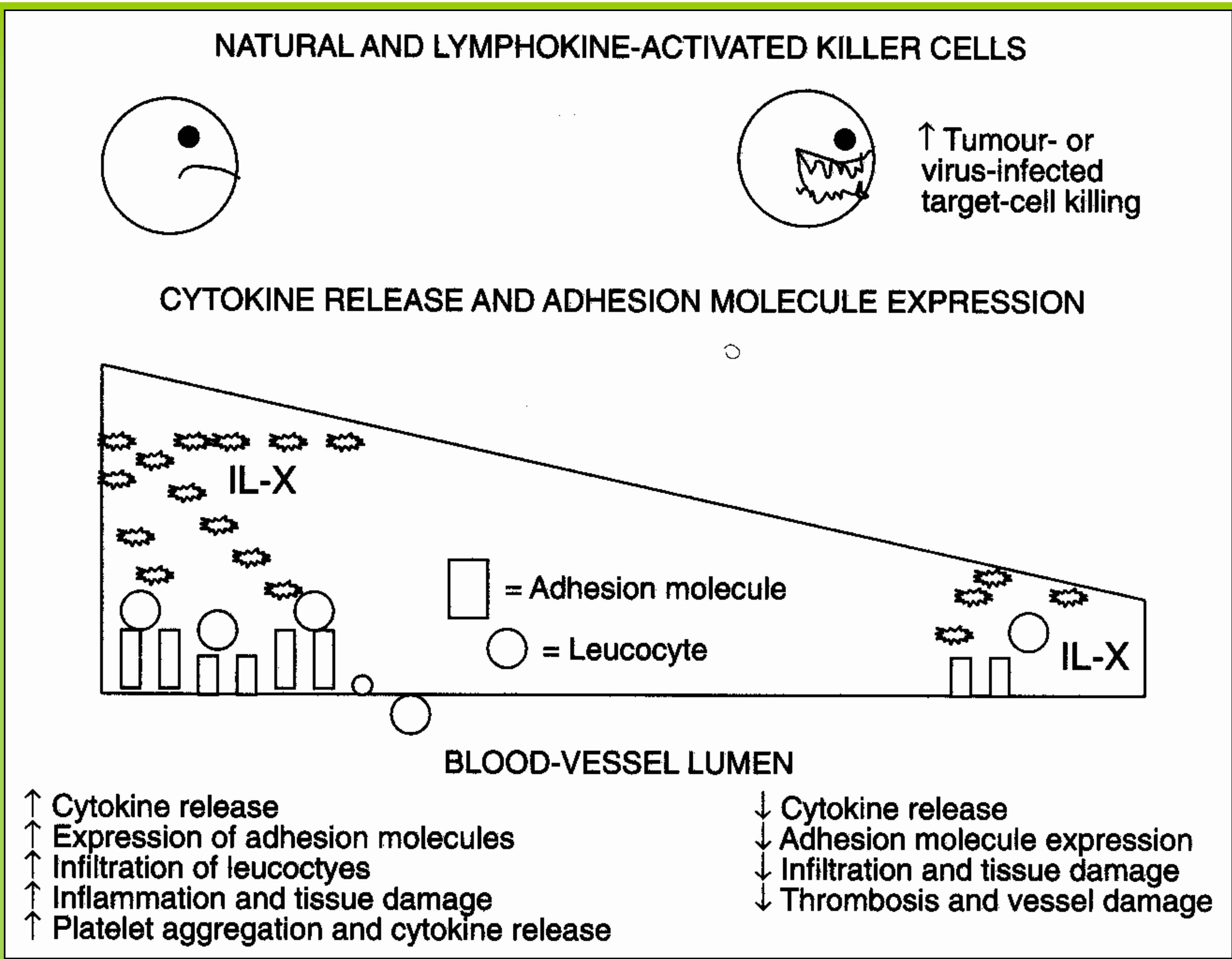
Fig. 2 - Central role of nutritional immunology in maintenance of animal health (infectious diseases)

Table 1. Feed components important in immunomodulation (Adams, 2001)

