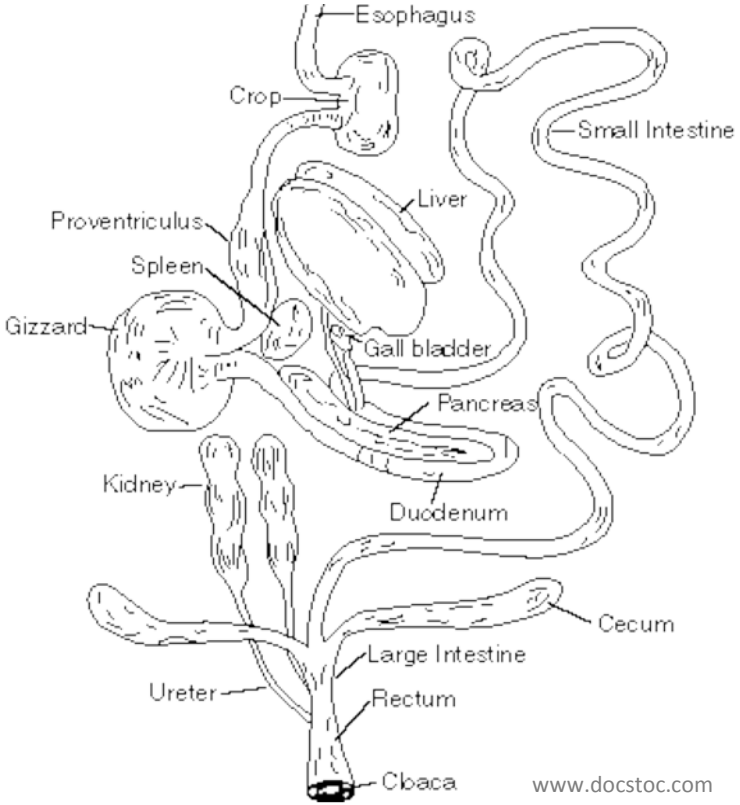
THE OHIO STATE UNIVERSITY
OARDC

Poultry Gut Microbiology

Lisa Bielke (and many other contributors)

THE OHIO STATE UNIVERSITY
COLLEGE OF
FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

How Complicated Can it be?



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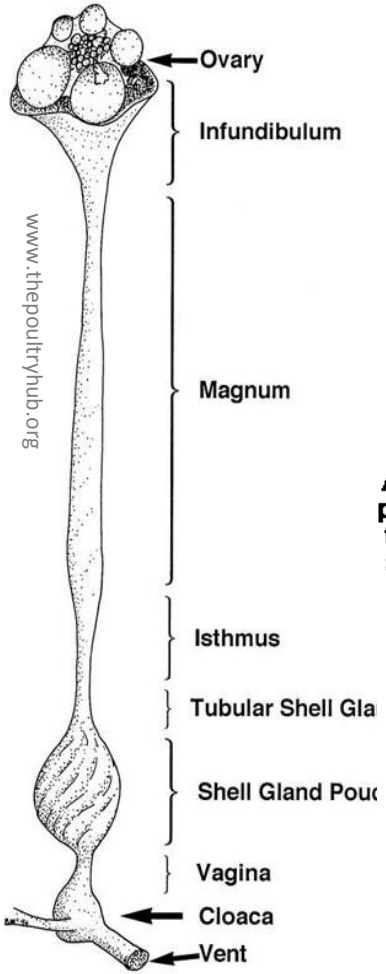

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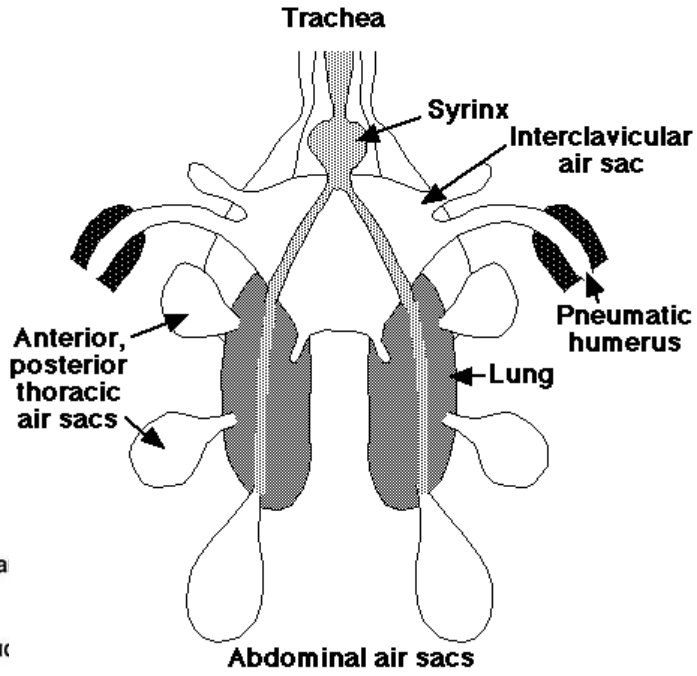
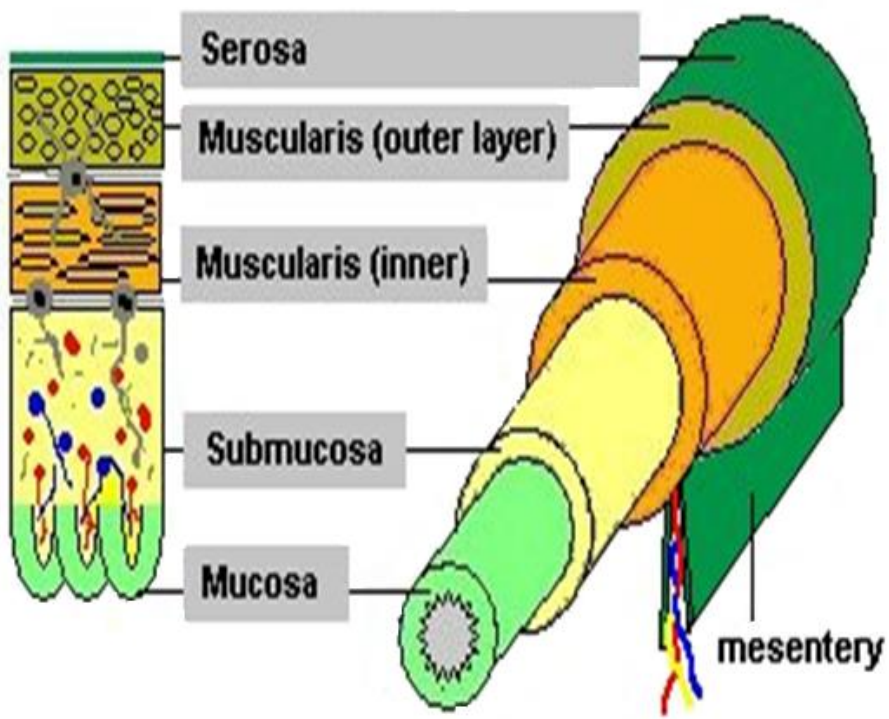
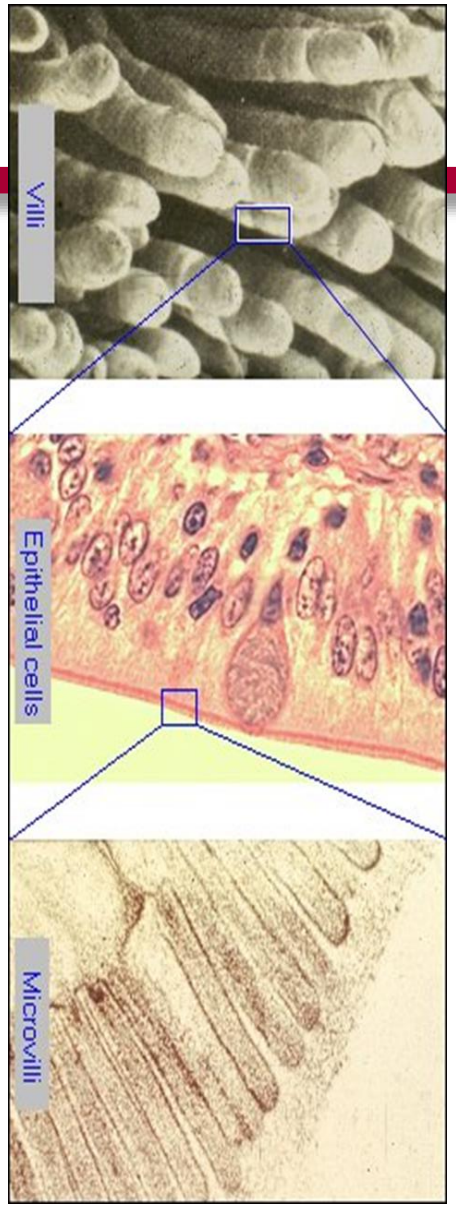


