The relationship between nutrition and immunity – determining the nutritional cost

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Kemin Industries, Inc.

PTP-13508

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Agenda

- Growth, nutrition, and immunity
- What is the nutritional cost of immunity
- How to mitigate the nutritional cost of immunity

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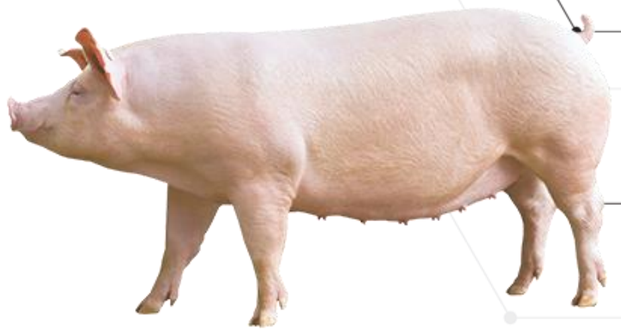
About Me – Nutrition and Immunology

C57BL/6J



Then

Now

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Define Immunity

- The role of the immune system is to protect our body from all foreign organisms that might cause any damage or homeostasis imbalance
- How does it do that?
    - The immune system is made up of a network of **cells**, **tissues,** and **proteins** that work together to protect the body
        - Non self vs. self
        - Gut health – immune tolerance
- Recognition, Response, Resolution

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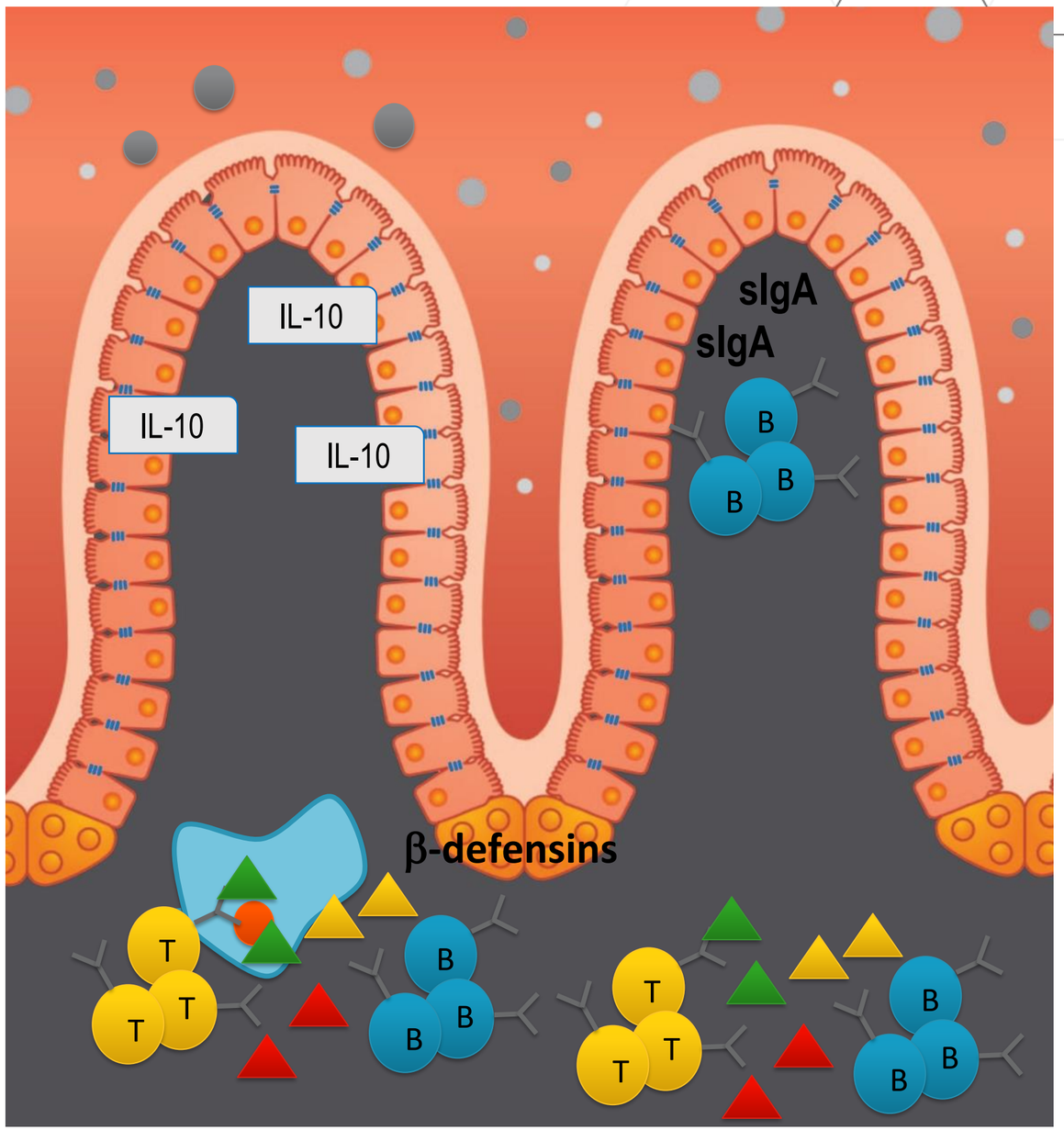
Factors Involved in Gut Health: Intestinal Immunity

- Help maintain the division between the host and microbiota
- Respond to microbial incidences in a controlled manner
- Clear infection with a limited degree of inflammation (including systemic)



Hooper, L., et al. Nat Rev Immunol, vol 10: 159. 2010.

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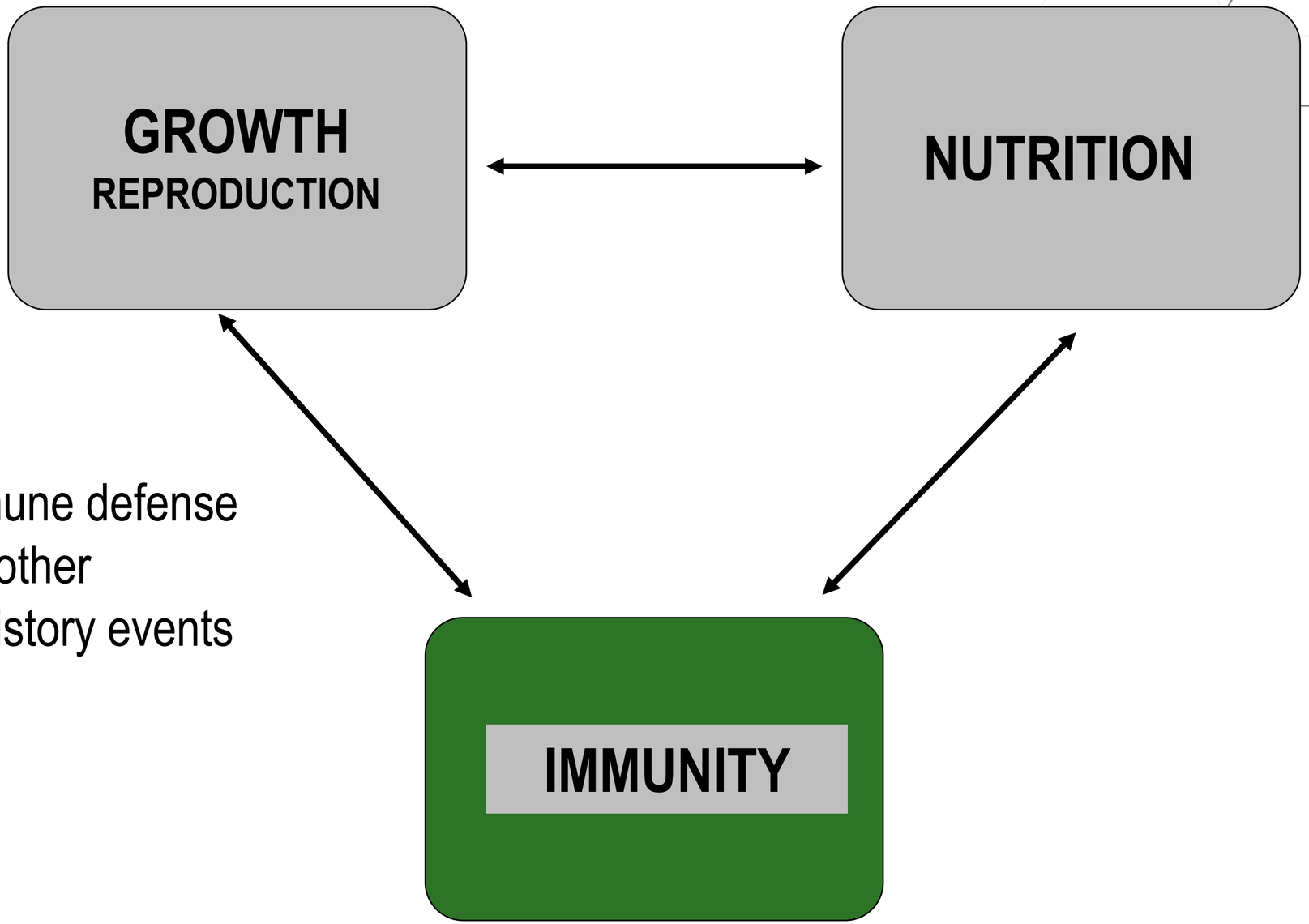

