Assessing bioavailability of essential trace minerals in animal nutrition

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Bioavailability of essential trace minerals: restrictions resulting from general definition

In vitro studies cannot fully cover bioavailability

Bioavailability = *capability* of metabolic use at the absence of homeostatic regulation

bio – availability

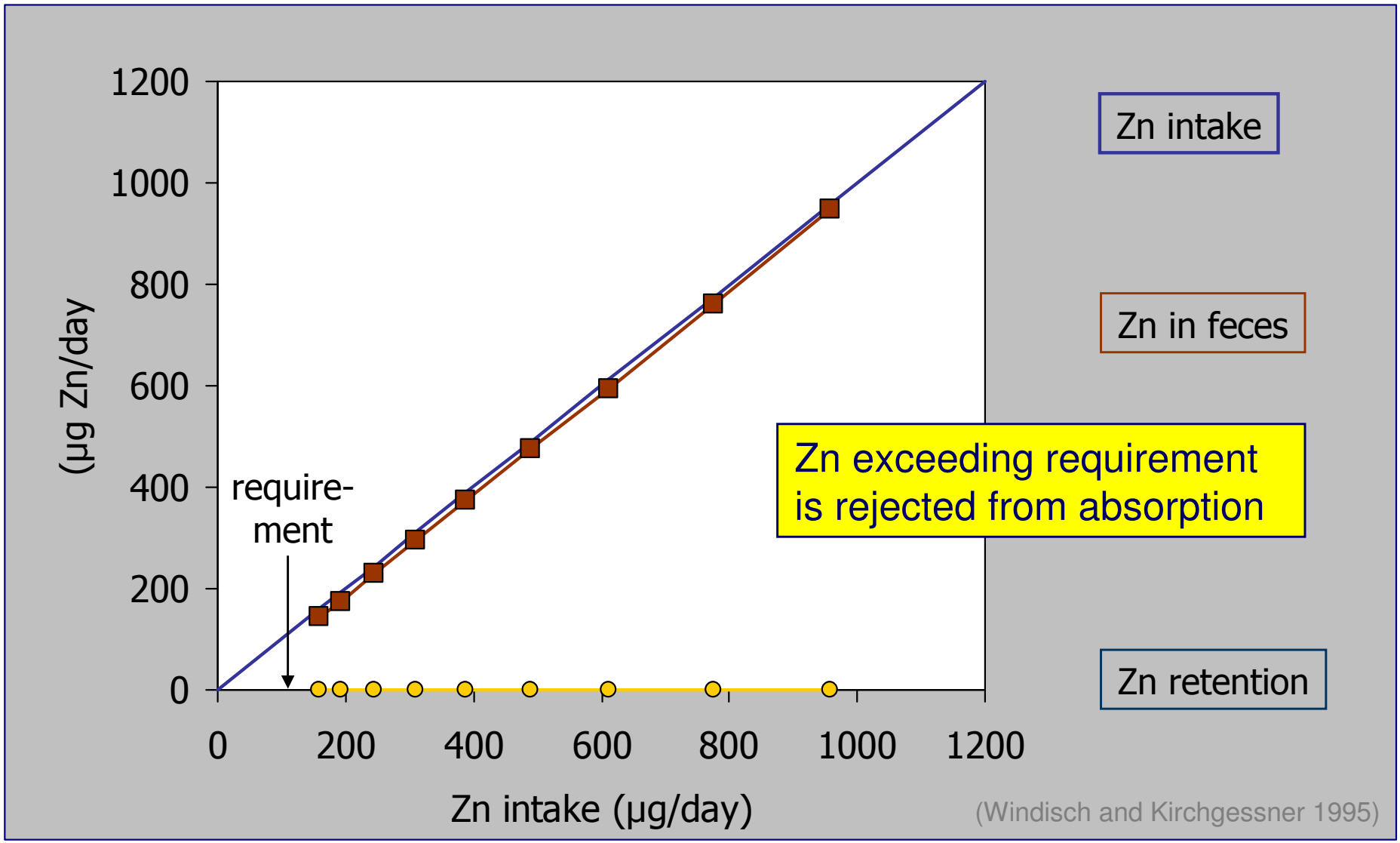
metabolic (re)actions

dietary properties

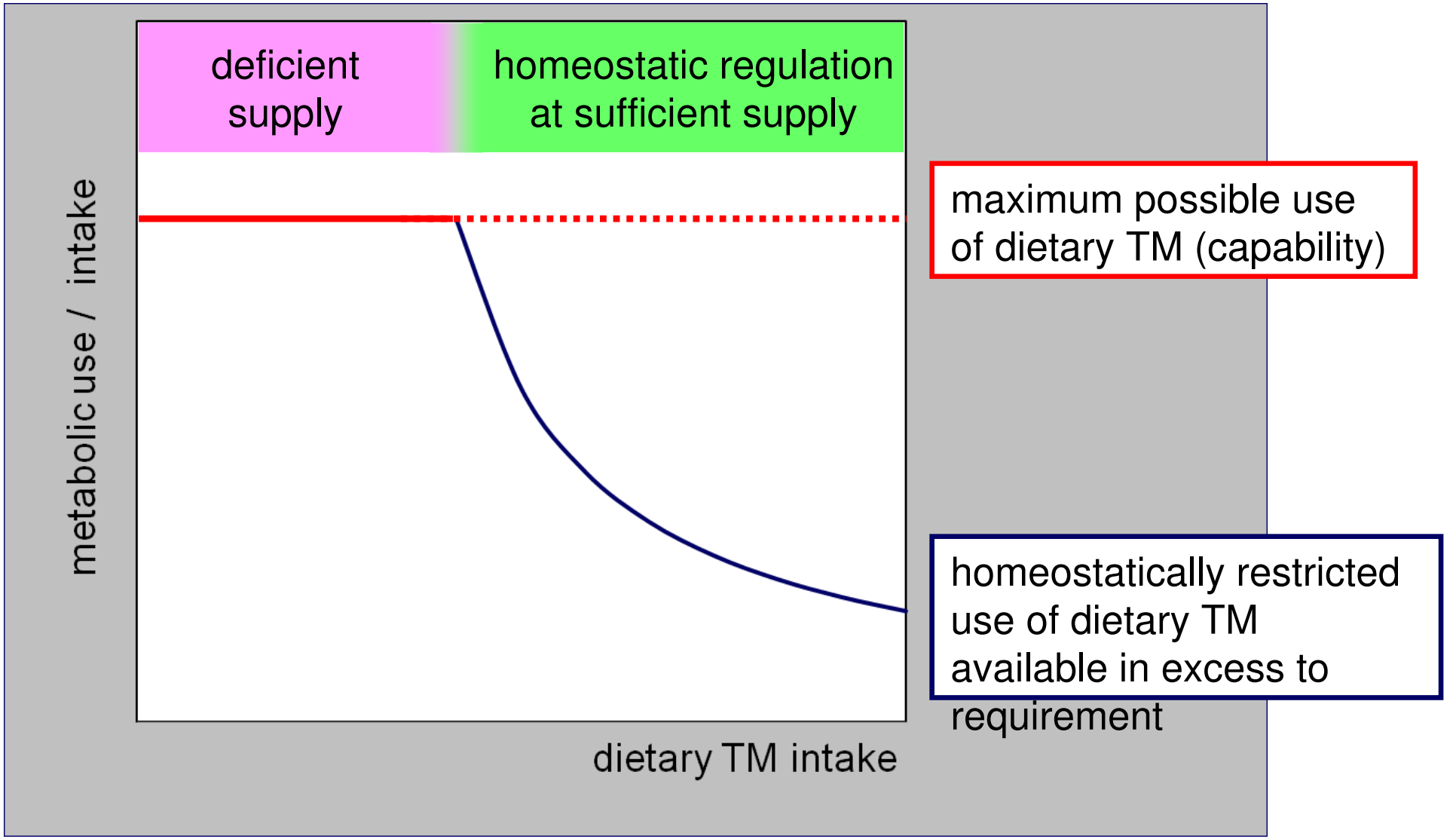
…the maximum possible yield of a nutrient that the body may extract from the ingested food and use for its metabolic functions…

(Kirchgessner et al. 1993)