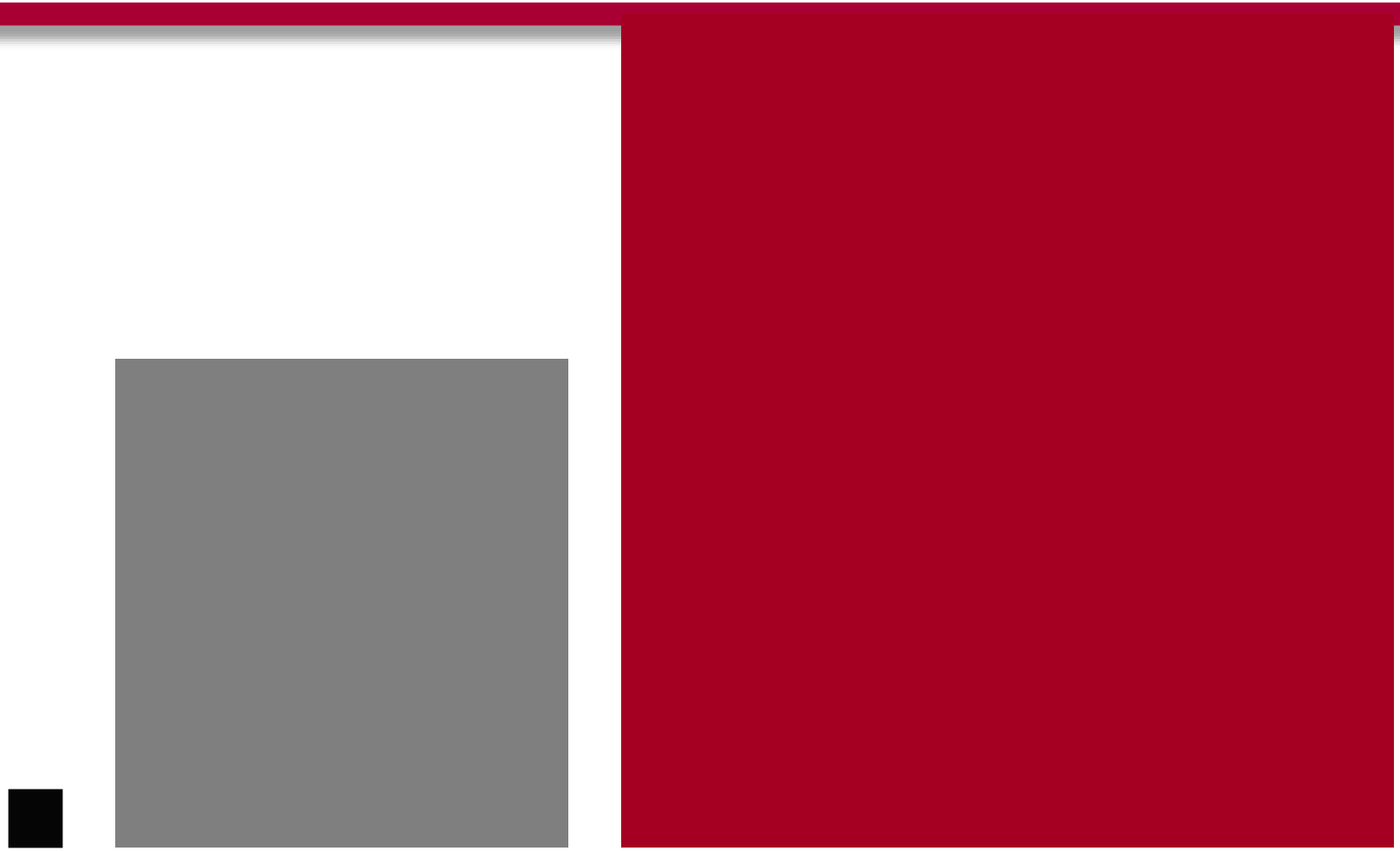
http://people.eku.edu/ritchisong/birdrespiration.html

Deceptively Simple



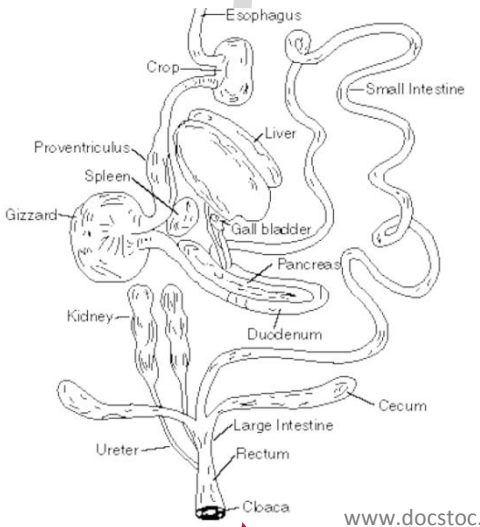


Total Surface Area



Skin Lungs GIT

Common Mucosal System



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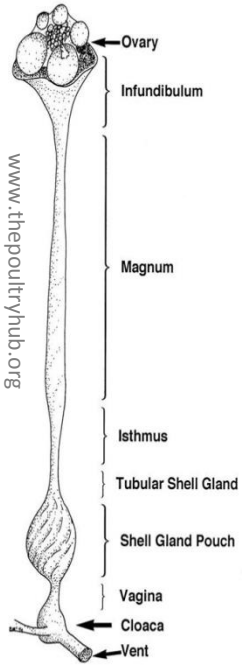

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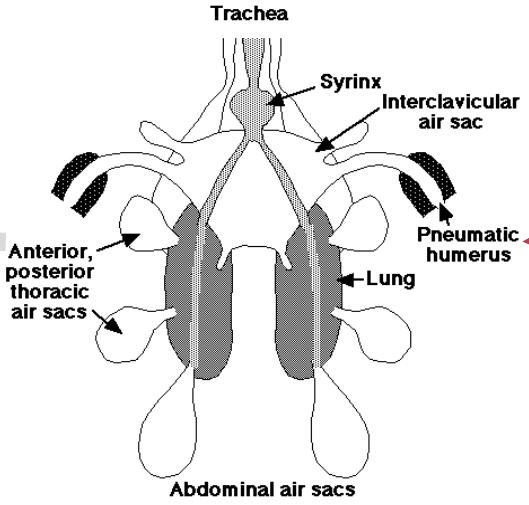