Demands of immune defense can conflict with other demanding life history events

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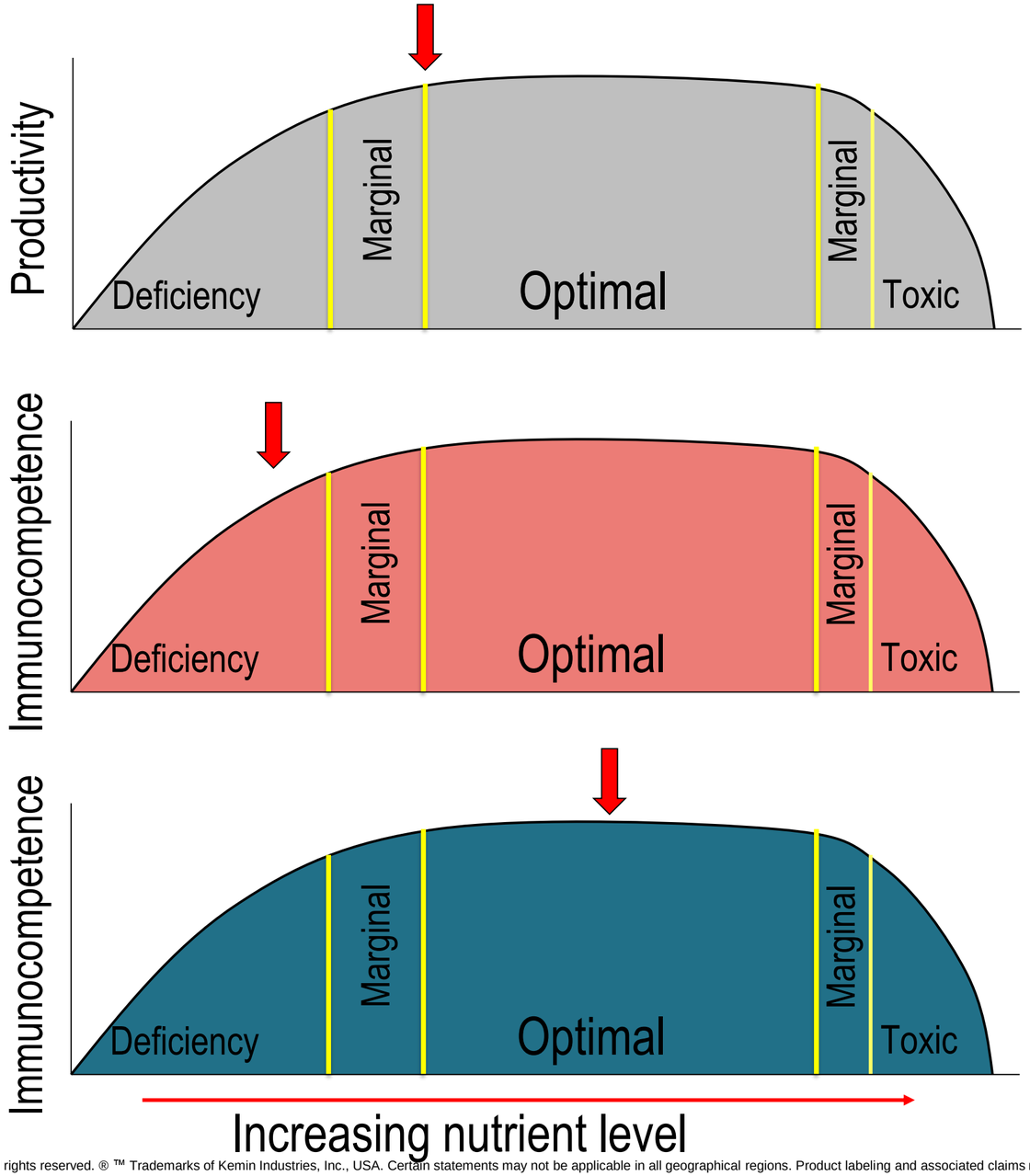
Impact of Nutrients on Immune Effector Functions



Vitamin E, plasma, oats

Image provided by K.C. Klasing

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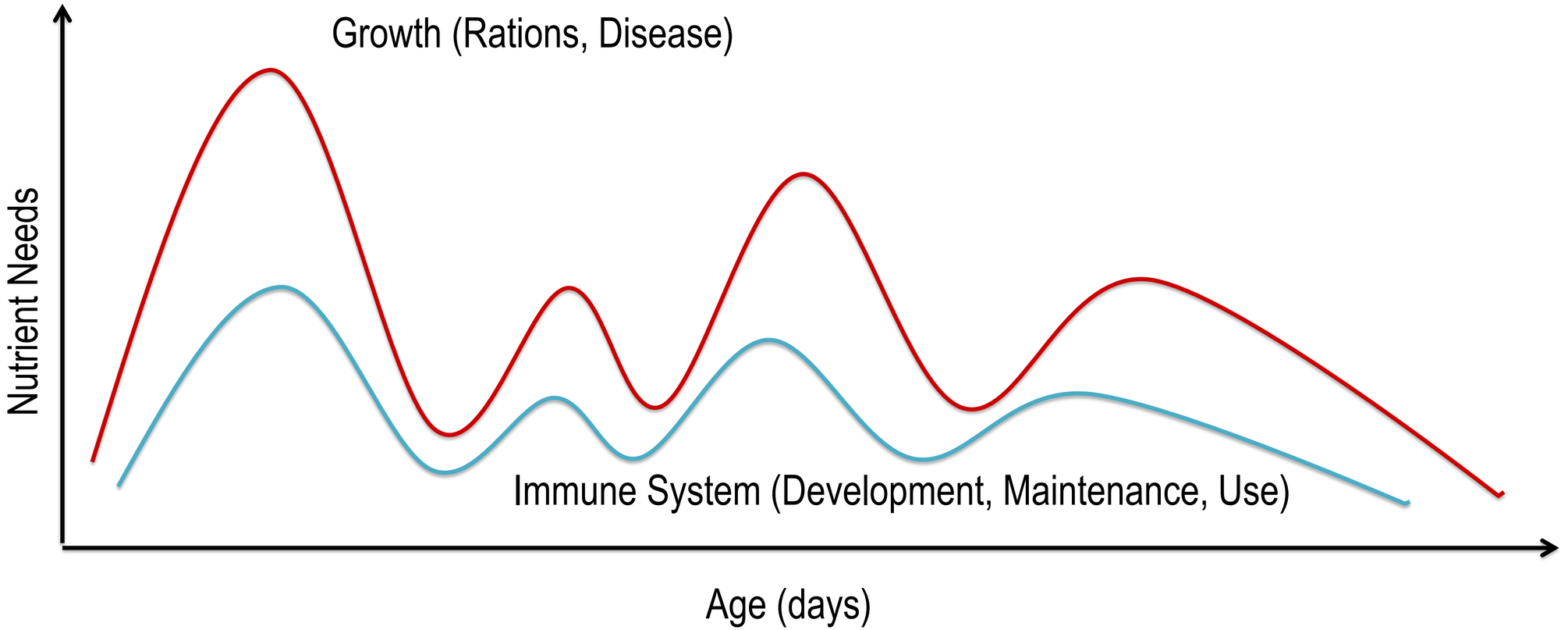
Nutrient Needs – Right Amounts and Right Time



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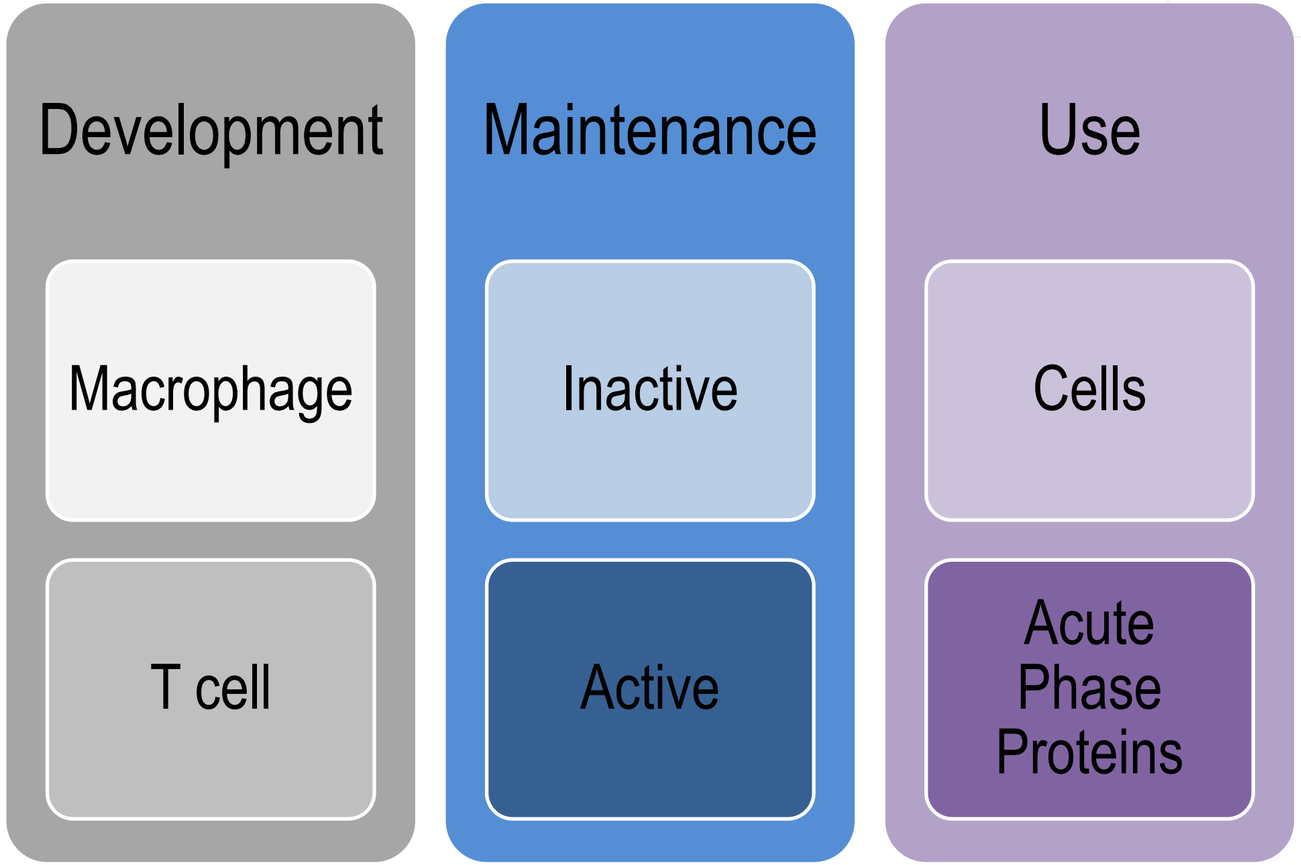

So…. what are the right amounts?