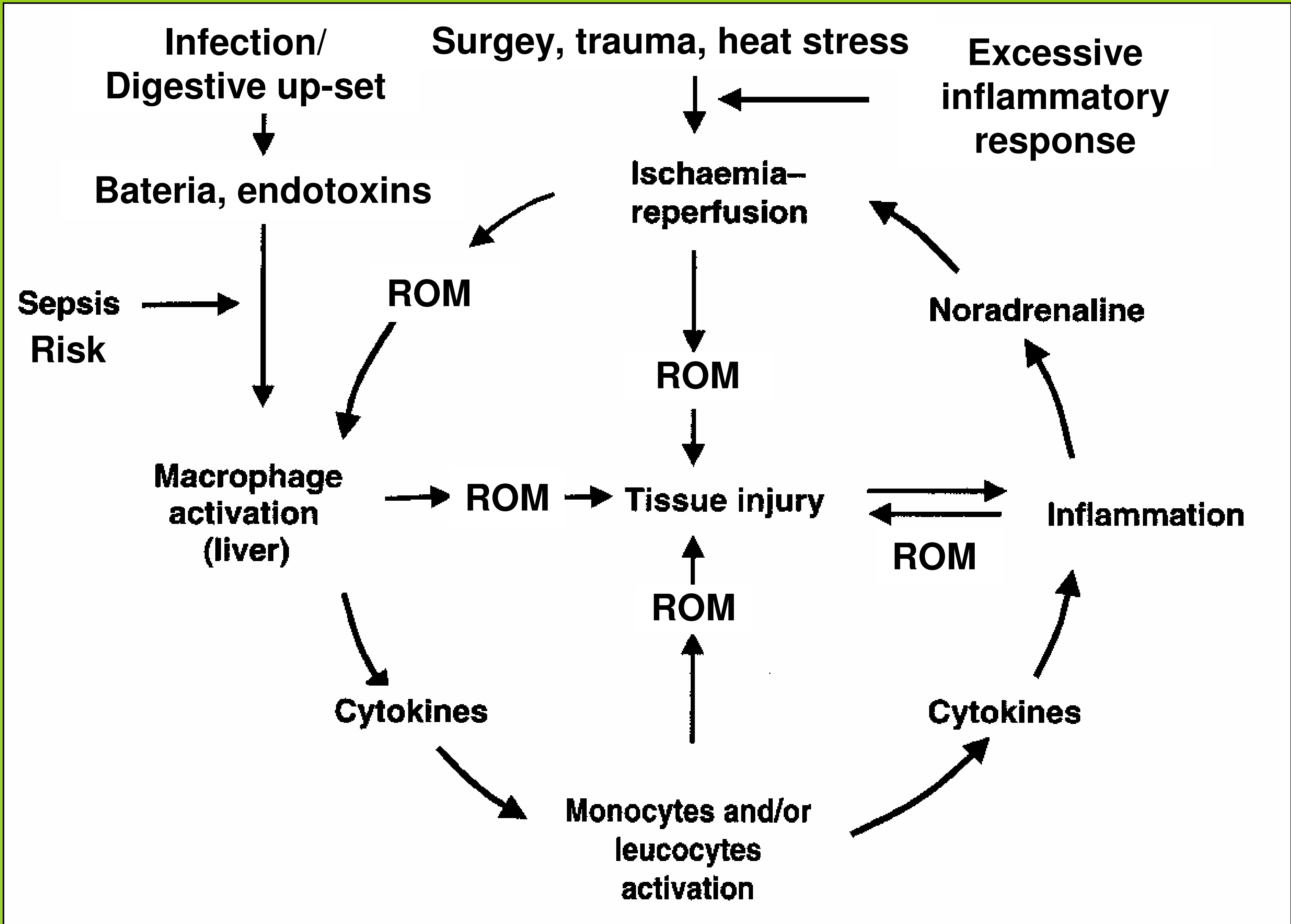
Immunomodulator	*Function*
Arginine	Substrate for nitric oxide (NO) synthesis, improves helper T-cell numbers.
Carotenoids	Antioxidant function, stimulates vaccine response.
Cysteine	Enhances antioxidant status via glutathione synthesis
Flavonoids	Enhances virus elimination from blood
Glutamine	Nutrient for immune cells, improves gut wall functions, precursor for glutathione.
Nucleotides	RNA and DNA precursors, improves T-cell function
n-3 polyunsaturated fatty acids	Anti-inflammatory agents, reverses immunosuppression.
Zinc	Maintains T-cell response and antibody production

and Selenium (Fig.)

and anti-inflammation … (among them antioxidants)



Fig…. Effects of selenium (Se) deficiency (left-hand column) or Se supplementation (right-hand column) on cells and molecules mediating innate immunity. t signifies an increase in activity or numbers and .1. denotes a decline in activity or numbers. Ros, reactive oxygen species. IL-X, various interleukins (McKenzie e coll., 2002)



An example of how different causes of cytokine release – some of feeding origin - can induce ROM (Reactive Oxygen Metabolite) and inflammation; both can in turn activate a new release of cytokines in a vicious cycle (Adapted from Heyland et al., 2006)