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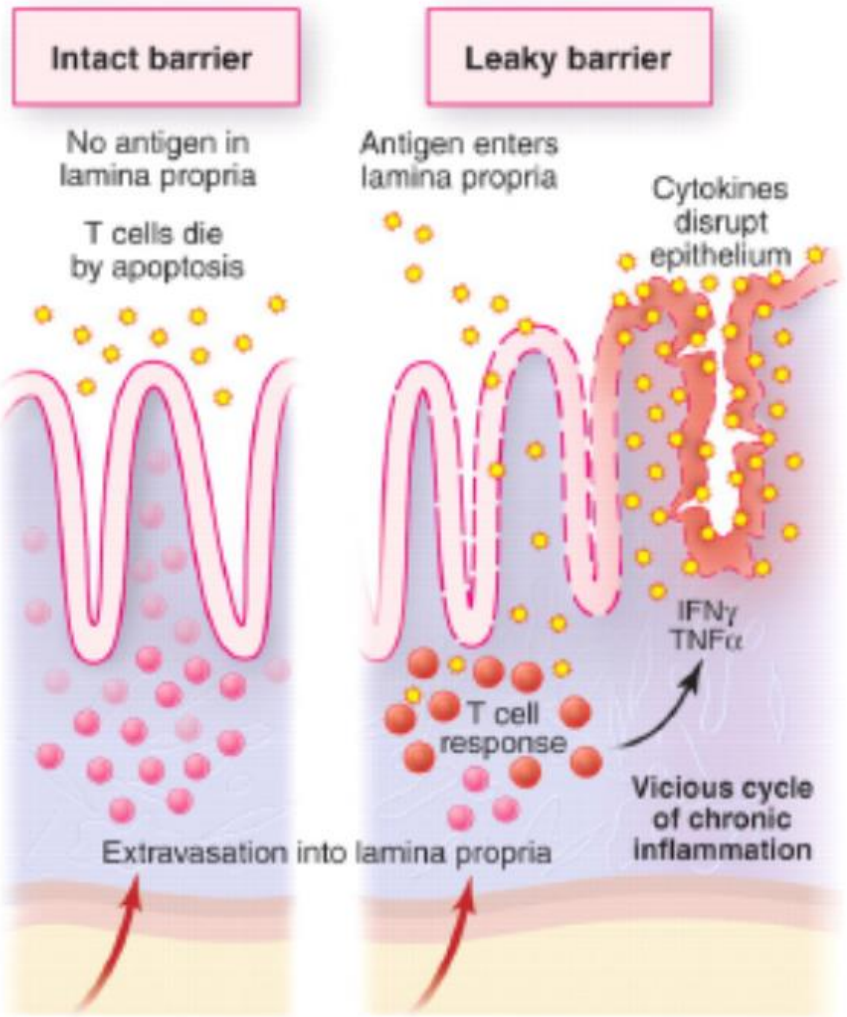
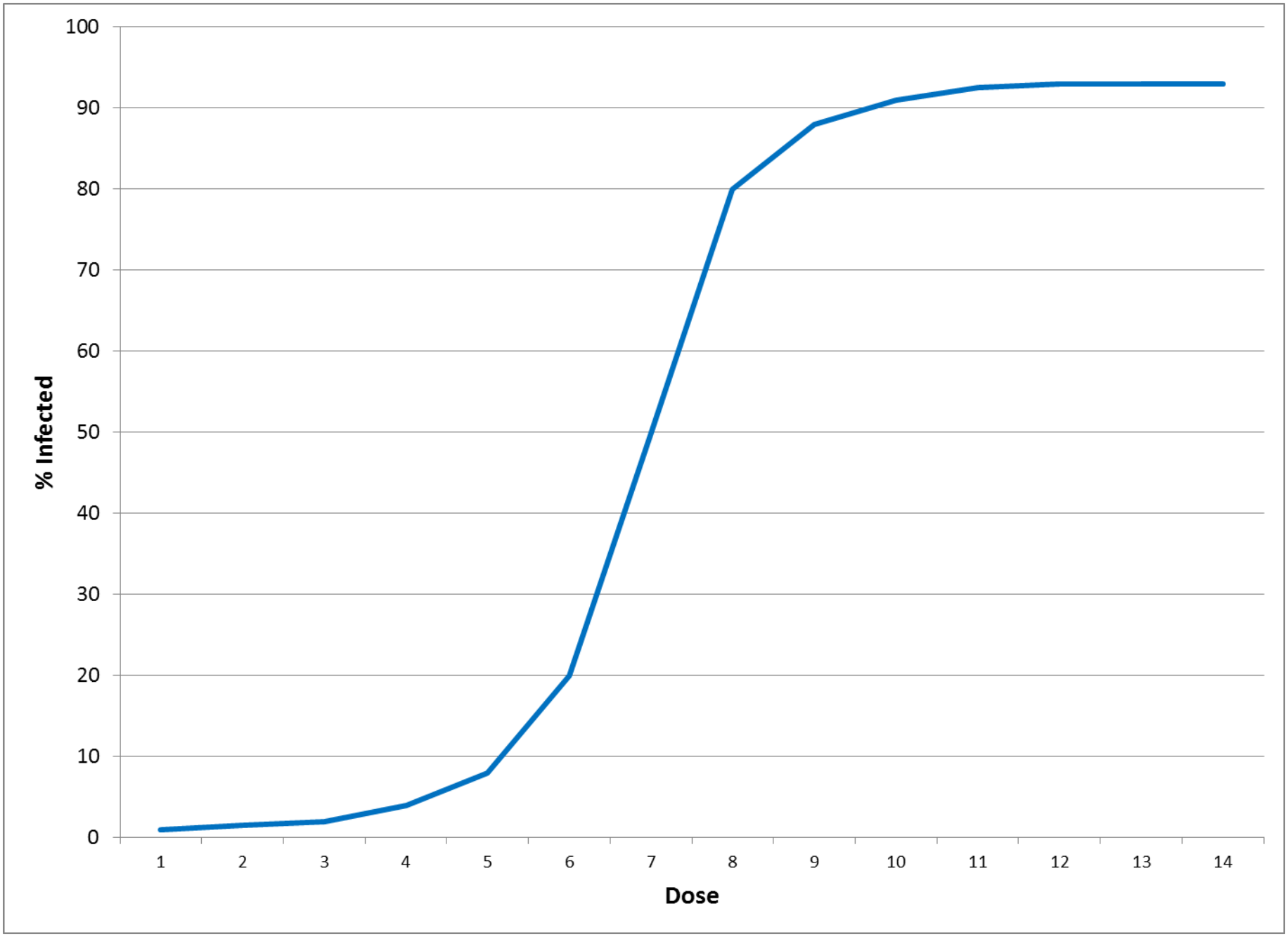
Barrier and Protection