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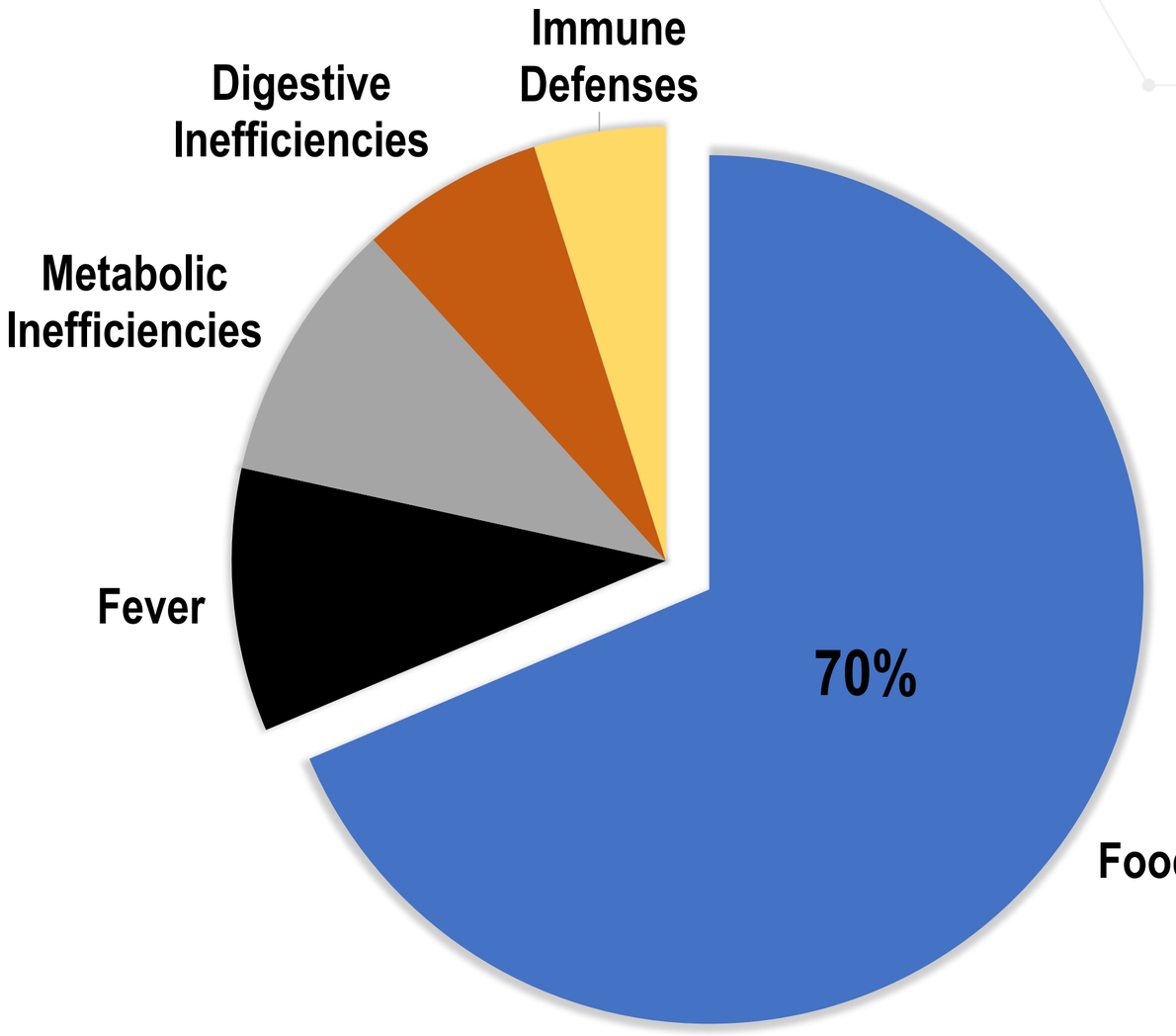
Nutritional Costs of an Immune Response



Jiang et. al. (2010),
Klasing et. al. (1987)
Marais M., 2011
Reeds P.J. (1994),
Sirimongkolkasem P.(2007)

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Daily Use of Lysine in *Salmonella*-Challenged Chicks

Process	Healthy		Challenged	
	Production (mg/kg)	Cost (µmol lys/kg)	Production (mg/kg)	Cost (µmol lys/kg)
Leukopoiesis	650	45.5	1300	90.9
Ig synthesis	114	65.6	121	69.6
Acute-phase proteins	0.5	18.0	710	386
Total for immunity	764	129.1	2131	546.5
Body weight gain	85,000	5950	72,446	5212
% of retained used for immunity		2.16		10.5

Klasing & Calvert, 1999

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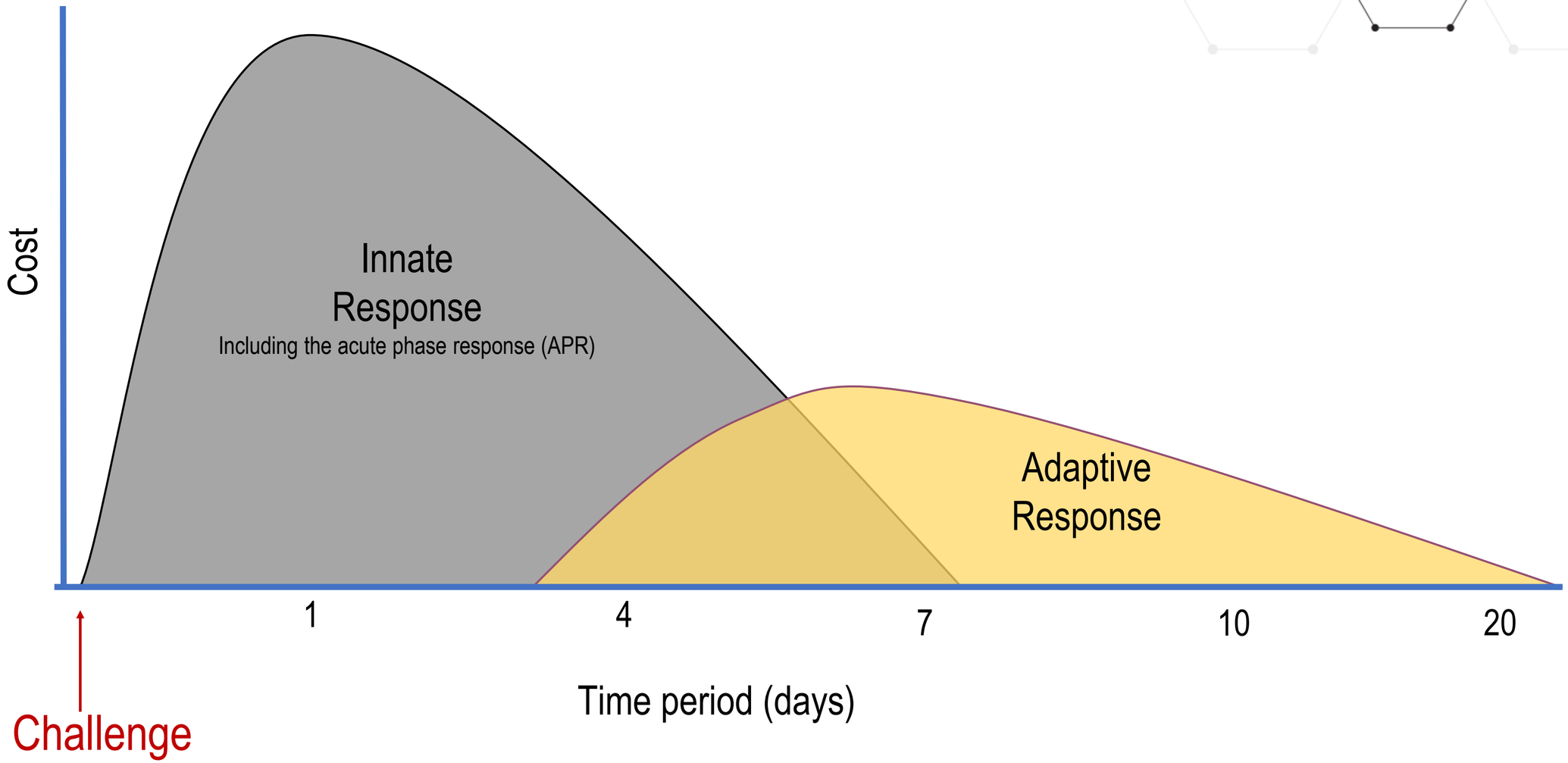
Kinetics of an Immune Response – Defining the Cost



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Monitoring the Systemic Immune System