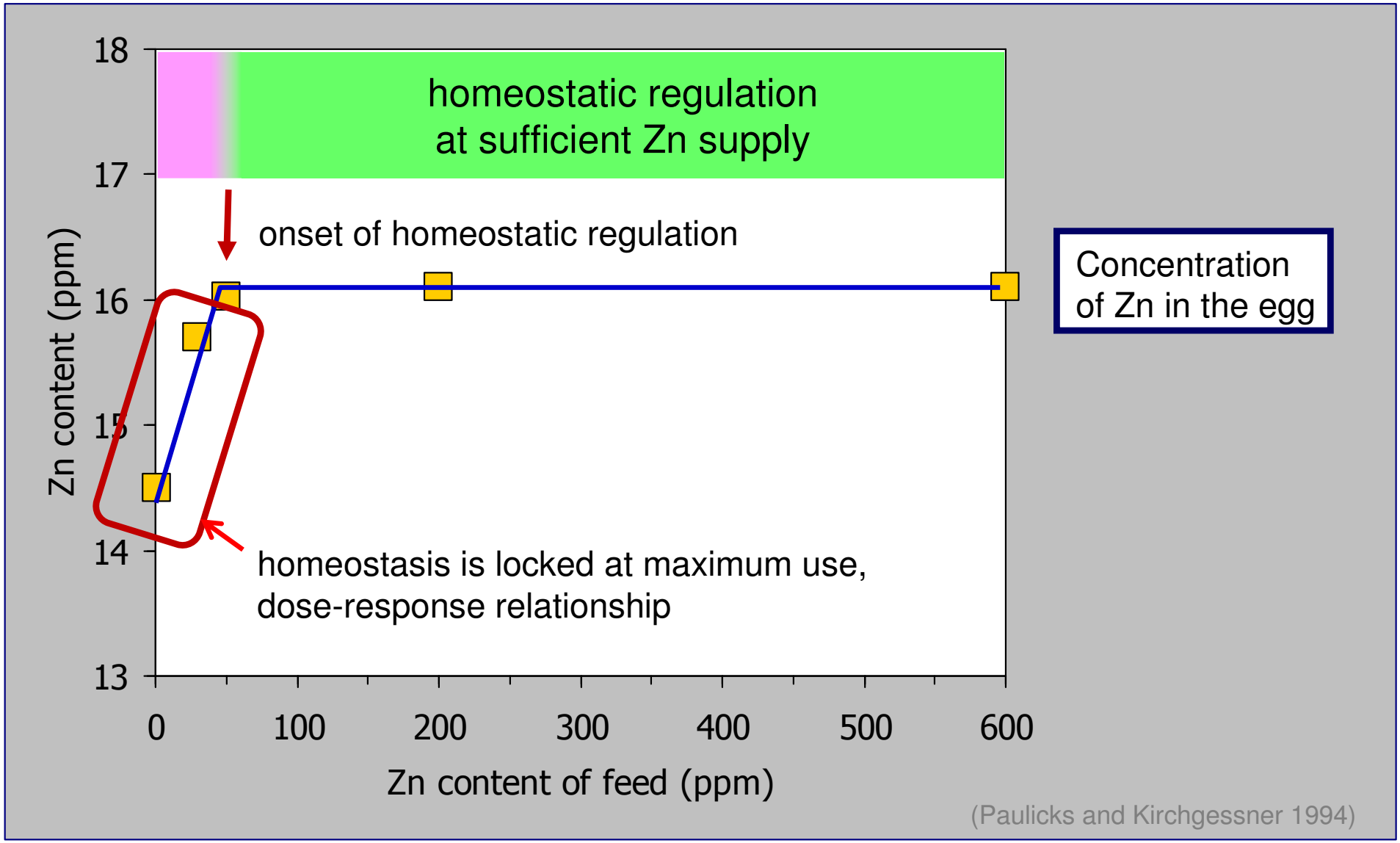
E.g. homeostatic regulation of Zn metabolism: Precise control of Zn uptake from intestinal tract



Metabolic use of dietary trace minerals in relation to homeostatic counter-regulation