MacDonald & Monteleone (2005) Science

- When the mucosal barrier is broken:
  - Disease!
  - Innate immune system initiated
  - Impaired nutrient absorption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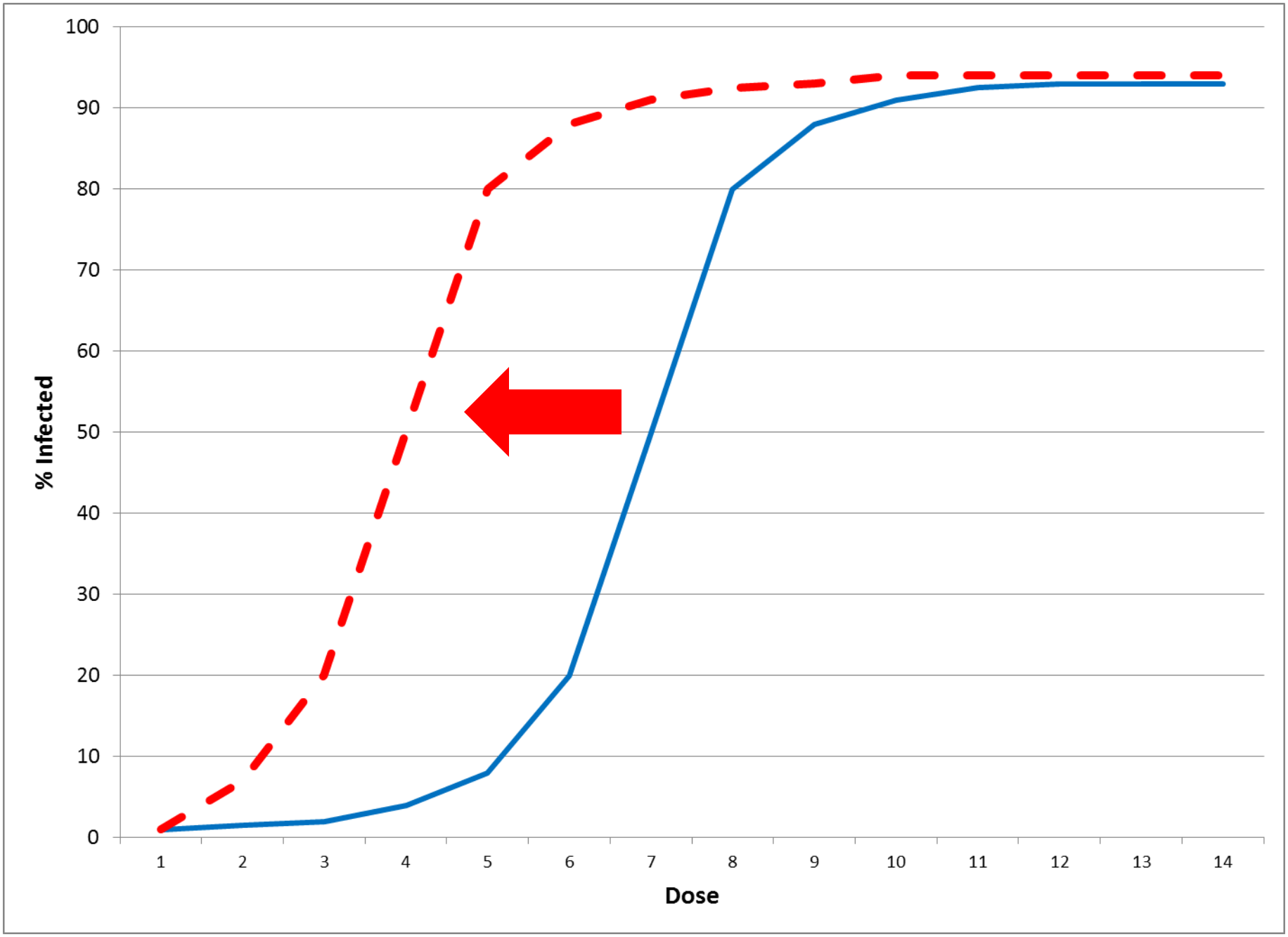
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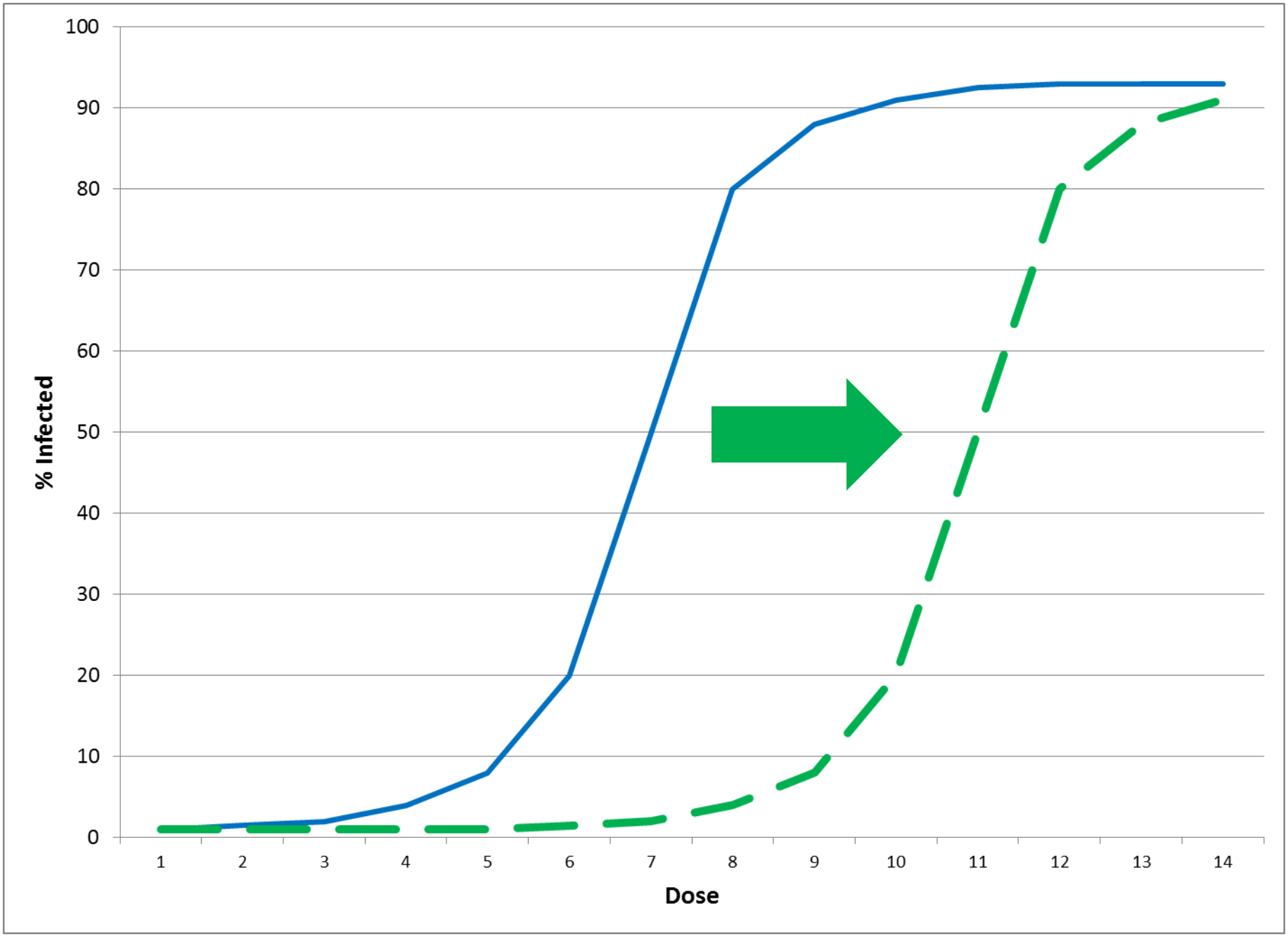
Dose