Tissues	Leukocytes	Secreted Molecules
• Bursa • Thymus • Liver • Spleen • Bone Marrow	• CD4 • CD8 • Bu-1 (IgM, IgG) • Monocytes/ macrophages • Heterophils • Thrombocytes	• Total (IgY, IgA, IgM) • Specific (IgY, IgM) • Acute phase proteins • Complement

Support Organs

Whole Body Muscle (pectoralis and semitendinosus)

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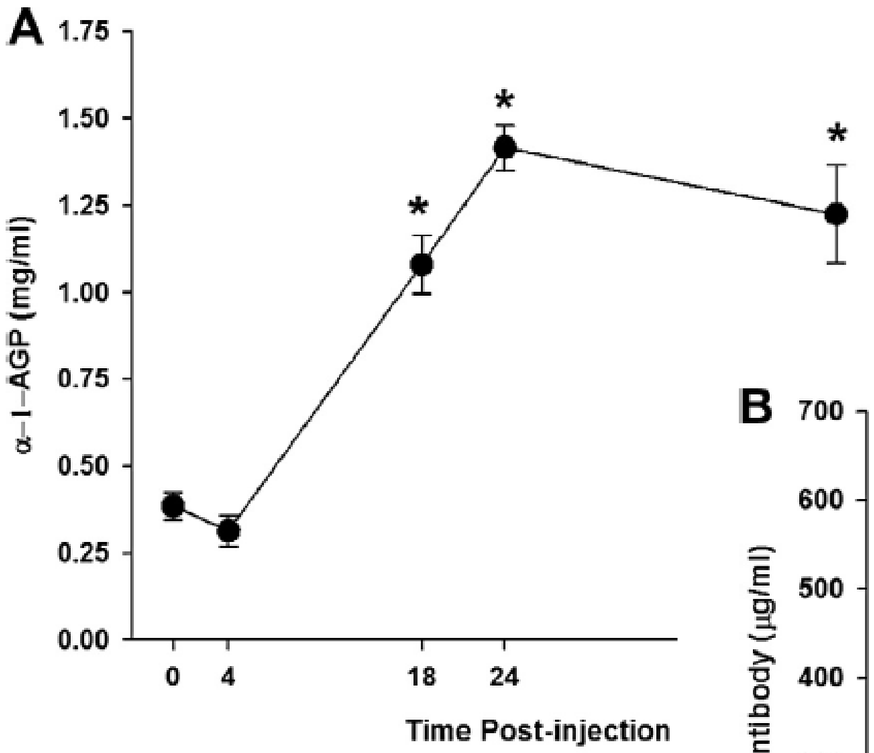
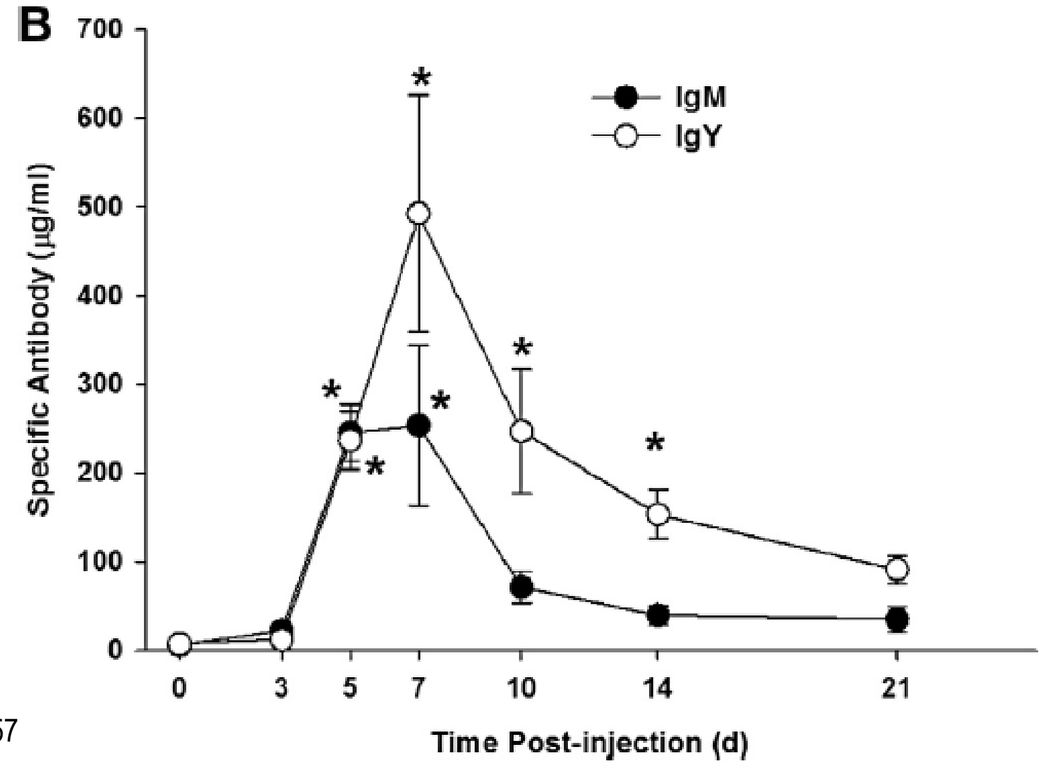
α-1-AGP and Specific IgY and IgM Increase in Response to *E. coli*





Iseri, V. and Klasing, K.. Developmental and Comparative Immunology 40 (2013) 248–257

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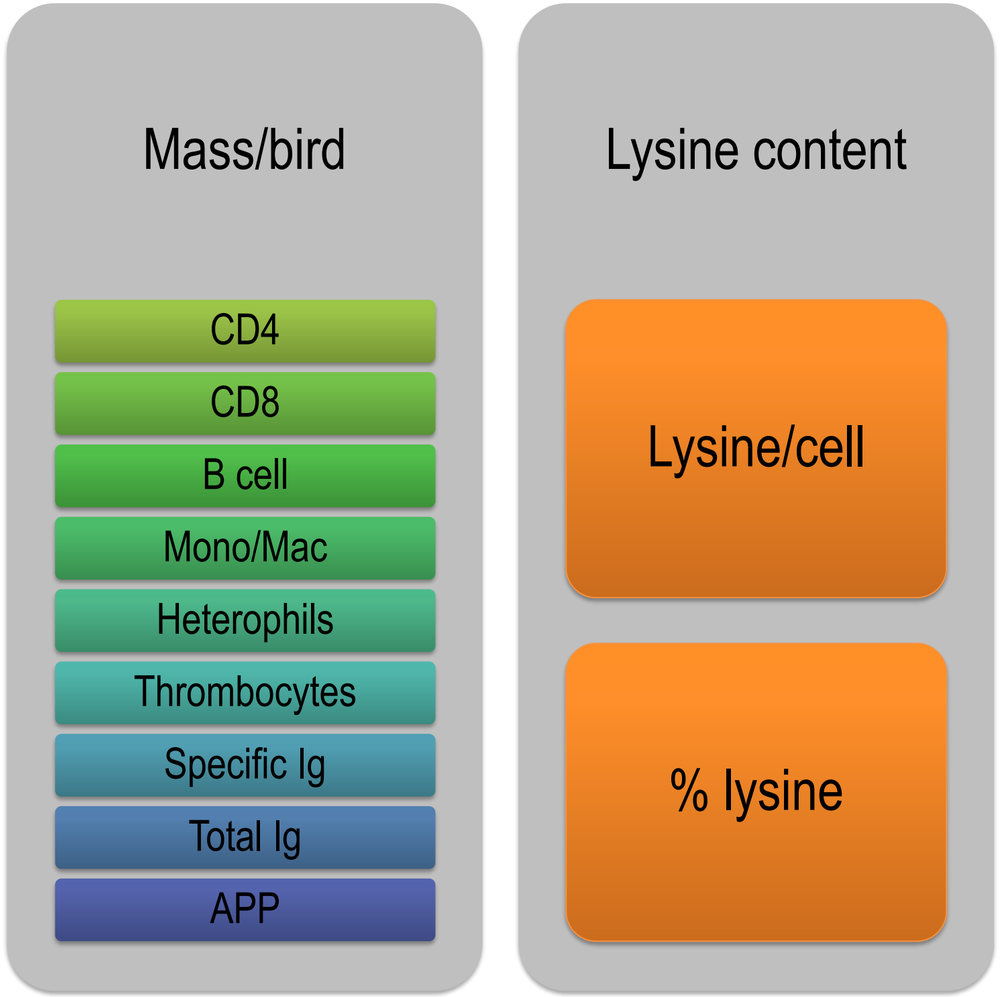
Lysine as Metric for Nutrient Content



CD4 cells/bird * mg lysine/CD4 = Total amount of lysine in CD4/bird

α-1-acid glycoprotein mg/bird * % lysine= Total amount of lysine in α -1-acid glycoprotein /bird

Iseri, V. and Klasing, K.. Developmental and Comparative Immunology 40 (2013) 248–257