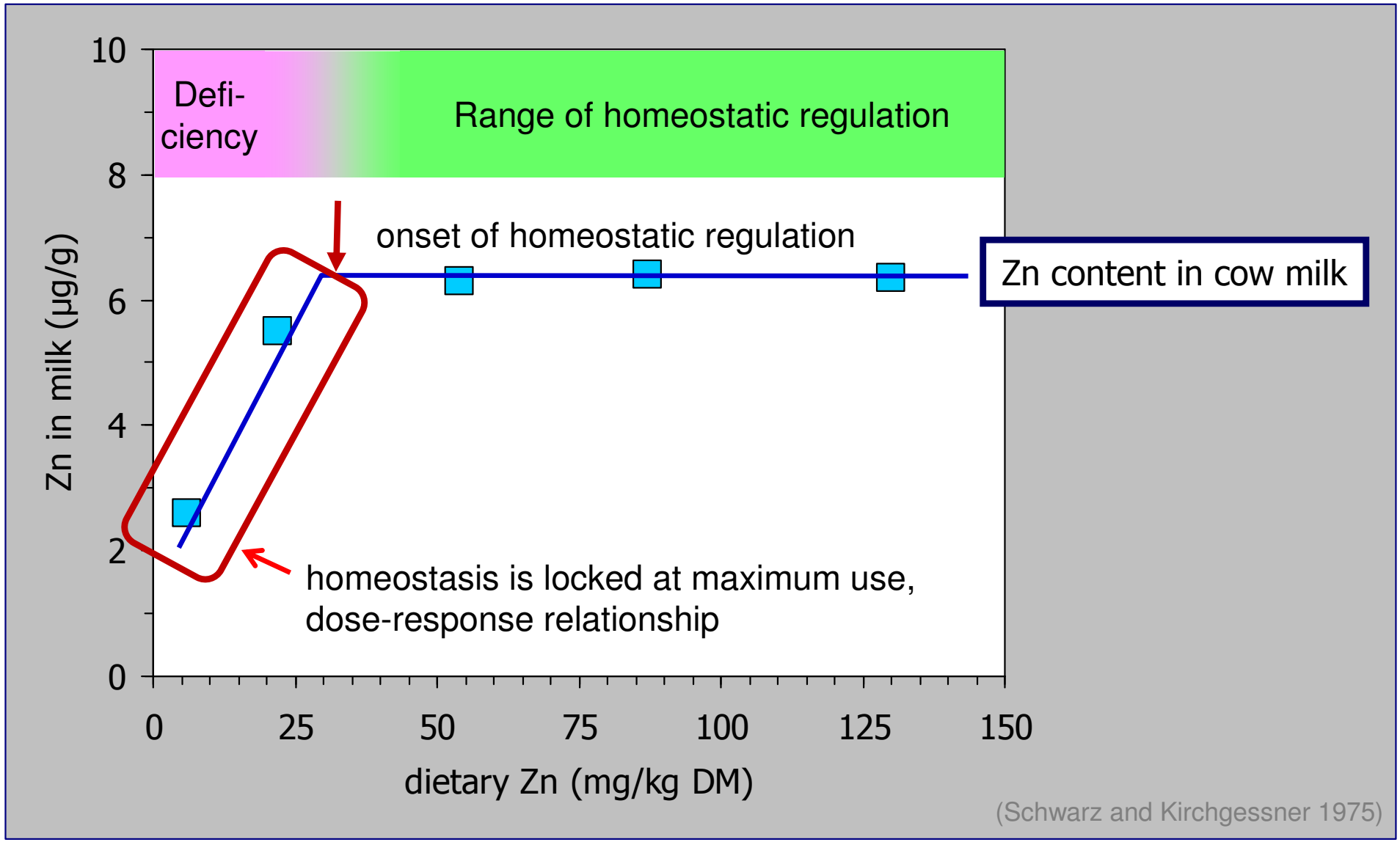


e.g. Zn homeostasis: Zn concentration in eggs



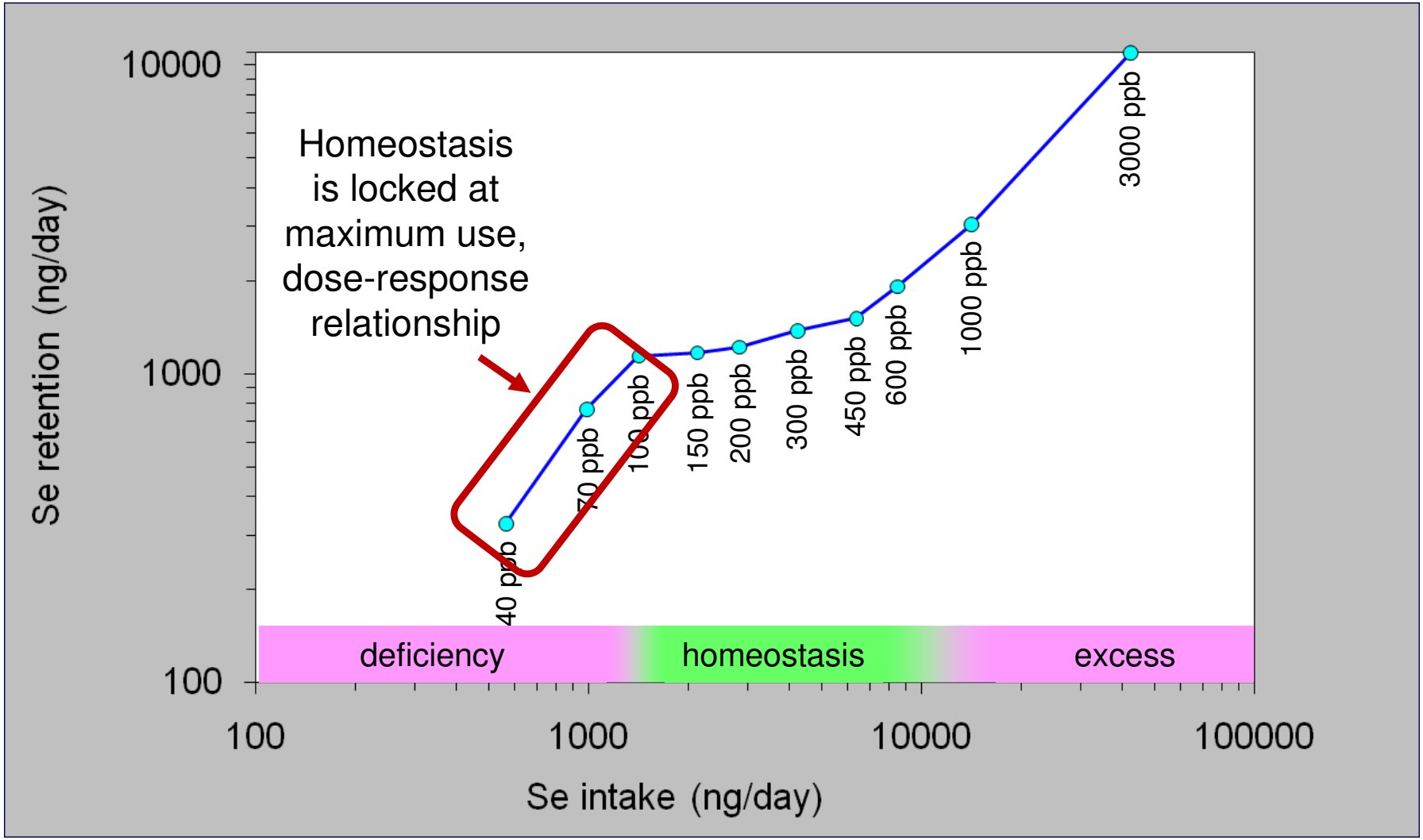
(Paulicks and Kirchgessner 1994)

Example Zn homeostasis: Zn steady state in products (e.g. milk)



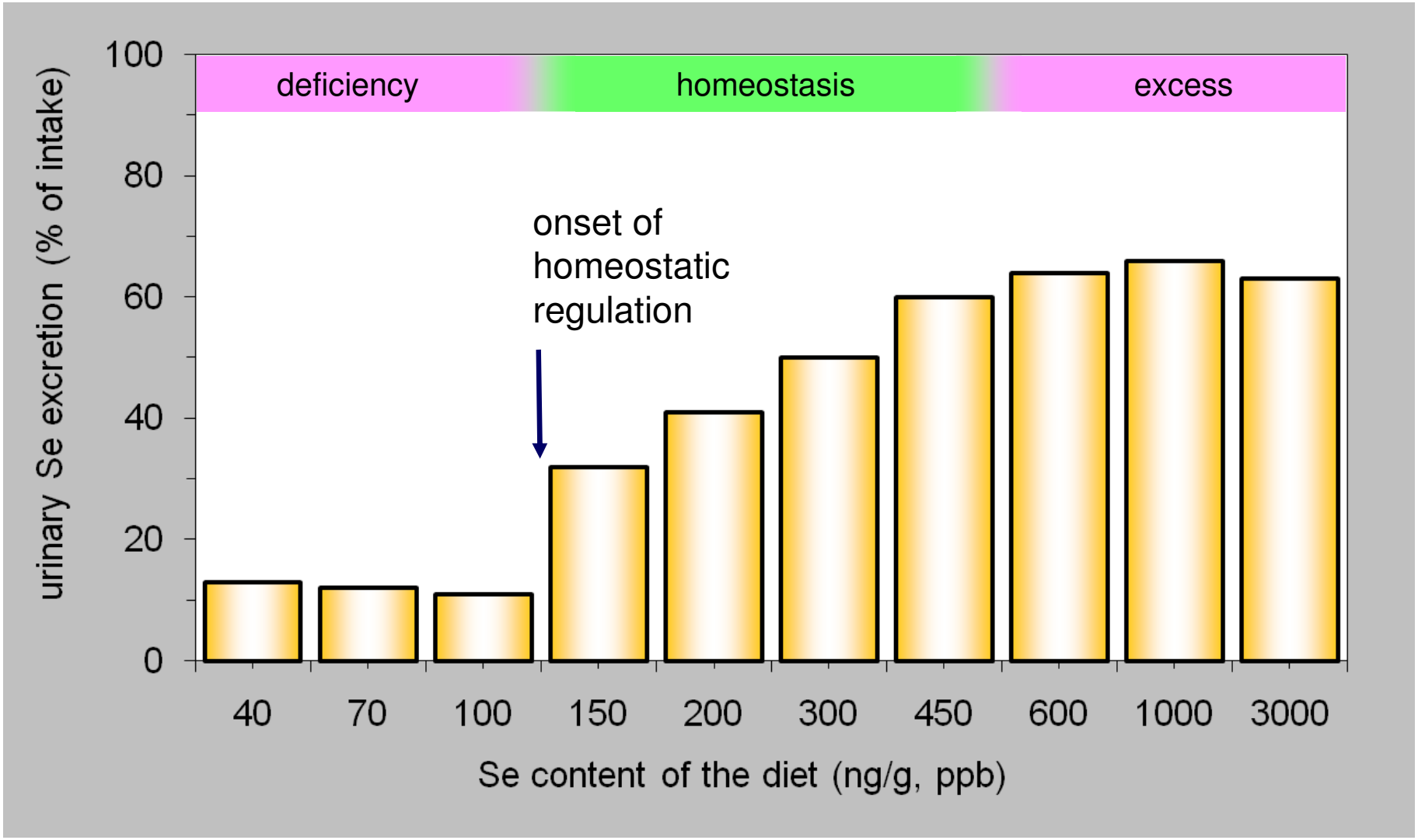
(Schwarz and Kirchgessner 1975)

e.g. Se homeostasis: whole body Se retention



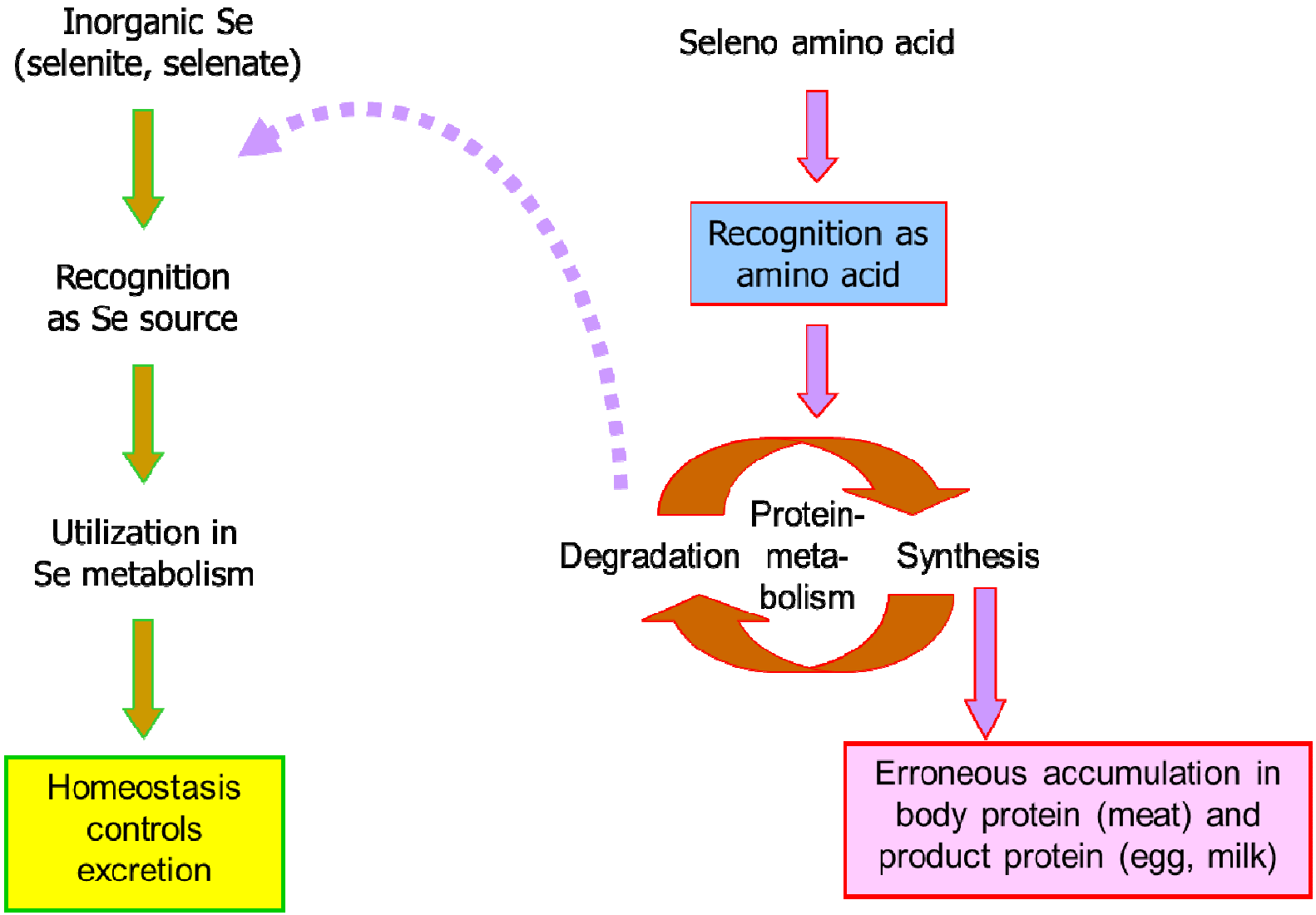
(Kirchgessner et al.1997)