Failed Mucosal Barrier

- Opportunistic infections
- Necrotic enteritis
- Not just GIT:
  - gangrenous dermatitis
  - enterococcal spondylitis
  - femoral head necrosis
- Nutrient Absorption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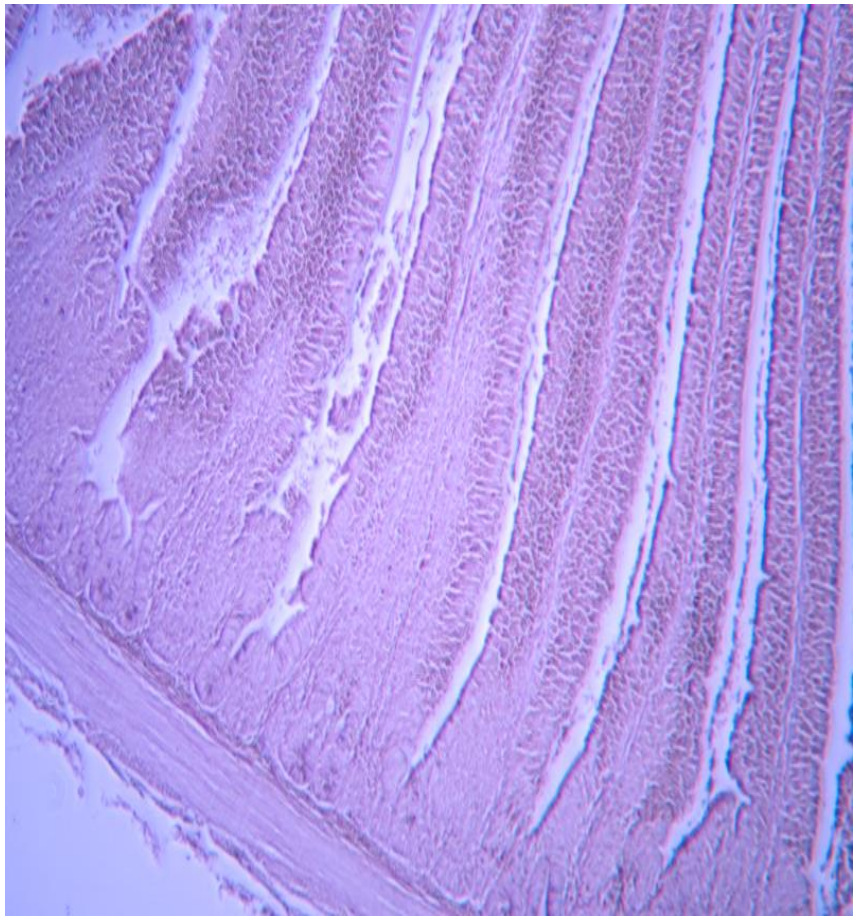
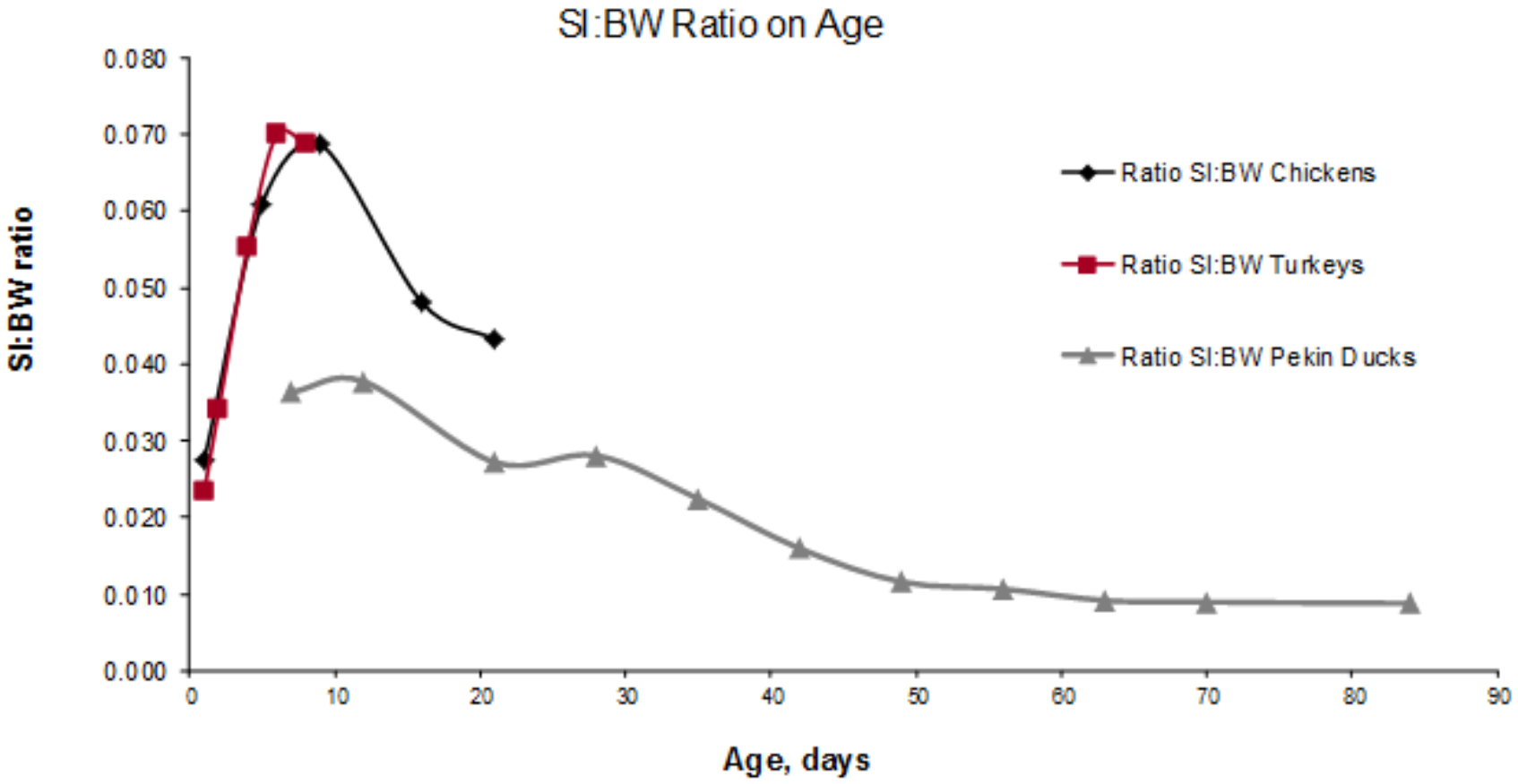
Dose

In the immediate post hatch period

- Birds must undergo the transition from energy supplied by the endogenous nutrients of the yolk to exogenous carbohydrate-rich feed.
- During that critical time dramatic changes occur both in the intestinal size and morphology



In poultry, intestinal villi, which play a crucial role in digestion and absorption of nutrients, are underdeveloped at hatch but maximum absorption capacity is attained by 10 days of age.



Interspersed among the villi is an area called the Follicle-associated Epithelium (FAE) which overlay the Peyer's patches

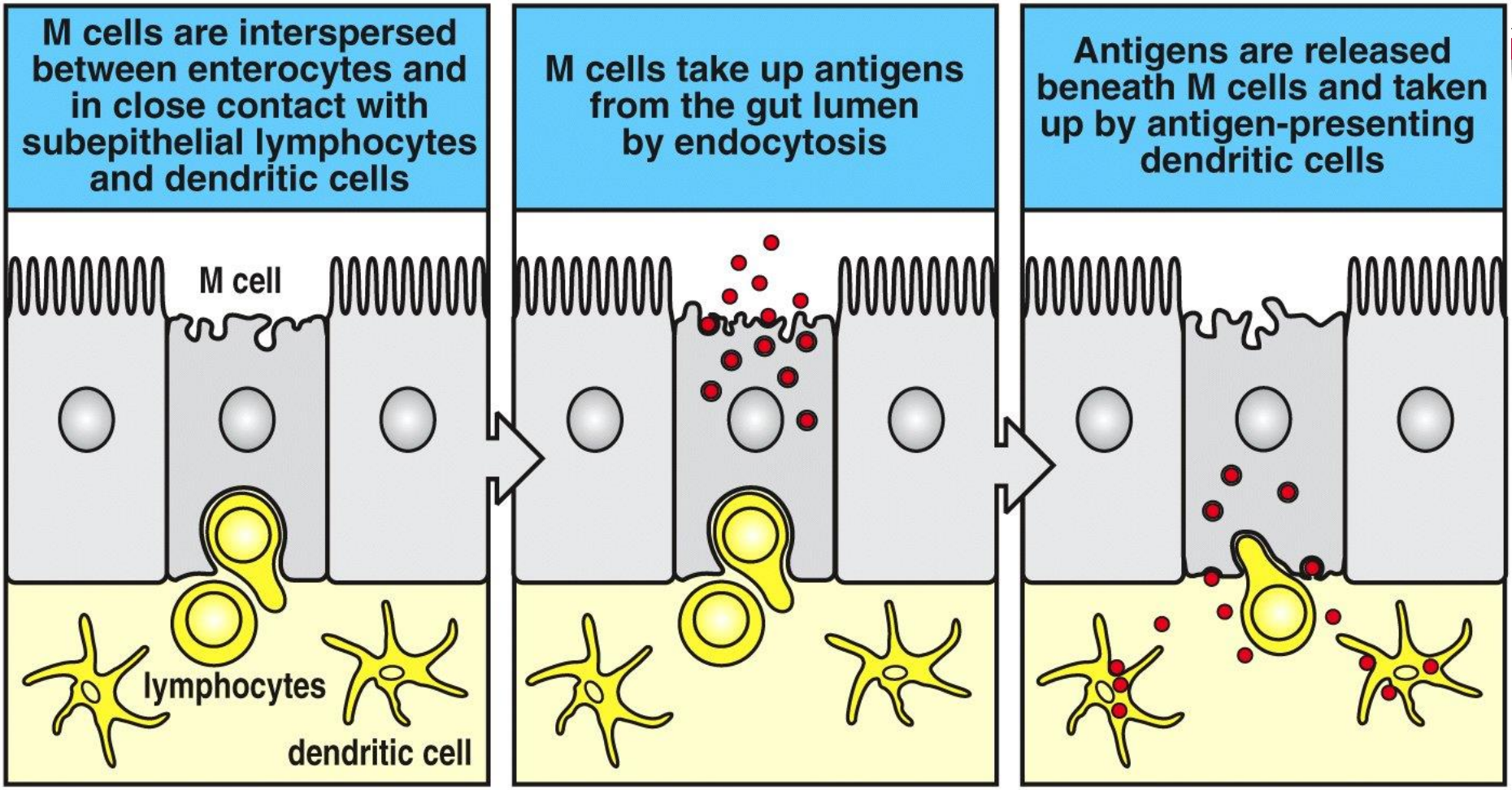


Figure 10-19 Immunobiology, 6/e. (© Garland Science 2005)

The Gut Microflora

Microbial population of ~ 100 trillion (10^{14}) cells

- Highest cell densities recorded for any ecosystem
- An interface with 10^{13} host cells
- Organ within an organ

Microbiome as an "Organ"