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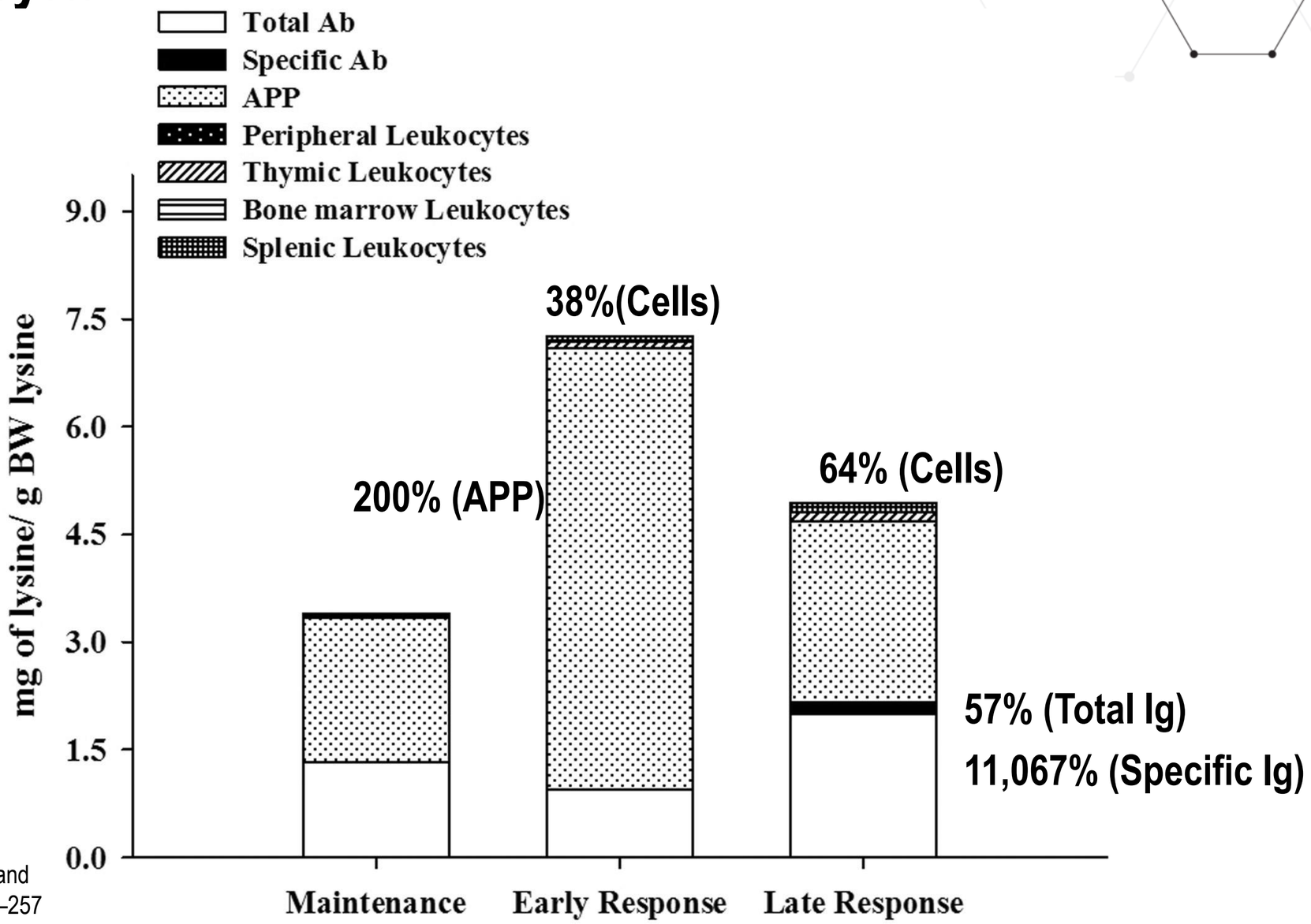
Lysine Content of Cellular and Effector Protein Components of the Systemic Immune System



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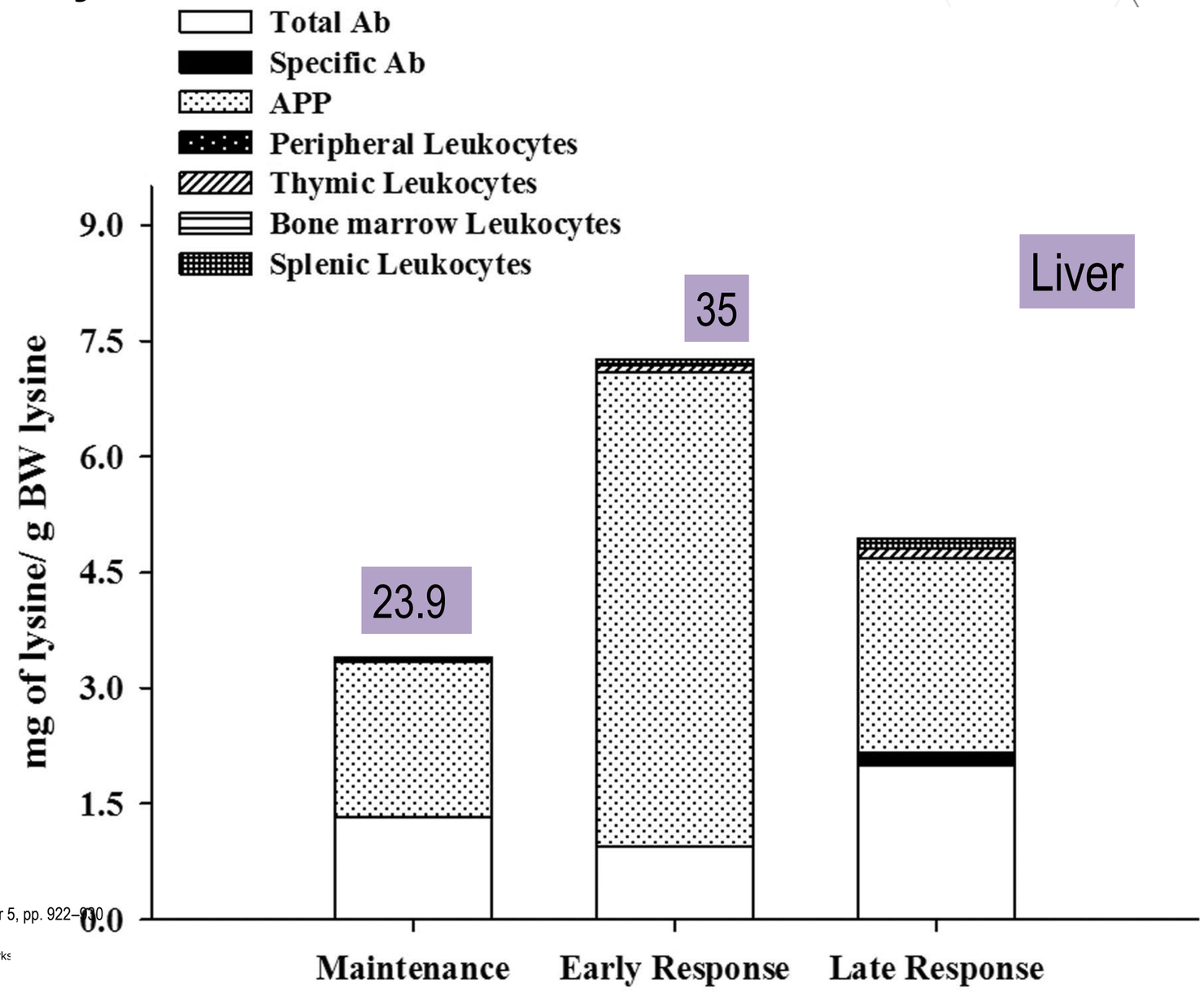

Iseri V., Klasing K..Integrative and Comparative Biology, volume 54, number 5, pp. 922–930

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Defining the Cost – Acute Phase Response

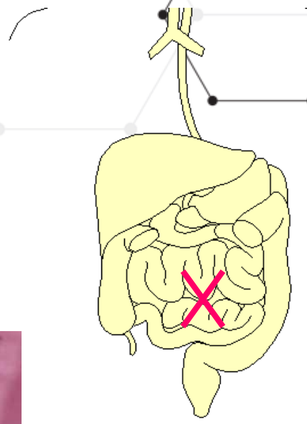
Pro-inflammatory cytokines

TNFα

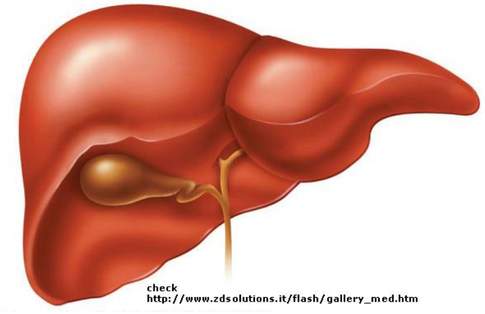
IL-1

IL-6

Digestive Inefficiencies



Fever



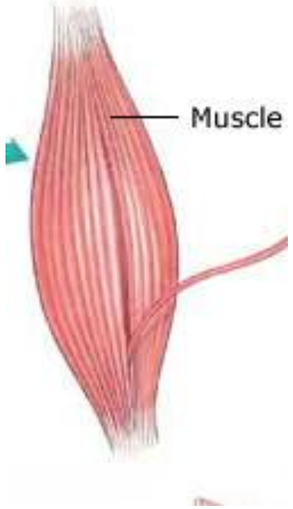
Acute Phase Proteins

Reduced Food Intake

Protein Metabolism

Synthesis

Degradation



Kushner, 1982

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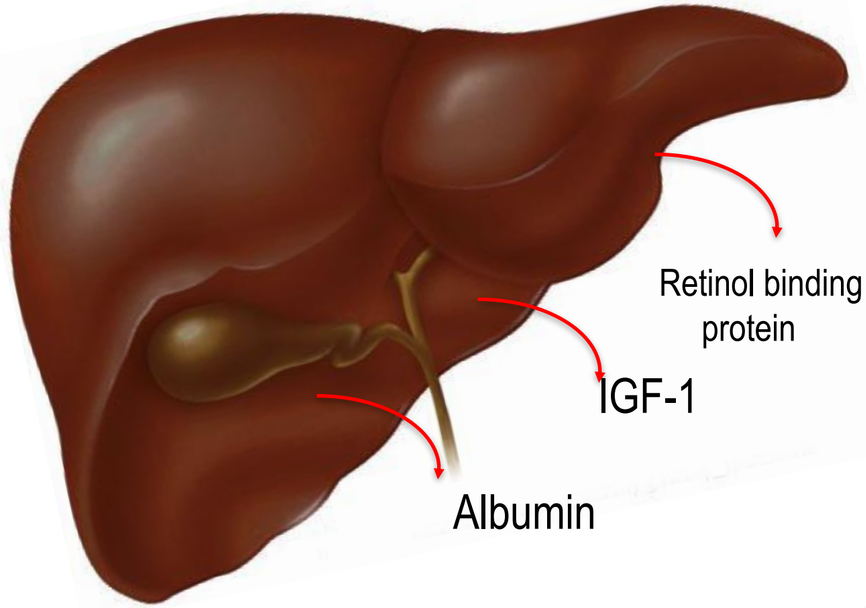
Healthy