e.g. Se homeostasis: urinary Se excretion

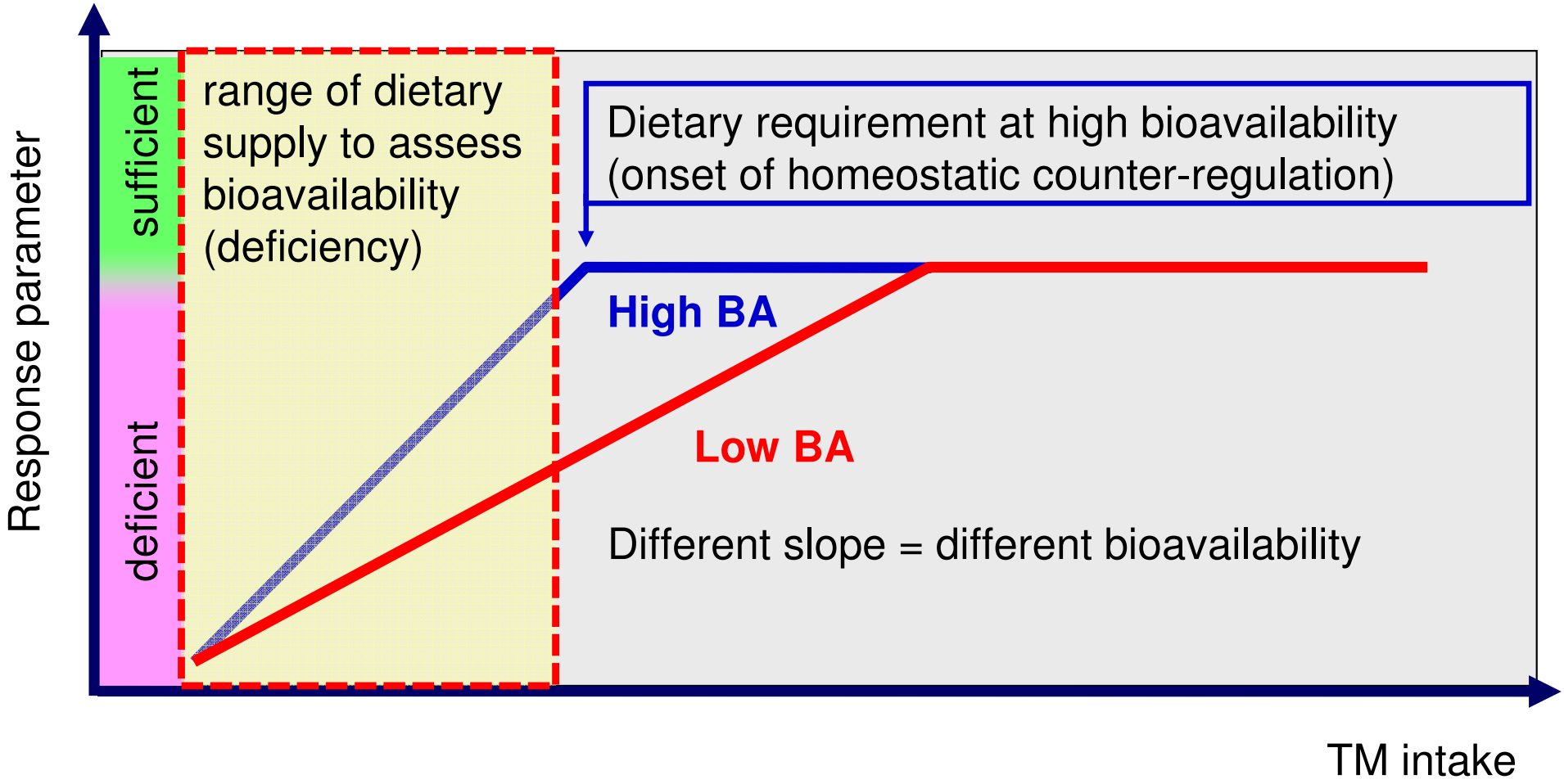


(Kirchgessner et al.1997)

Inorganic vs. organic Se compounds



General principle to assess bioavailability of trace minerals



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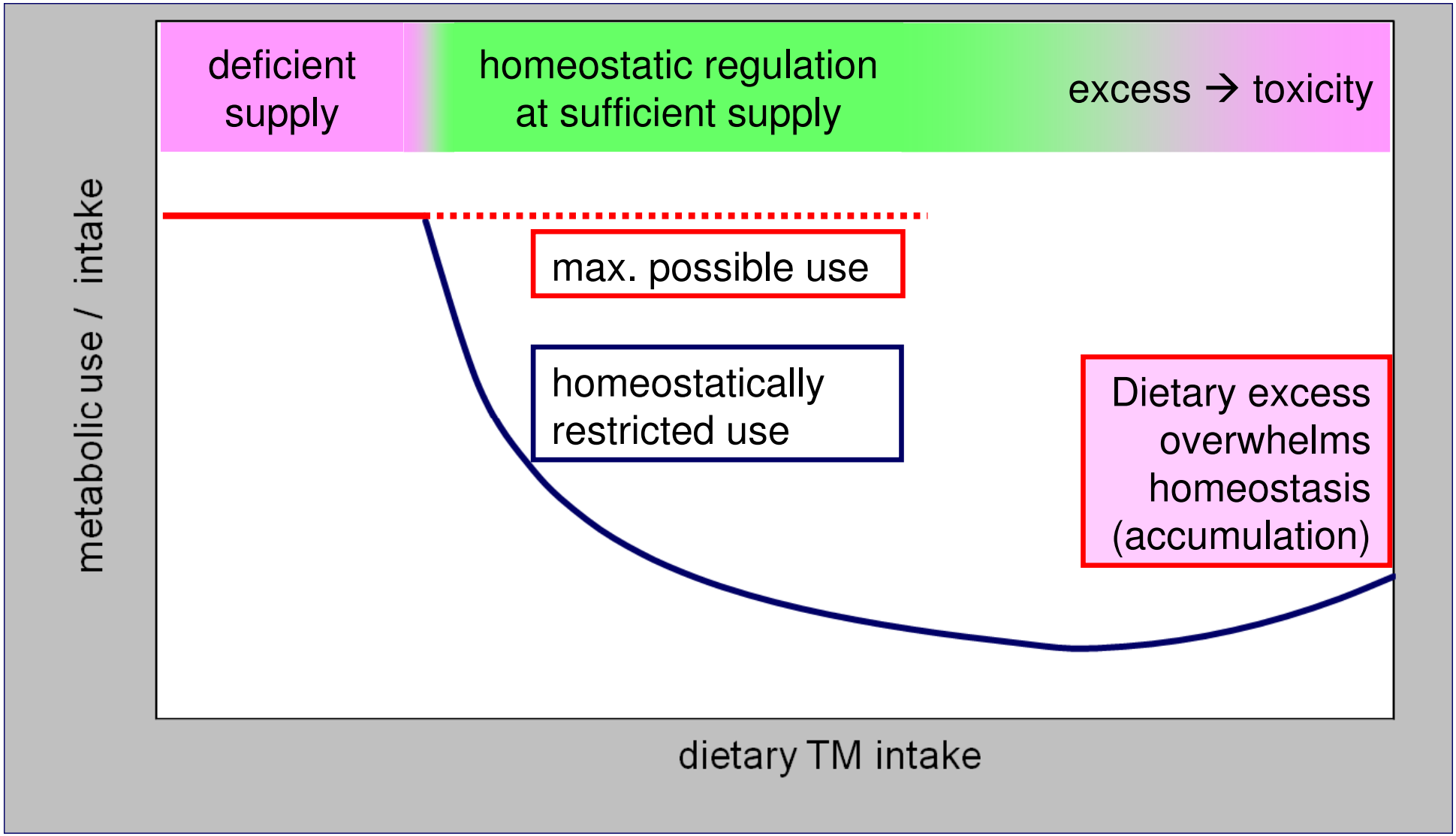
(Kirchgessner et al. 1993)