- Composed of different cell lineages with a capacity to communicate with one another and the host
- Consumes, stores, and redistributes energy
- Mediates physiologically important chemical transformations
- Can maintain and repair itself through self-replication

Factors Affecting Intestinal Ecology

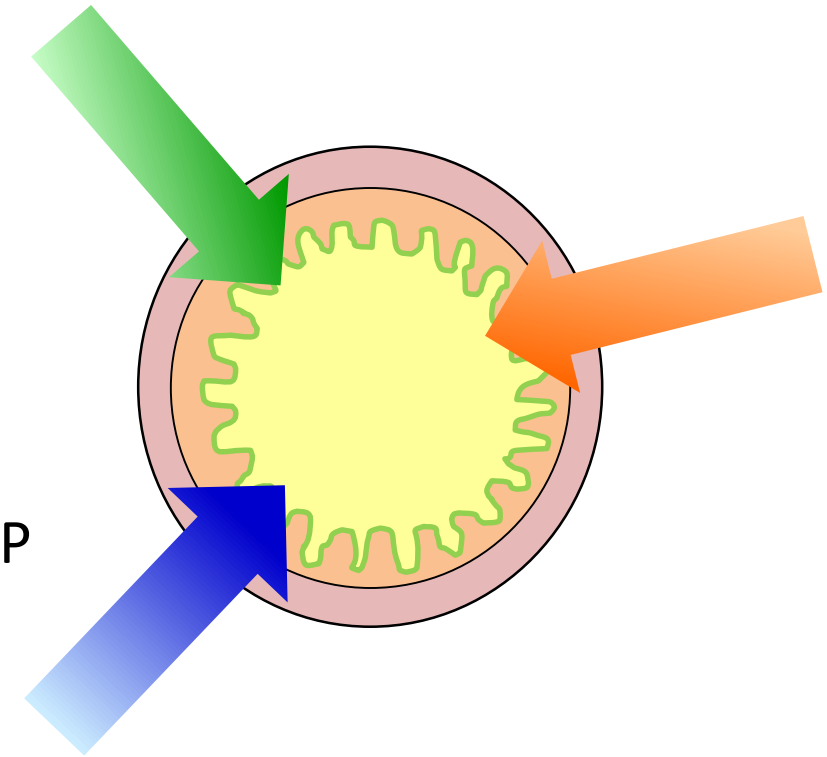
Microflora

Bacteria

Fungi

Parasites

Viruses



Secretions

Electrolytes

Enzymes

Proteins

Hormones

Mucus

pH

Nutrition

Fiber & NSP

Nutrients

Minerals

Vitamins

Water

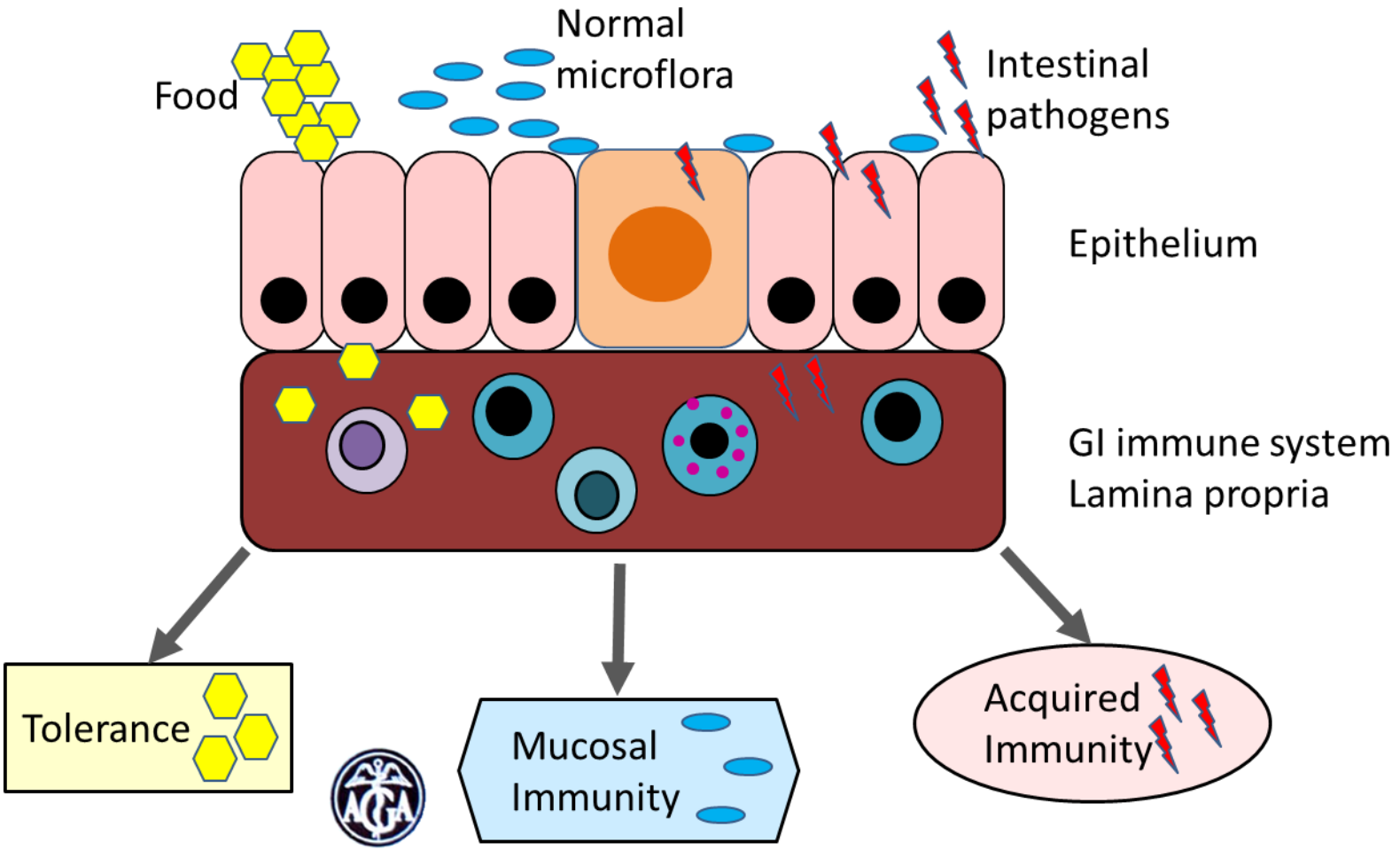
Metabolic Machines

- Carbohydrate fermentation
- Production of short chain fatty acids
- Metabolize proteins
- Enhance mineral and lipid absorption
- Increased growth of host cells
- Gnotobiotic mice required 30% more energy to maintain the same weight as normally colonized mice (Sears (2005) Anaerobe 11:247)

Early establishment of intestinal microbiota promotes:

- Proliferation and differentiation of its epithelial lineages
- Regulates angiogenesis
- Modifies the activity of the enteric nervous system
- Extraction and processing nutrients in the diet
- **Assembly of the gut-associated lymphoid tissue**
- **Education of the immune system**
- **Affects the integrity of the intestinal mucosal barrier**