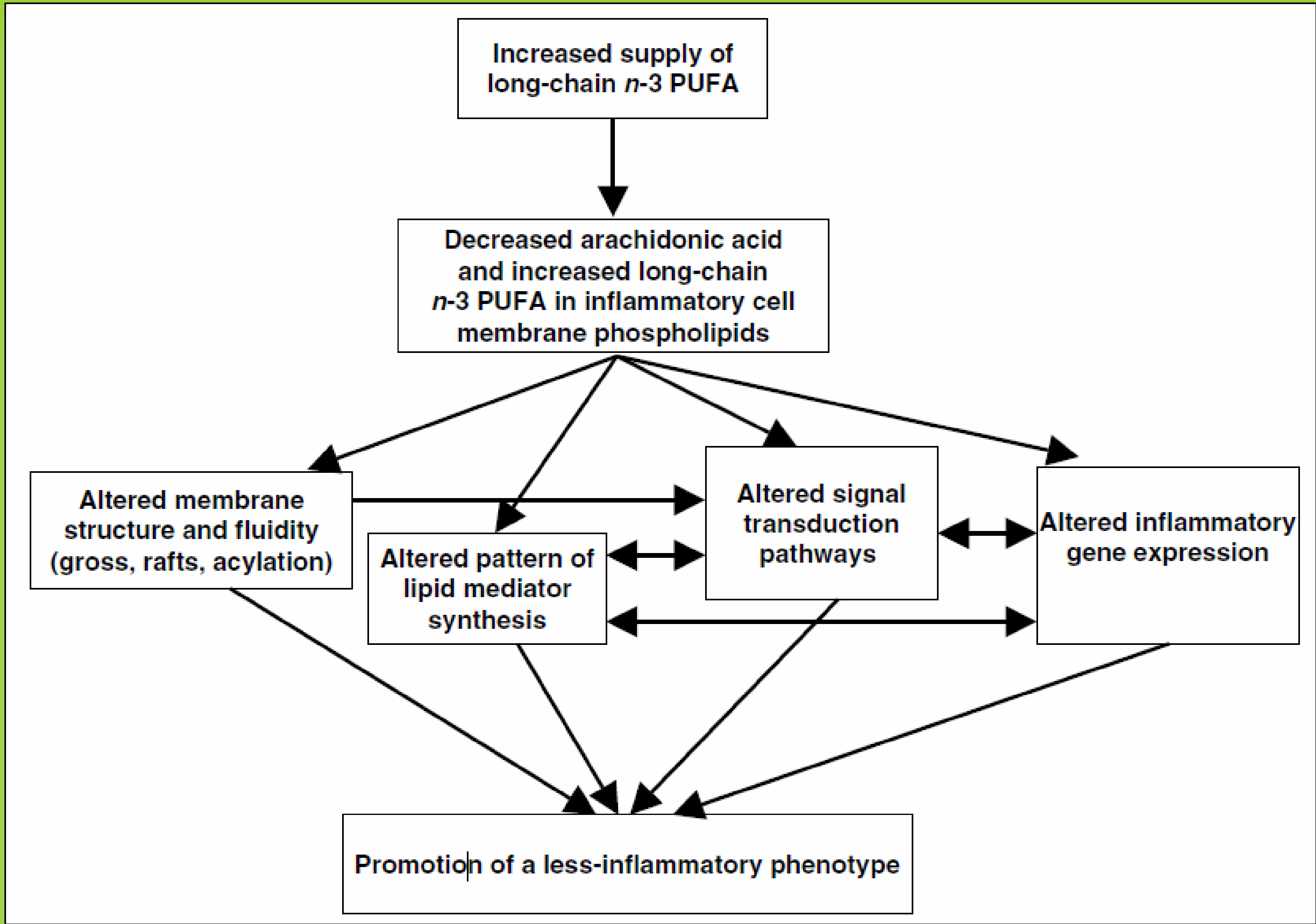


Figure xx – Mechanisms by which n-3 PUFA can affect inflammatory cell activity. (Calder, 2008)

Thus, in case of any inflammation, the response (and welfare reduction) can be different and … nutrition can be involved