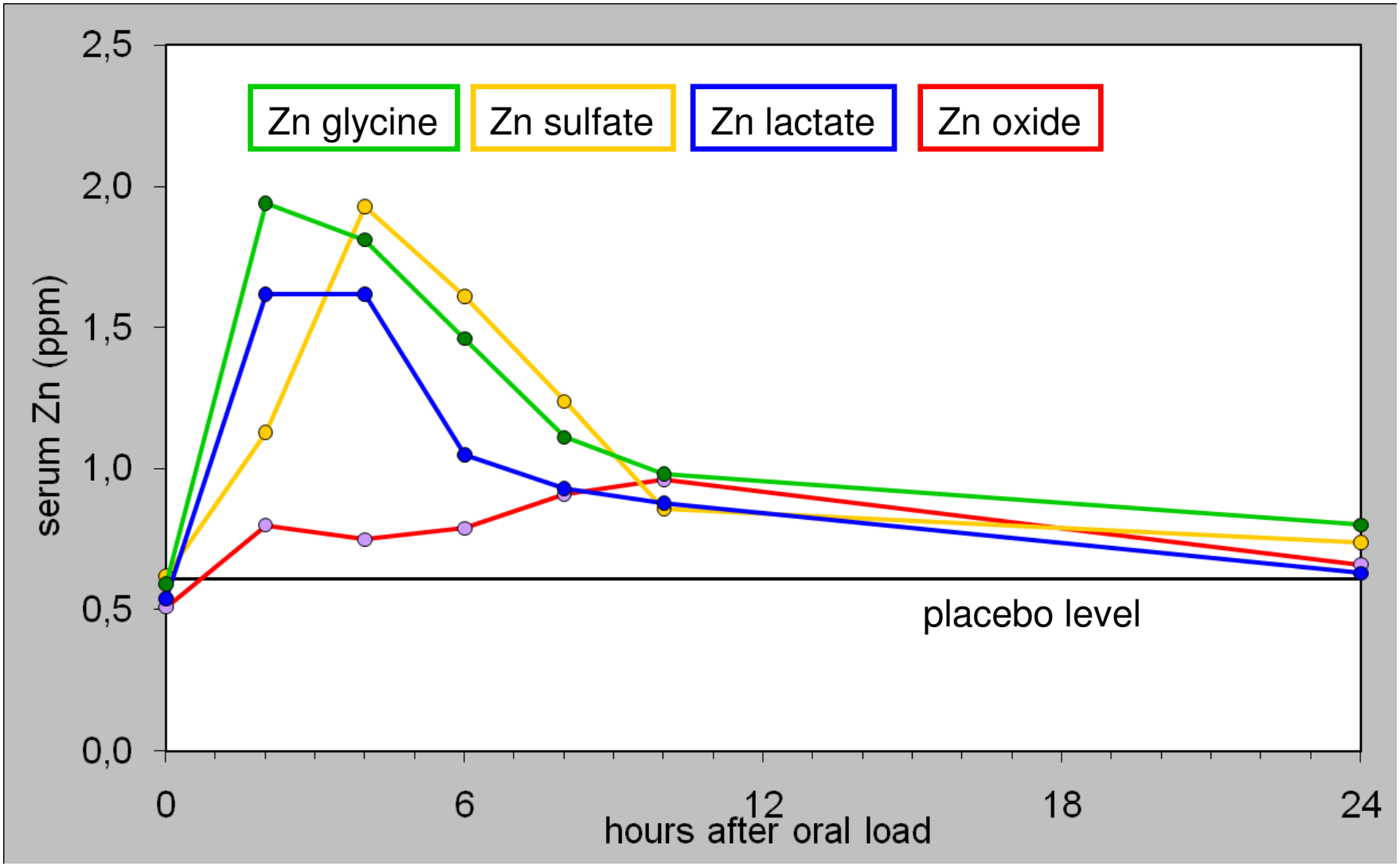
Bioavailability = *capability* of metabolic use at the absence of homeostatic regulation

Physiological conditions of metabolism, sensitive response parameter

Metabolic use of dietary trace minerals in relation to homeostatic counter-regulation



Short term oral excess demonstrates ability to overwhelm homeostatic counter-regulation (AUC-method)



(Single oral Zn load in horses: Wichert et al. 2001)

Bioavailability of essential trace minerals: restrictions resulting from general definition

In vitro studies cannot fully cover bioavailability

bio – availability

metabolic (re)actions

dietary properties

Interactions with other dietary components

…the maximum possible yield of a nutrient that the body may extract from the ingested food and use for its metabolic functions…

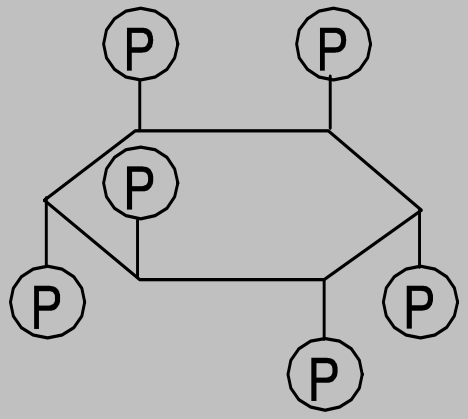
(Kirchgessner et al. 1993)

Bioavailability = *capability* of metabolic use at the absence of homeostatic regulation

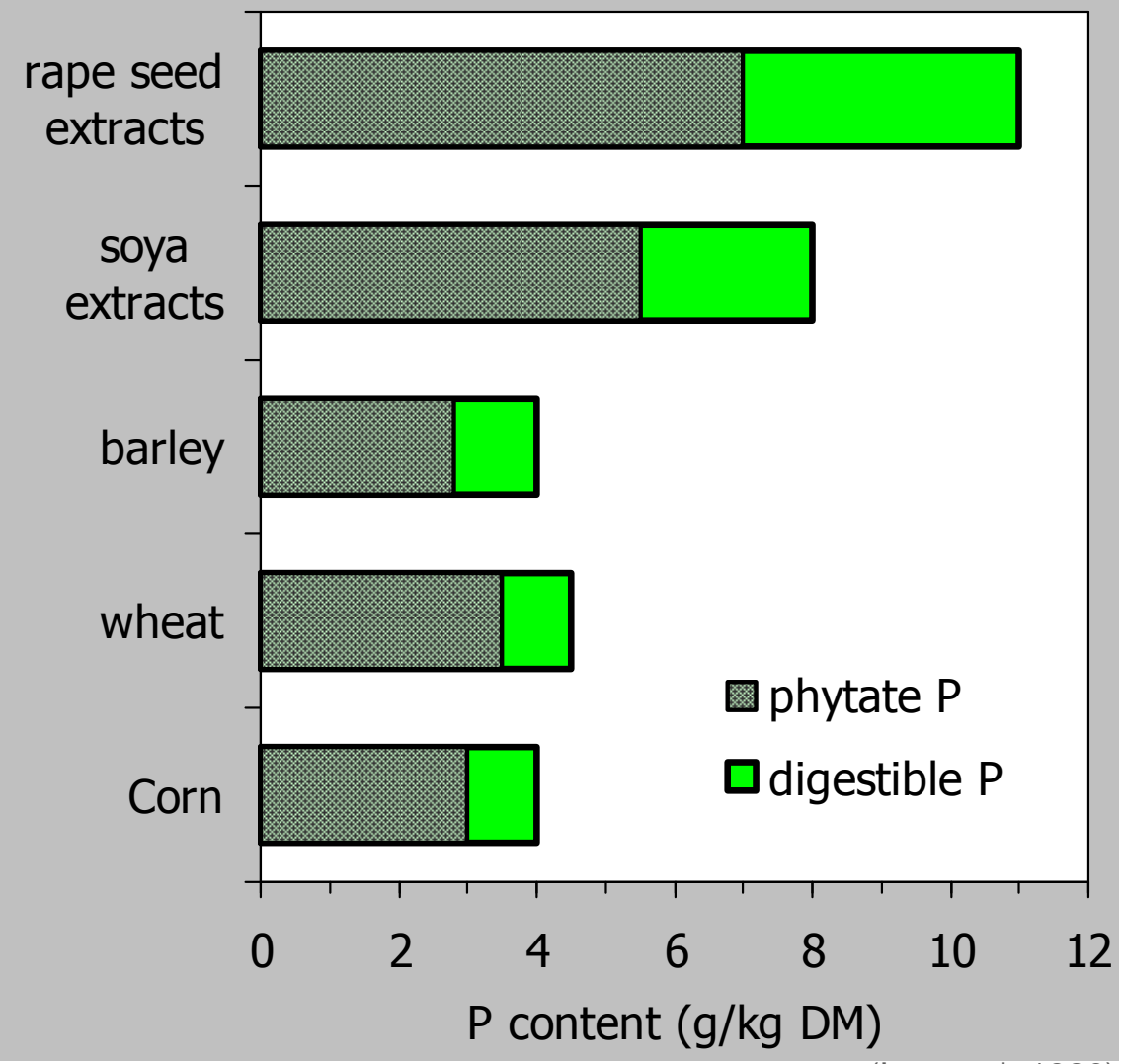
Physiological conditions of metabolism, sensitive response parameter