Microflora are important for maintaining the mucosal immune system



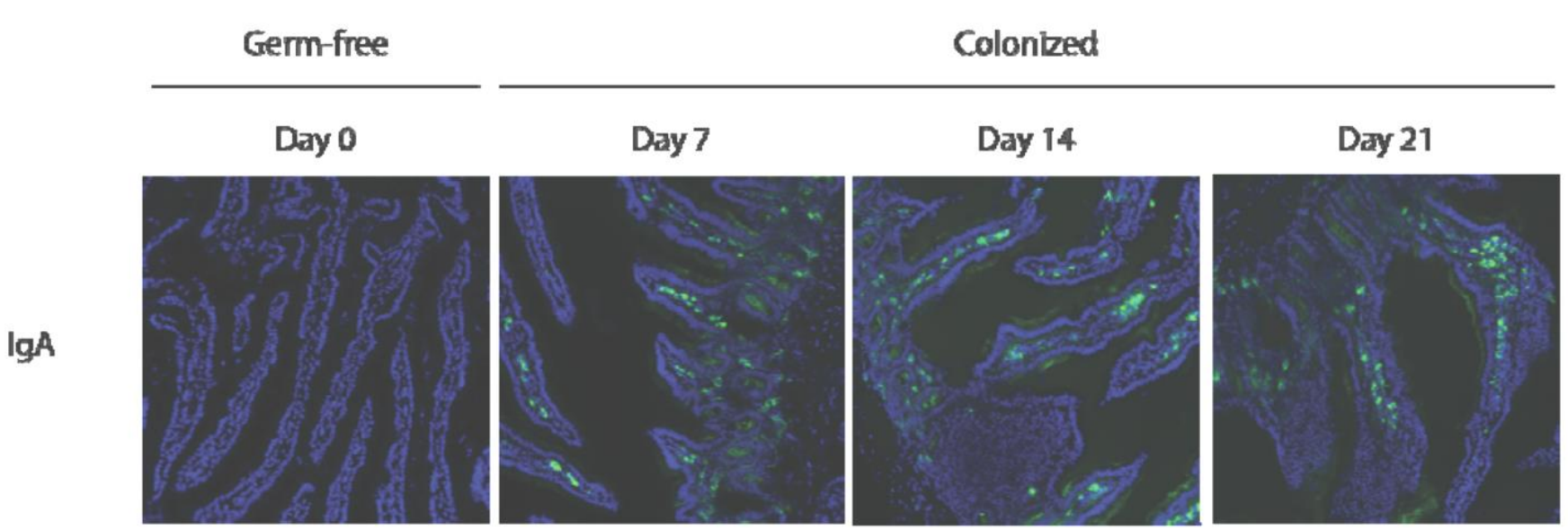
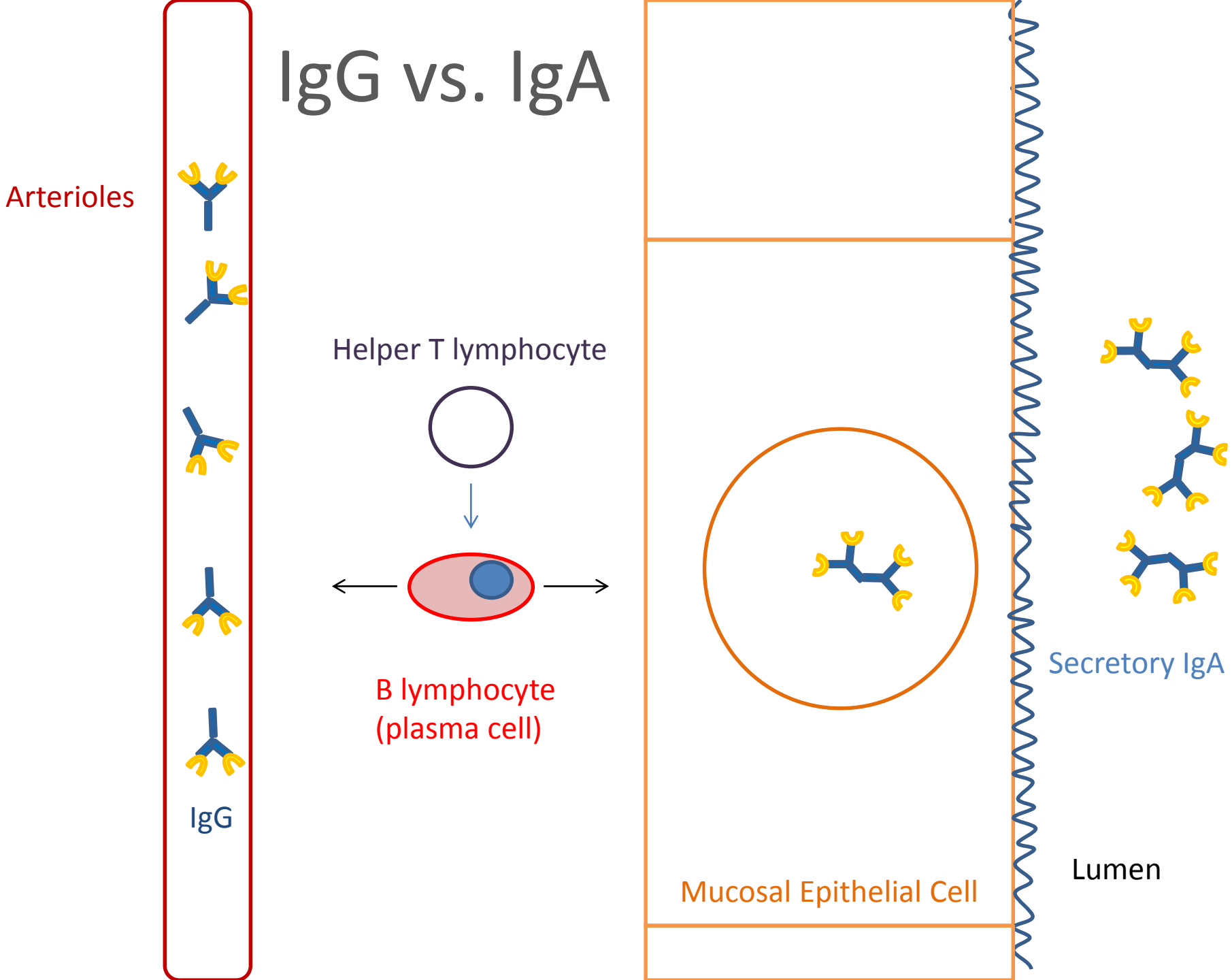


Fig 2. Colonization of germ-free mice leads to increased IgA in the intestinal lamina propria. The small

- Antibiotic treated mice vs. normal mice:
  - Impaired innate and adaptive antiviral immune response
  - Delayed and defective response – limited ability to inhibit viral replication
- Commensal bacteria augment immunity against systemic or mucosal infections
- Colonization of germ free mice led to increased T cell and B cell abundance in the lamina propria

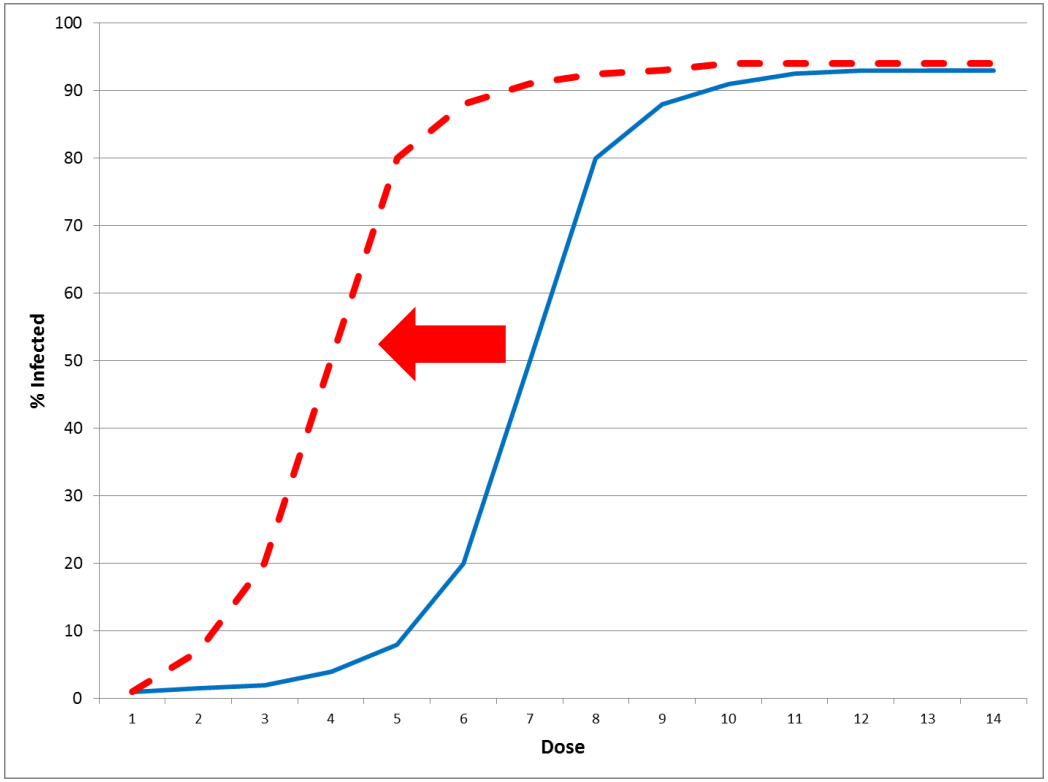
Abt et al. (2012) Immunity 37: 158-170
http://anhi.org/abbottnutritionrd/pdfs/109th%20proceedings/Role_of_Commensal_Flora_in_Mucosal_Immune_Development.pdf McCoy, K.