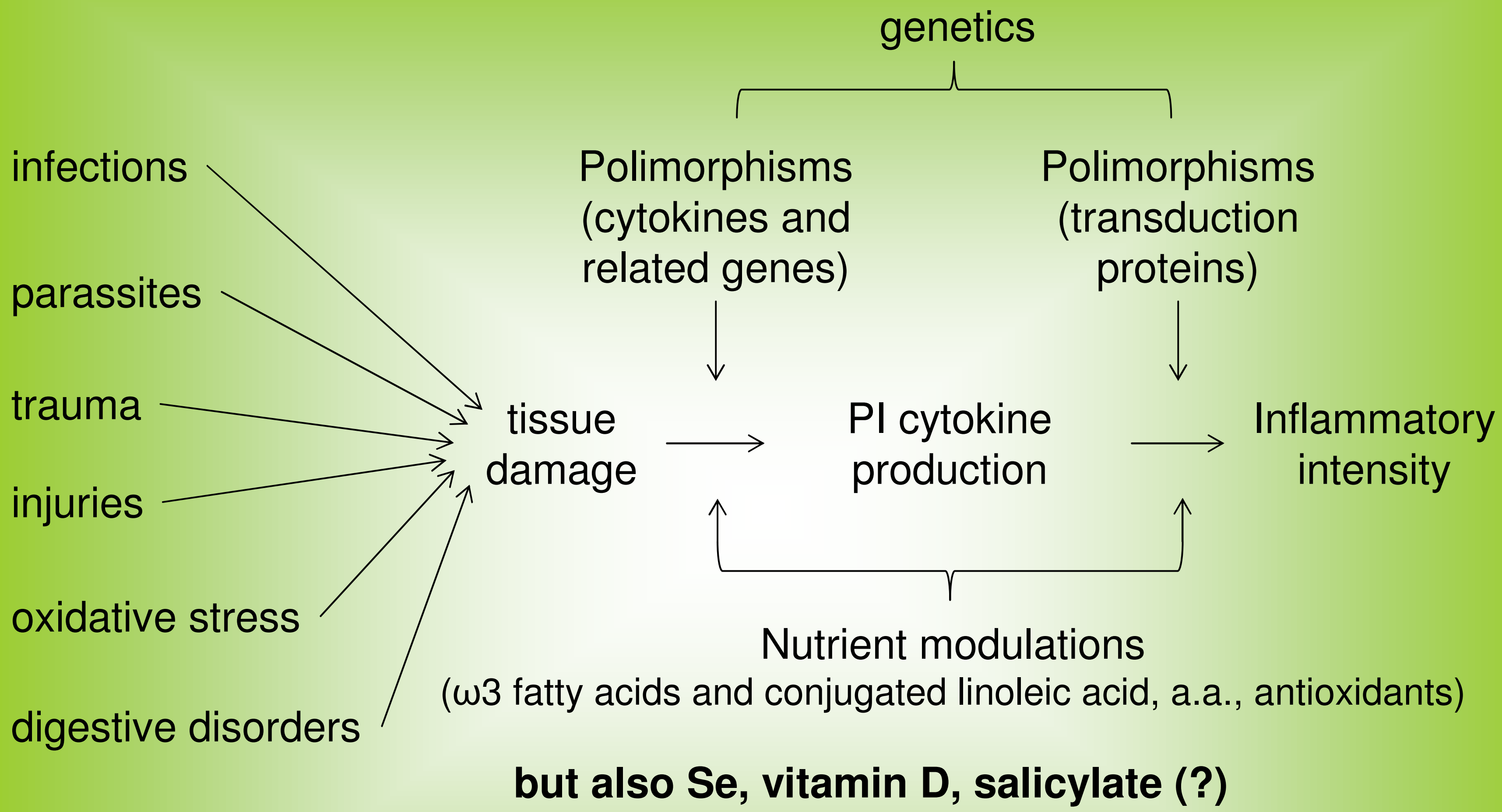


Fig. 8 – Genetic and nutritional influence on pro-inflammatory (PI) cytokine production and inflammatory response. Adapted from Grimble, 2001

CONCLUSIONS

Nutrition and feeding can, in several different ways, contribute, both in extensive and intensive farming systems:

- **to worsen**
- **to improve**

} animal welfare

To worsen:

- **tissue damage**
- **diseases (metabolic or infectious)**
- **suffering (hunger, thirst, depression)**

Inflammation is often involved (sometime as meta-inflammation)

To improve:

- **immune nutrition (i.s. modulation) to reduce inflammation risks (not only infections)**
- **anti-inflammation (and antioxidants) to reduce (intensity and duration) the response to inflammation (fresh forages are much better?)**

Future findings would allow better knewledge on epigenetic mechanisms:

- **to prevent "troubles" occurring much later respect to malnutrition**
- **to improve with appropriate nutrition some essential functions (i.e. anti-inflammatory phenotype)**

THANK YOU!

Questions?