Phytic acid is a strong chelator to trace minerals

Phytic acid (phytate)

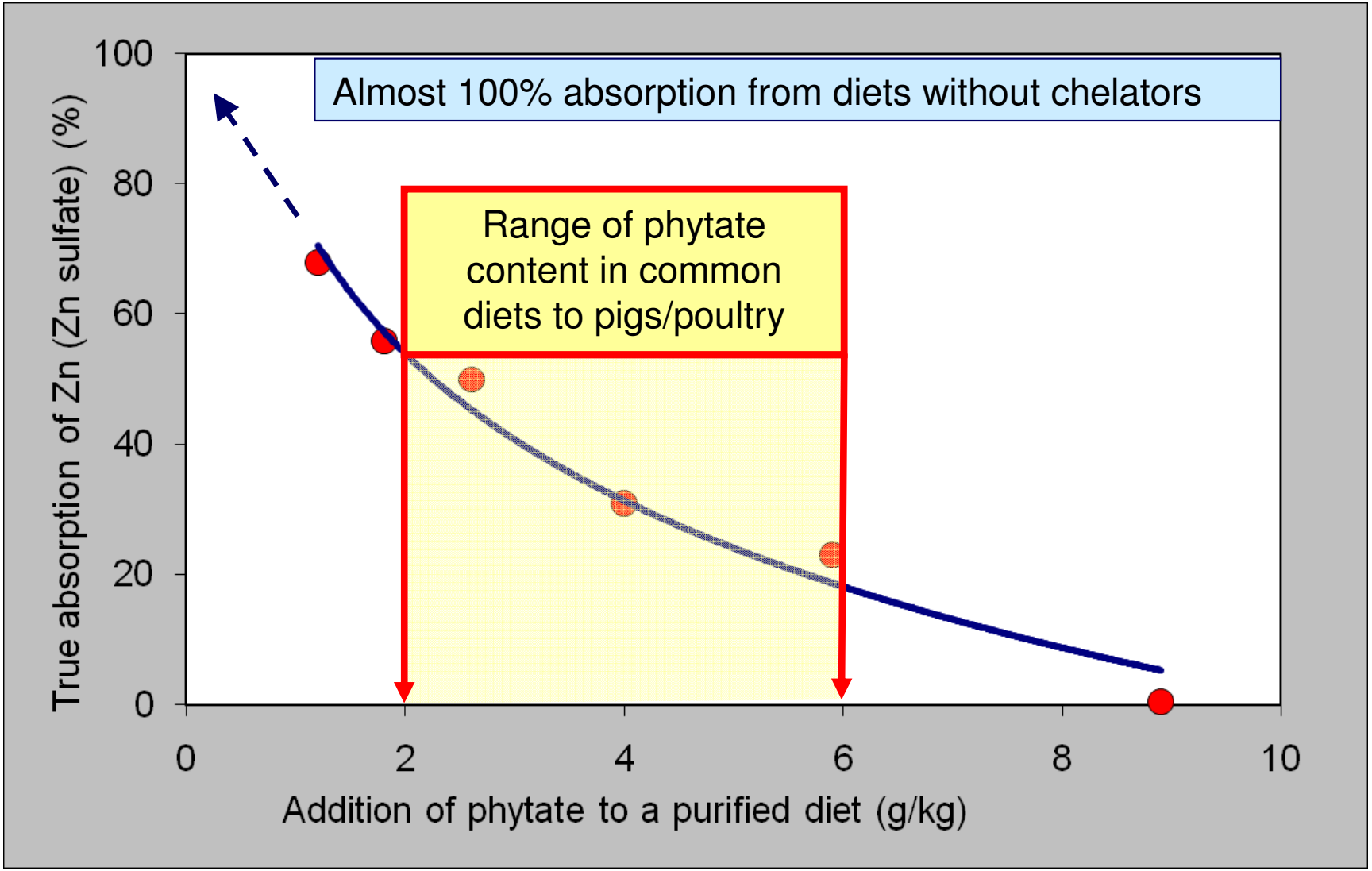


Inositol 1,2,3,4,5,6-Hexakis-dihydrogenphosphat



(Lantzsch 1990)

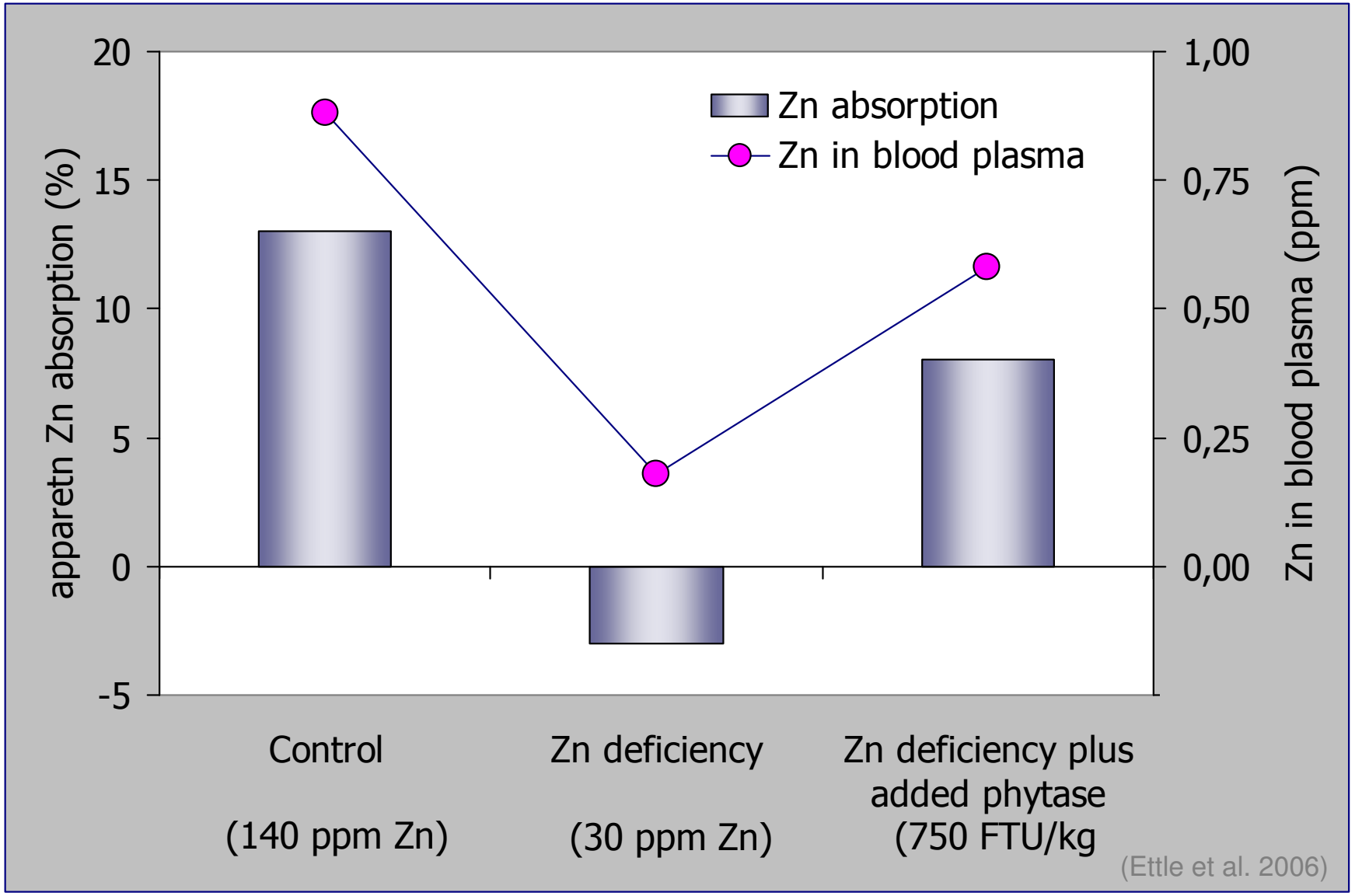
Dietary phytate may massively reduce maximum possible Zn absorption measured at Zn deficiency