Retinol binding protein

IGF-1

Albumin

Challenged

- Repartitioning
- Oxidation

Glutathione

Hepcidin

Complement

Transferrin

α 2 Macroglobulin

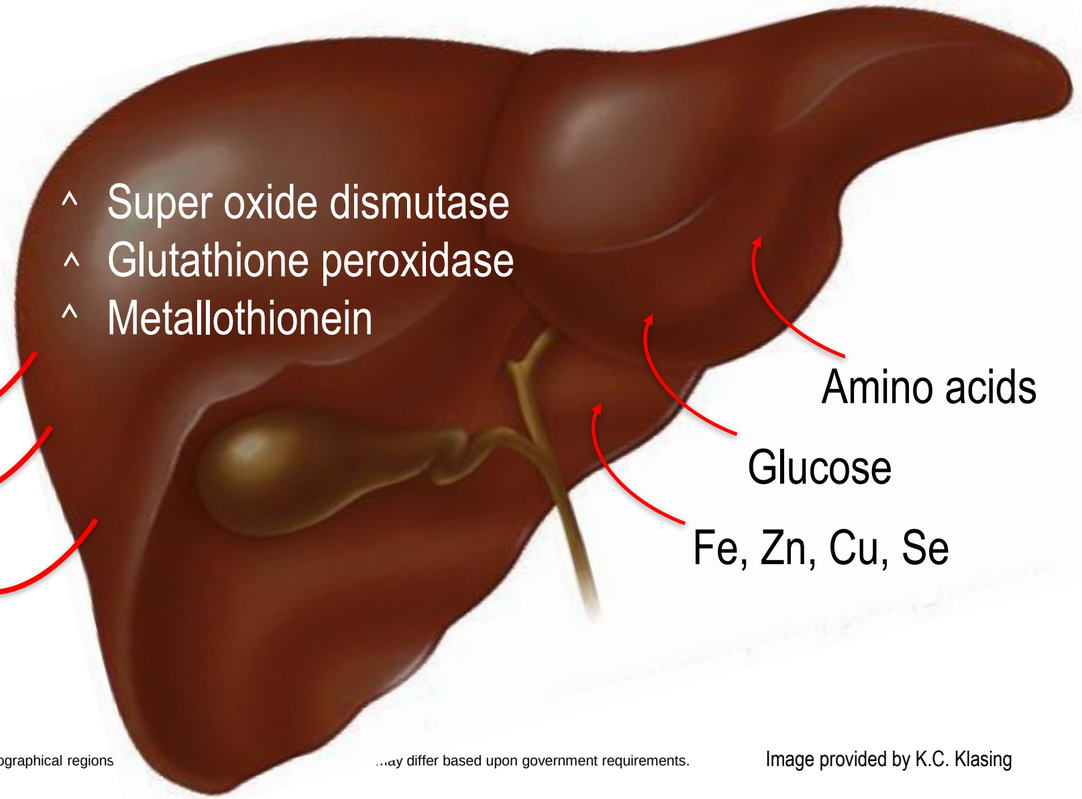
α-1-acid glycoprotein

Ceruloplasmin

Mannan-binding protein

C-reactive protein

Hemopexin, haptoglobin



^ Super oxide dismutase
^ Glutathione peroxidase
^ Metallothionein

Amino acids

Glucose

Fe, Zn, Cu, Se

Image provided by K.C. Klasing

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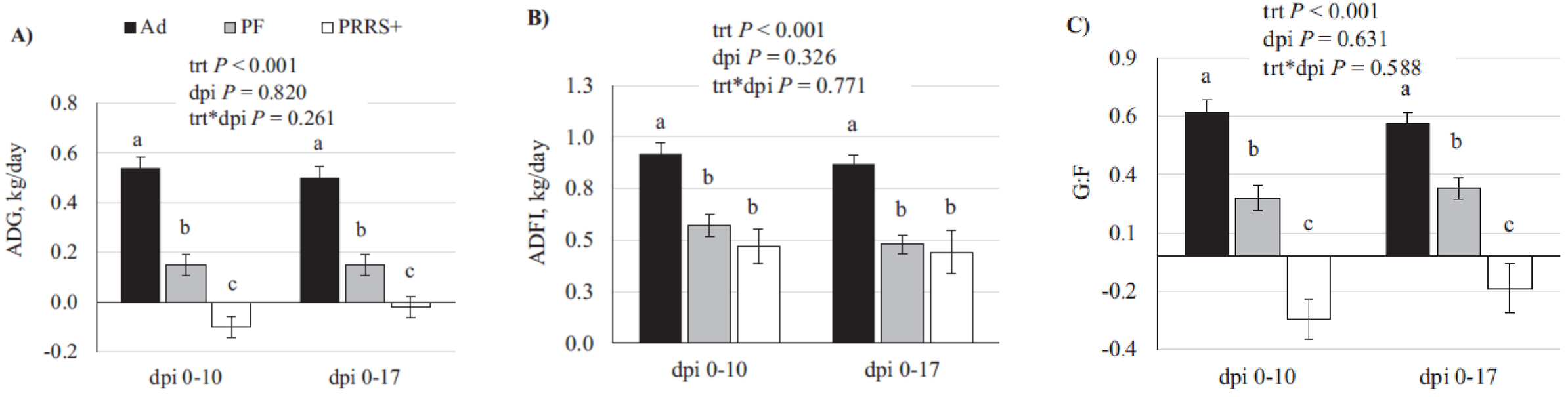
Indirect and direct effects of PRRS virus challenge on liver and skeletal muscle metabolism



RFLP_1-3–4 isolate of PRRS virus (1-mL intramuscular injection and 1-mL intranasal inoculation; 10_6 genomic copies per mL)

Figure 1. Pig performance. (A) Average daily gain (ADG), (B) average daily feed intake (ADFI), and (C) feed efficiency (G:F) in pigs challenged with porcine respiratory and reproductive syndrome virus (PRRS+), naïve and fed ad libitum (Ad), or naïve and pair-fed to PRRS+ pigs intake (PF) selected for necropsy at either days postinoculation (dpi) 10 or dpi 17. Differing letters a,b, and c represent $P < 0.05$. $n = 8$ pigs per treatment per dpi.

J. Anim. Sci. 2019.97:3213–3227

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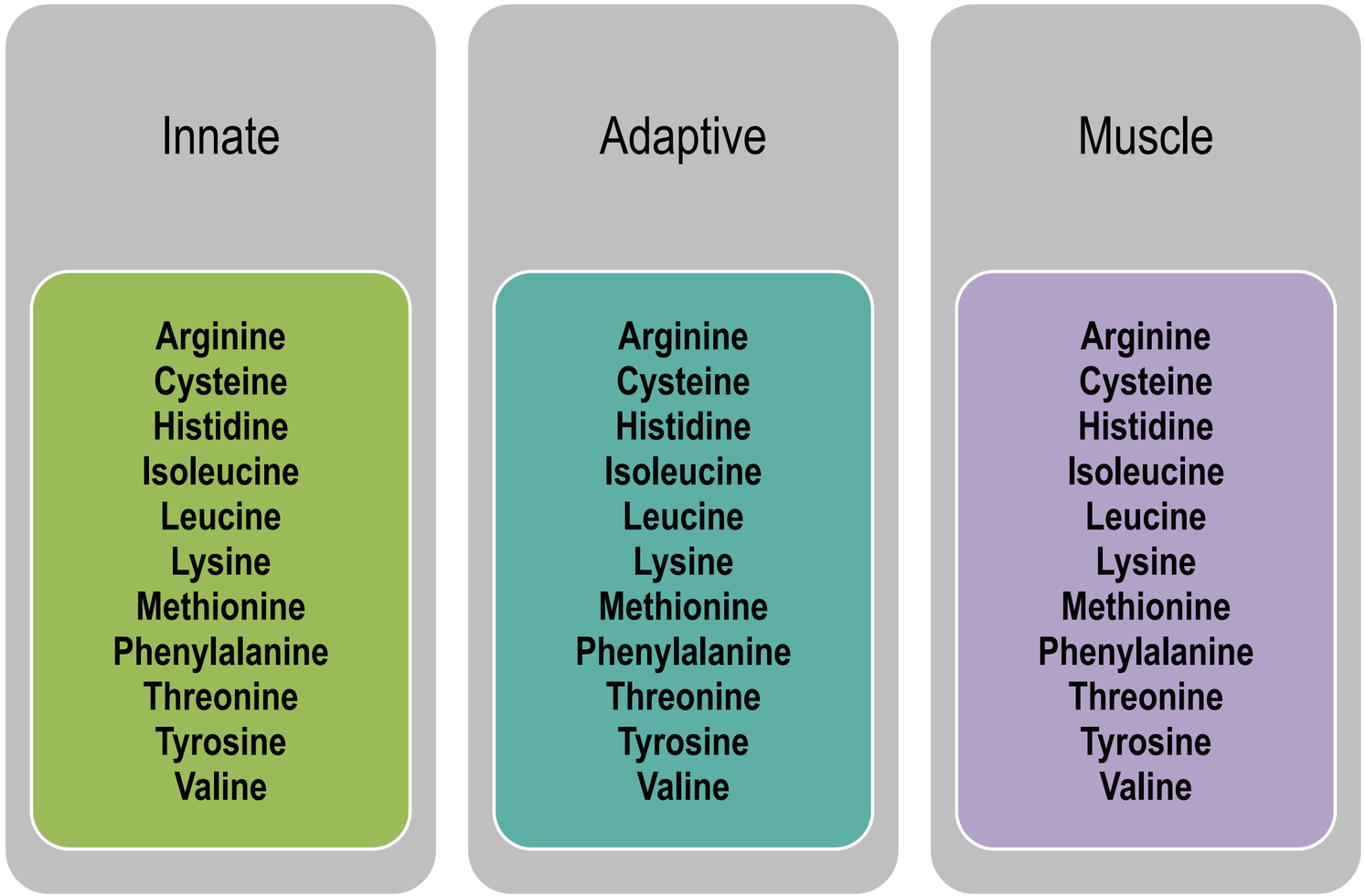
AA Ratio Between Immune System to Muscle