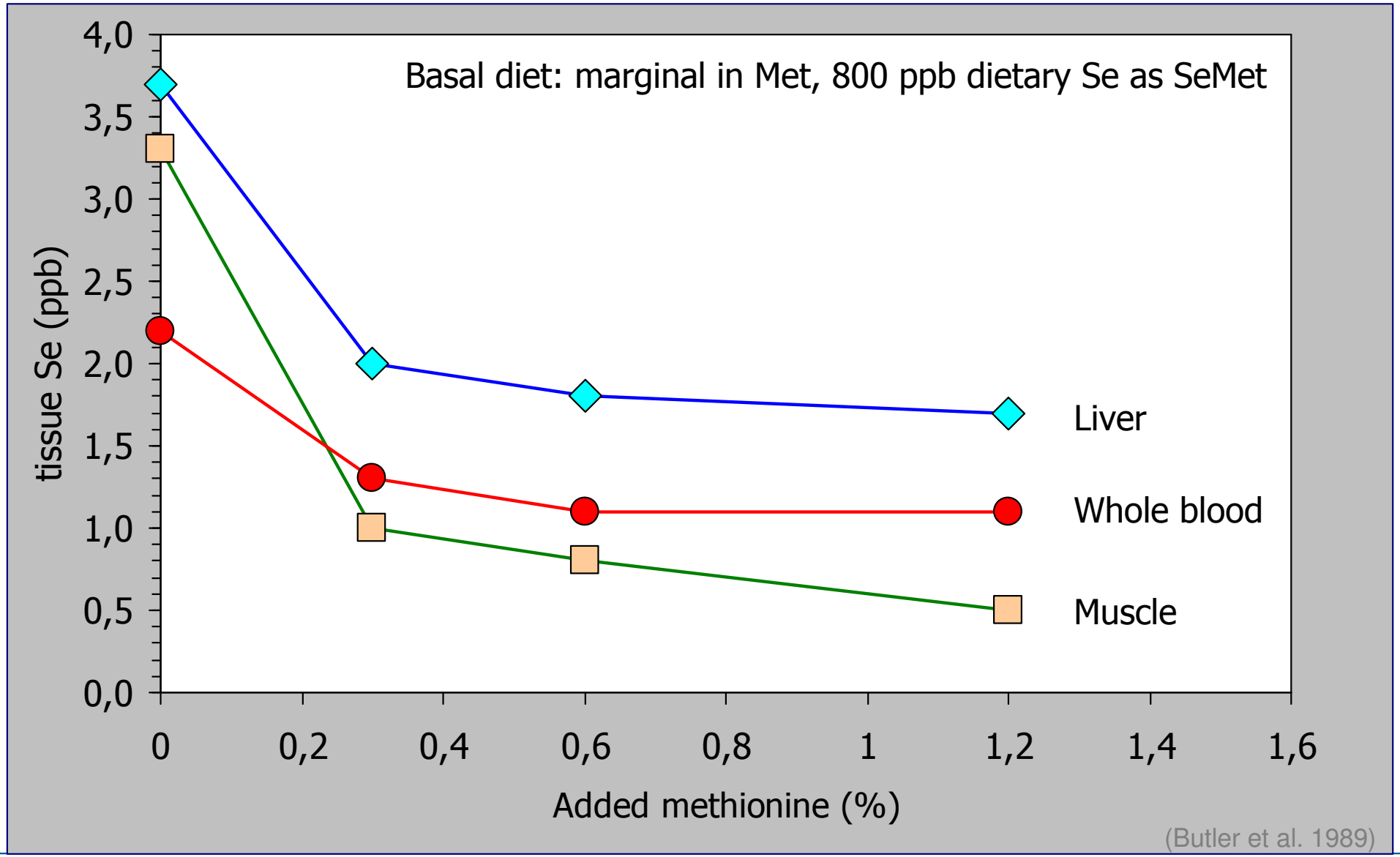
(Windisch and Kirchgessner 1999)

Added phytase may significantly improve Zn bioavailability

(e.g. from inorganic sources, Zn sulfate)



Se retention from organic Se depends on supply status with methionine (growing rat model)



(Butler et al. 1989)

Assessing bioavailability of essential trace minerals in animal nutrition

In vitro methods do not fully cover bioavailability (BA).

BA = *capability* of metabolic trace mineral use
It is not fully realized at normal feeding conditions

Assessment of BA at deficient trace mineral supply
(no interference with homeostasis).

BA cannot be assessed independent from dietary composition.

→ Example to Zinc

Example: Quantifying Zn bioavailability with a radiotracer study

Bioavailability = **true absorption of dietary Zn**

= influx of Zn from diet into the inside of the organism

x **metabolic utilization of absorbed dietary Zn**

…for tissue retention, endogenous faecal and renal excretion, surface losses, …

measured in a radiotracer study
at Zn deficiency
using a purified diet added with Na_{12}phytate (8g/kg)

(Schlegel and Windisch 2006)

Example: Quantifying Zn bioavailability in a radiotracer study

(Schlegel and Windisch 2006)

Treatment group: Added dietary Zn Zn status	positive control sulfate (52µg/g) sufficient Zn	negative control sulfate (12µg/g) deficient Zn	Test group Zn glycinate, (12µg/g) deficient Zn
Blood plasma Zn (µg/ml)	1.35 a	0.71 b	0.76 b
<u>Zn flux (µg/day)</u>			
intake	516	108	109
truly absorbed from diet	159 a	48 b	56 b
endogenous faecal excretion	48 a	18 b	18 b
urine	4 a	3 b	2 b
retention	107 a	27 b	35 b
Max. absorption (%)		44.2 b	50.8 a
Metabolic utilization (%)		94.7	95.7
Bioavailabiltiy (%)		41.8 b	48.6 a

Experimental model to assess Zn bioavailability in practical pig feeding

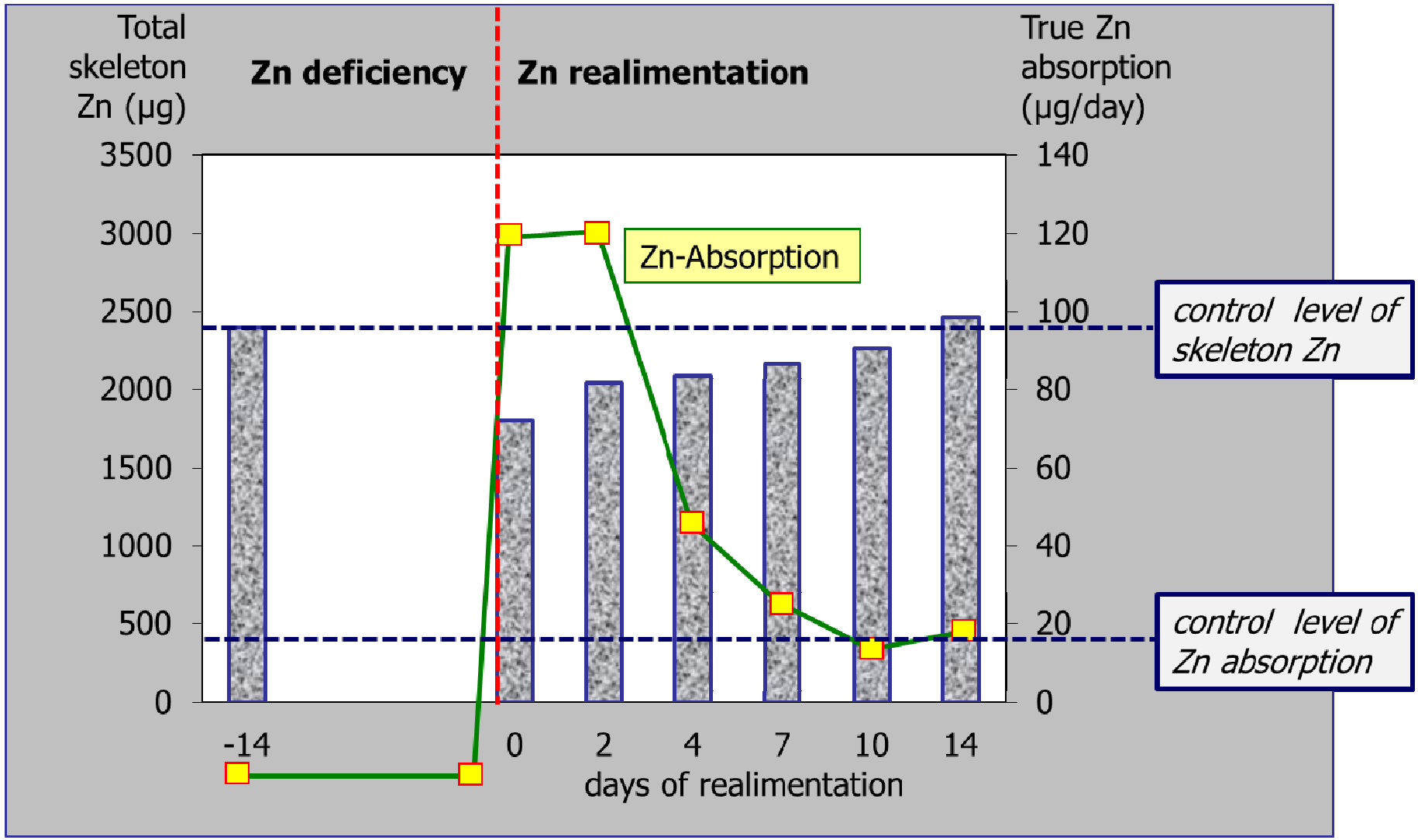
Diet?

"Worst case" diet (corn & soyban extracts): rich in phytate, low in native Zn, no phytase activity (pelleted with steam). Graded levels of added Zn (sulfate) from deficient to sufficient supply

Zn supply before the onset of study: depletion or adequate?

(Brugger et al. 2012)

Mobilization and refilling of mobilized bone Zn is highly regulated by homeostasis (rat model)



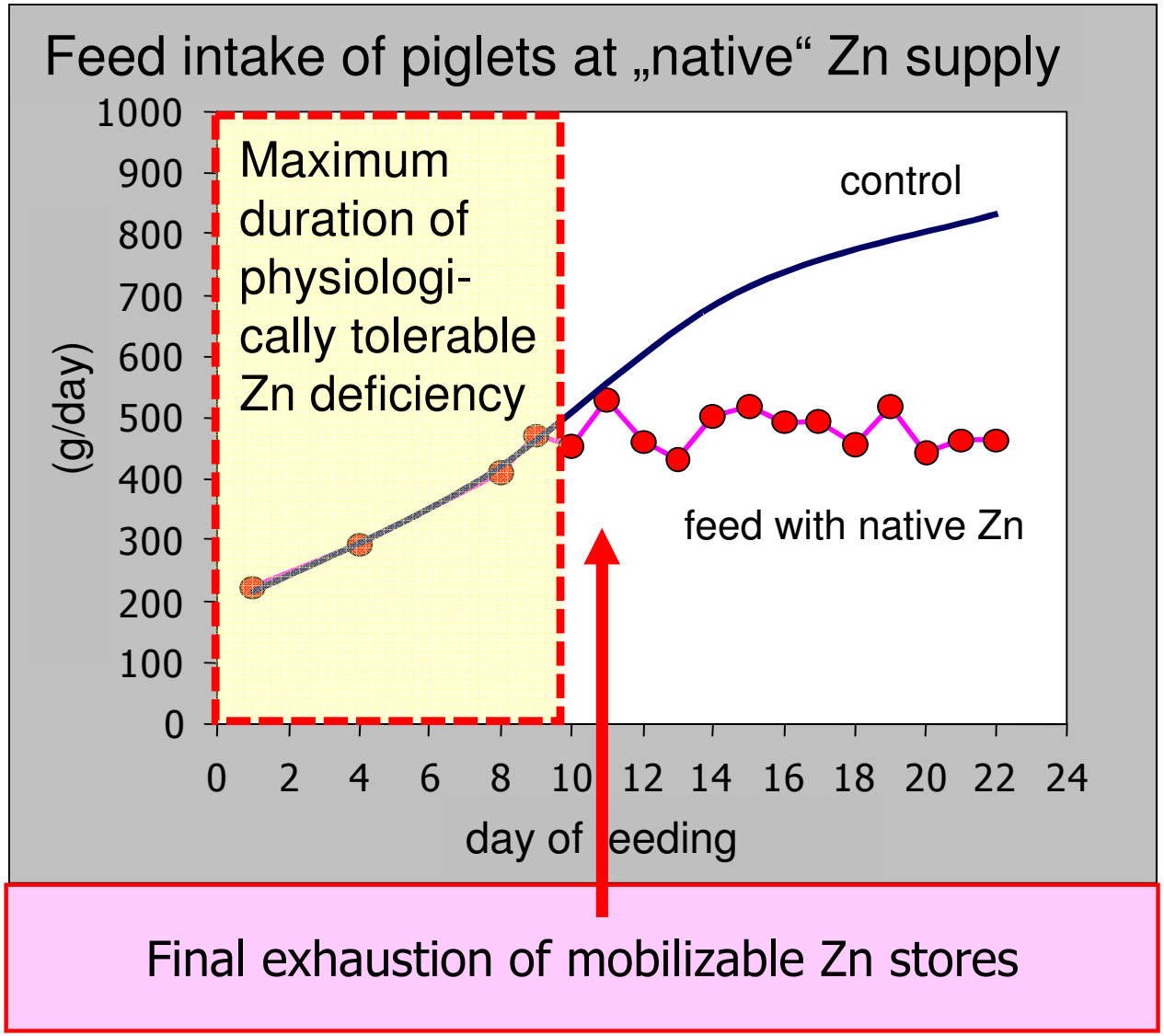
(Windisch 2001)

Experimental model to assess Zn bioavailability in practical pig feeding

Diet?	"Worst case" diet (corn & soybean extracts): rich in phytate, low in native Zn, no phytase activity (pelleted with steam). Graded levels of added Zn (sulfate) from deficient to sufficient supply
Zn supply before the onset of study: depletion or adequate?	Adequate Zn supply before the onset of study
Duration of Zn deficiency? (no Zn deficiency symptoms)	

(Brugger et al. 2012)

Symptoms of Zn deficiency in piglets fed a soya-corn-based diet without Zn supplementation



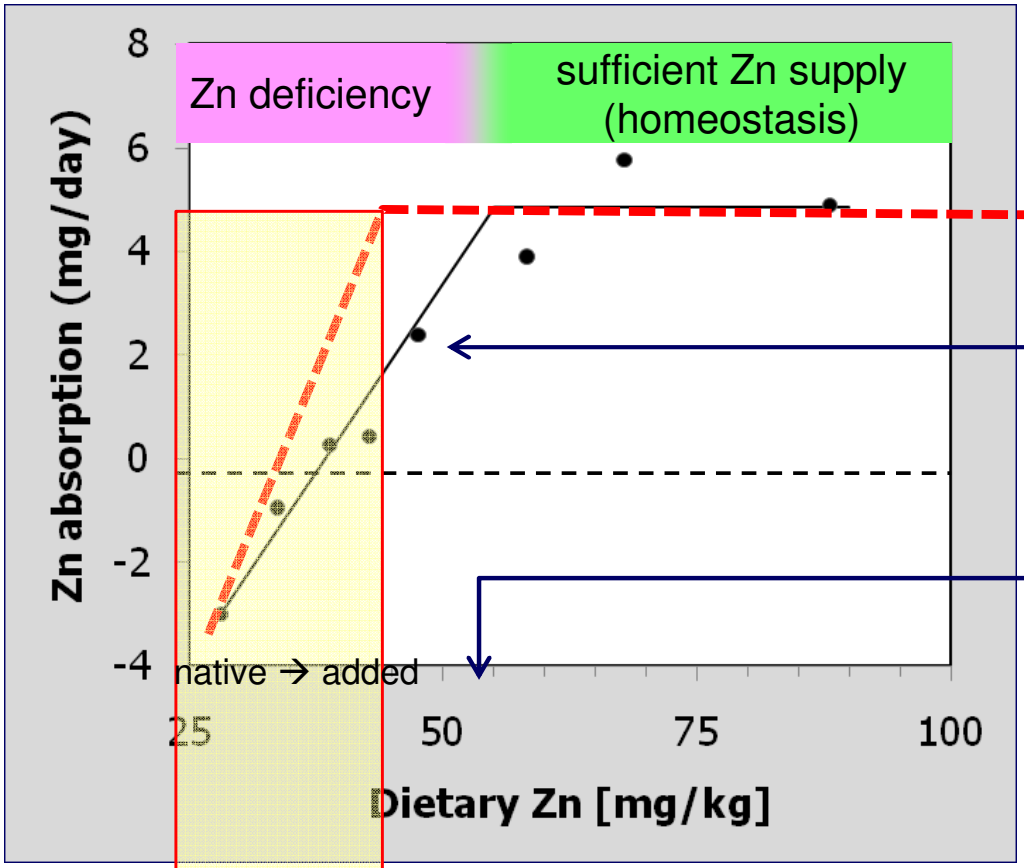
(Windisch et al. 2003)

Experimental model to assess Zn bioavailability in practical pig feeding

Diet?	"Worst case" diet (corn & soybean extracts): rich in phytate, low in native Zn, no phytase activity (pelleted with steam). Graded levels of added Zn (sulfate) from deficient to sufficient supply
Zn supply before the onset of study: depletion or adequate?	Adequate Zn supply before the onset of study
Duration of Zn deficiency? (no Zn deficiency symptoms)	Maximum 8 days
Response parameter?	• Apparently absorbed dietary Zn (mg/day) • Blood plasma: total Zn, AP activity • Bone Zn • mRNA of metallothioneine in intestinal tissues

(Brugger et al. 2012)

Reaction of apparently absorbed dietary Zn indicates absence/presence of homeostatic counter-regulation



theoretical max. slope of 1.0 (100% BA)

measured slope = 0.23

break point at 59mg/kg

Relevant range of dietary Zn to compare Zn sources of unknown bioavailability.

(Brugger et al. 2012)

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In vitro methods do not fully cover bioavailability (BA).

BA = *capability* of metabolic trace mineral use.
It is not fully realized at normal feeding conditions.

Assessment of BA at deficient trace mineral supply (no interference with homeostasis) and absence of deficiency disorders

BA cannot be assessed independent from dietary composition.

Comparison of dietary trace mineral sources for BA should be done on base of a well defined standard “worst case” diet.