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AA Ratio Between Immune System to Muscle

Amino acid	g amino acid/kg protein		
	Haptoglobin	Alpha1- acid glycoprotein	SMP[1,2]
Arginine	28	52	69
Cysteine	24	18	13
Glycine	44	19	48
Histidine	38	17	51
Isoleucine	47	48	48
Leucine	82	101	81
Lysine	75	92	98
Methionine	16	11	25
Phenylalanine	30	64	40
Proline	44	34	48
Serine	40	31	41
Threonine	54	74	47
Valine	84	46	54

[1]Acute-phase proteins calculated from the amino acid sequences summarized by Barker (1984 and 1987|. References to the original analyses can be found within these papers.
[2]Mean values of bovine, porcine and ovine muscle taken from Anderson et al. (1986).

Adapted from Reed 1994. J. Nutr. 124: 906-910

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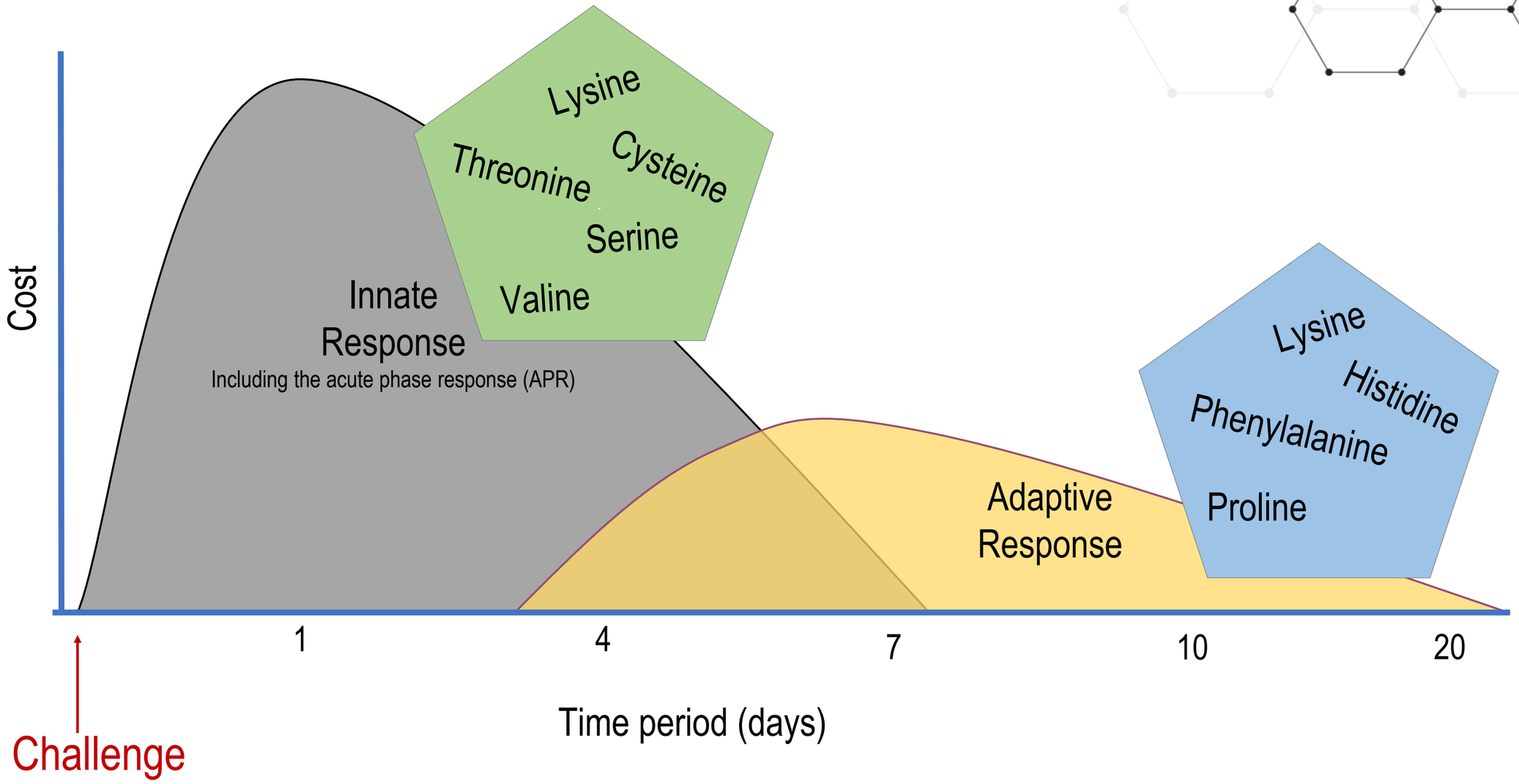
Kinetics of an Immune Response – Defining the Cost



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What about BRD?

- BRD is a multifactorial syndrome
  - Predisposing factors (“stressors”)
    - Transportation, commingling with other cattle, dust, cold, sudden and extreme weather changes, dehydration, hypoxia, exposure to endotoxin, cold coupled with wetness[1,2]
  - Bacterial component
    - *Mannheimia haemolytica*, *Pasteurella multocida*, *Histophilus somni*, and *Mycoplasma bovis*[3]
  - Viral component
    - Damage to respiratory clearance mechanisms and lung parenchyma[3]

- Similar multifactorial diseases
  - Coryza
    - Acute respiratory disease of chickens caused by the bacterium *Avibacterium paragallinarum*
  - PRRSv
    - Viral disease – reproductive and respiratory (macrophages)

[1] Lillie LE. The bovine respiratory disease complex. Can Vet J 1974;15:233–242.
[2] Irwin MR, McConnell S, Coleman JD, Wilcox GE. Bovine respiratory disease complex: A comparison of potential predisposing and etiologic factors in Australia and the United States. J Am Vet Med Assoc 1979;175:1095–1099.
[3]Taylor, J.D. et al. Can Vet J 2010;51:1095–1102

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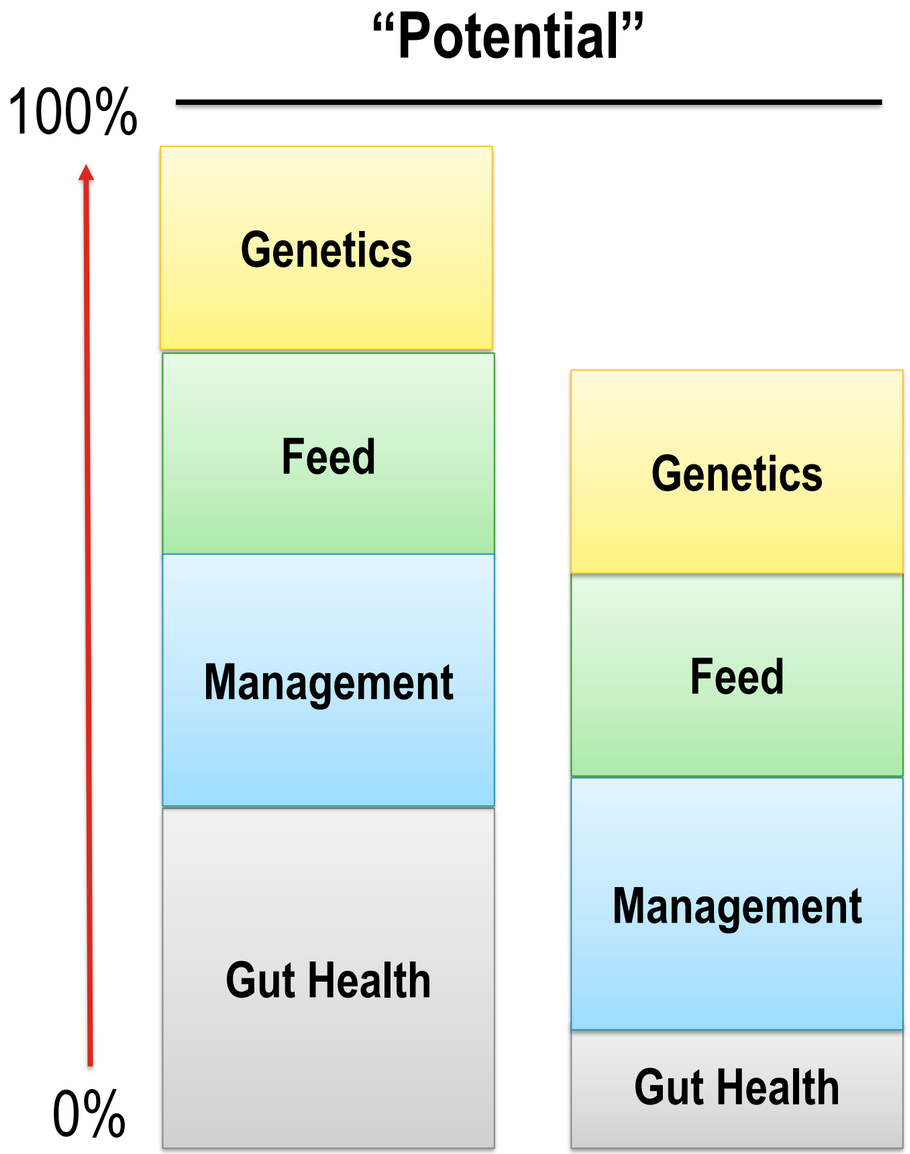
Reaching Potential



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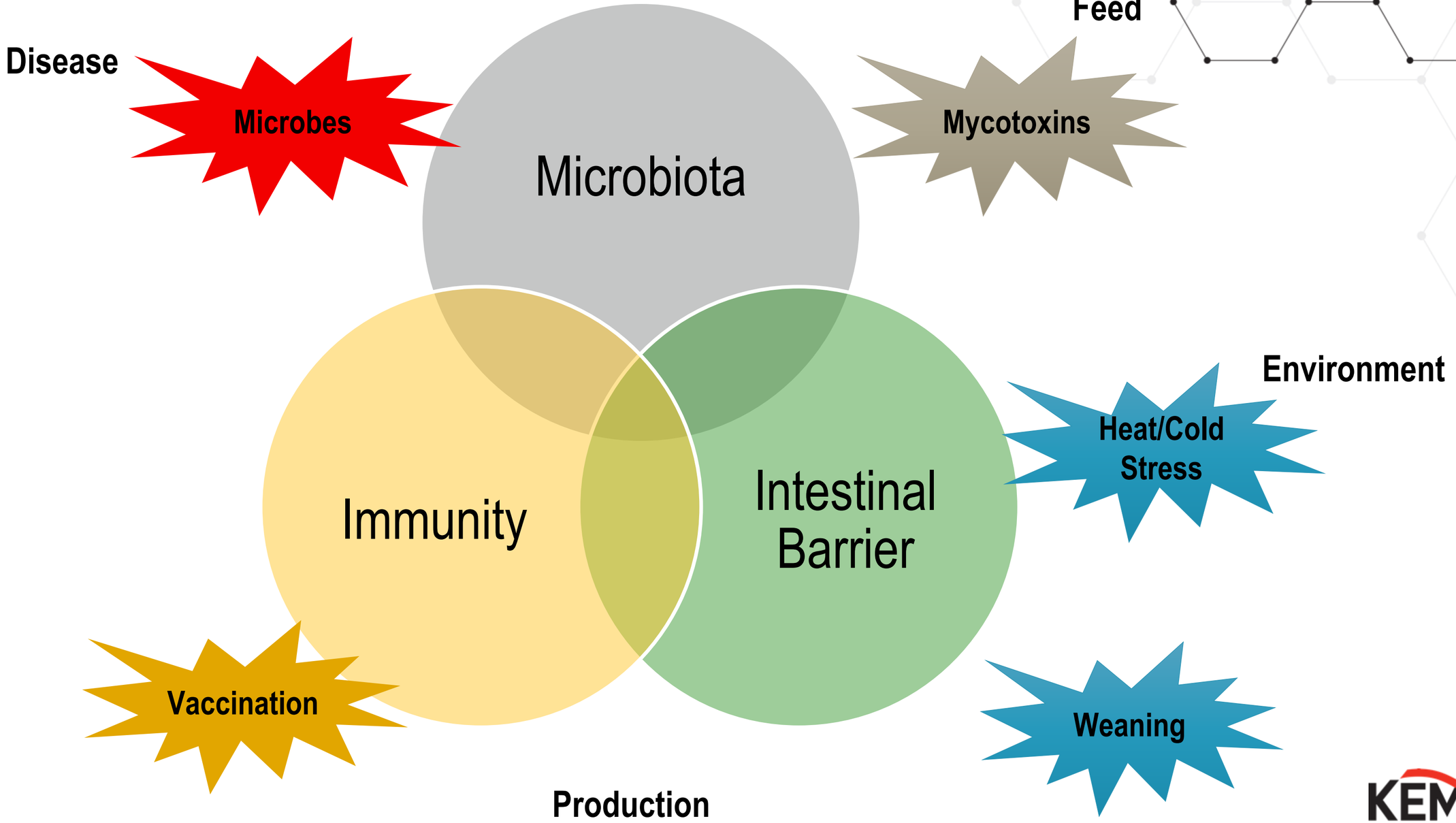
What Factors are Affected?



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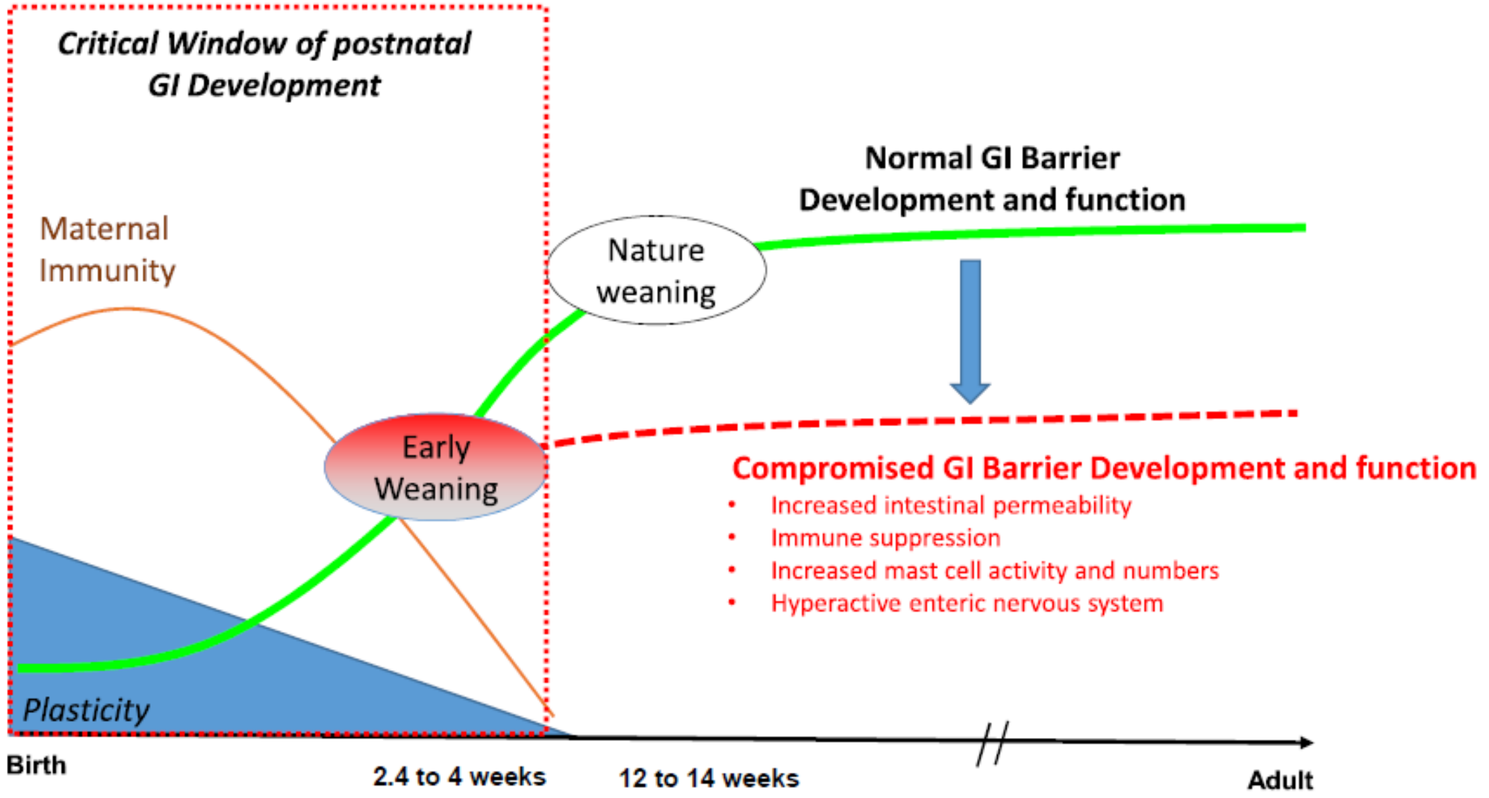
The Effect of Weaning on Postnatal GI Development

- Diet changes
  - Phasing out lactose and progressively introducing cereals and SBM
  - Highly digestible protein sources (soy protein concentrated) until phasing them out.
- Vaccination
- Castration
- Transporting
  - Ranges from a few miles to several hours
- Mixing
  - All production systems mix litters, which brings a battle for hierarchy ranking over the first 3 to 7 days.
  - Nursery or WTF barns are filled from different sow farms with different health status.

A.J. Moeser et al. / Animal Nutrition 3 (2017) 313–321



A.J. Moeser et al. / Animal Nutrition 3 (2017) 313e321

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Conclusions

- Growth, Immunity, Nutrition influence each other
- Feed intake is not the only cost
- Amino acids can be nutritionally expensive
- Management and gut health are becoming more vital to how we mange multifactorial diseases

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Questions?

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