IgG vs. IgA


Arterioles
IgG
Helper T lymphocyte
B lymphocyte
(plasma cell)
Mucosal Epithelial Cell
Secretory IgA
Lumen

Consequences of Chronic GI Inflammation

- Problems most often occur as a result of too much, rather than too little, control



The GIT is in a constant state of controlled inflammation

Consequences of Chronic GI Inflammation

- Human Diseases
  - Inflammatory Bowel Disease
  - Crohns Disease
  - Ulcerative Colitis
  - Other inflammation-related diseases
- Poultry
  - Decreased overall performance
  - Increased feed conversion ratio
  - Disease susceptibility

Effect of Feeding Antibiotics on the Intestinal Tract of the Chick[1]

H. G. JUKES, D. C. HILL AND H. D. BRANION

Department of Nutrition, Ontario Agricultural College, Guelph, Ontario, Canada

(Received for publication January 9, 1956)

GORDON (1952) reported that when antibiotics were fed to chicks the weight of the small intestine was significantly reduced. A similar observation was made by Coates *et al.* (1955) and by Pepper *et al.* (1953). Coates and coworkers noted that the length of the gut was little affected by the antibiotic, nor was its content of fat or moisture altered, and concluded that the antibiotic caused a thinning of the gut wall. They also reported, without presenting data, that his-

1. THE EFFECT OF ANTIBIOTICS ON THE DRY WEIGHT OF THE INTESTINAL TRACT

Four experiments were conducted for which the general procedure was the same. The birds were housed in battery brooders and fed *ad libitum* from day old for the duration of the experiment.

Basal diets used are given in Table 1. The diets are chick starters or broiler diets with modifications in the amount or kind of animal protein included.

2007 Poultry Science 86:605–609

The Nonantibiotic Anti-Inflammatory Effect of Antimicrobial Growth Promoters, the Real Mode of Action? A Hypothesis

T. A. Niewold

Nutrition and Health, Department of Biosystems, Katholieke Universiteit Leuven, Kasteelpark Arenberg 30, 3001 Heverlee, Belgium

- Antimicrobial mechanism unlikely
  - Sub-MIC administration
- Popular AGP accumulate in phagocytes

Cellular Accumulation of AGP

ANTIMICROBIAL GROWTH PROMOTERS INHIBIT INFLAMMATION

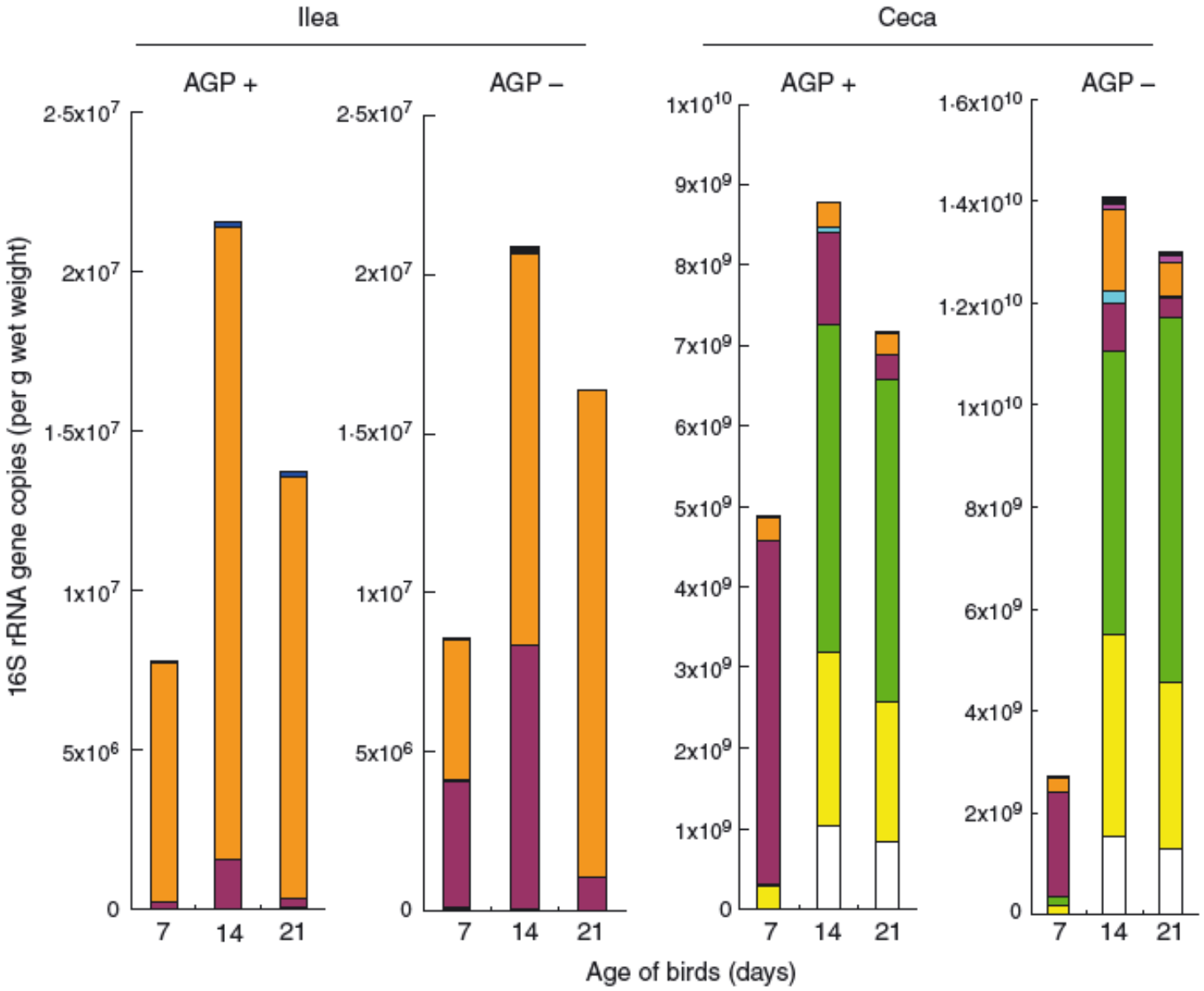
Table 1. Intraphagocytic accumulation of antibiotics that can lead to inhibition of function,[1] and relationship with use as antimicrobial growth promoters (AGP)

Antibiotic (class)	Intracellular accumulation (C:E ratio[2])	Phagocyte function inhibition	AGP use, past or present
Chloramphenicol	4	No	No
β-Lactams	<1	No/some/limited	No/some/limited
Cyclines	2	Yes	Yes
Quinolones	5	No	No
Macrolides	10–100	Yes	Yes
Streptogramin (peptide)	40	Yes	Yes

[1]Labro, 1998, 2000.

[2]C:E ratio = the cellular:extracellular concentration.

Niewold (2007) Poultry Science 86:605-609



Wise and Siragusa (2007) J Appl Microbiol 102:1138

Decreasing Acceptance of AGP

- Banned in EU & some Asian countries
- Consumer demand in USA
- USA ban in near future?
- Economical and sustainable alternatives are imperative

Possible Alternatives

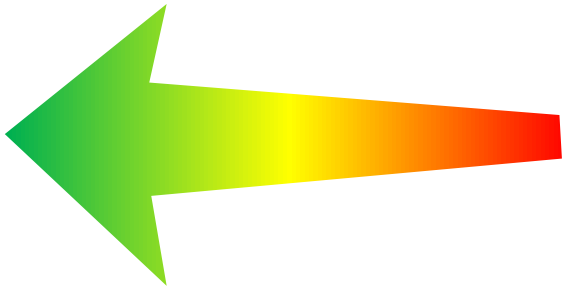
- DFM/Probiotics
- Prebiotics
- Vaccines
- Anti-oxidants
- Anti-inflammatory compounds
- Nutrient composition

DFM/Probiotics

Eubiosis (balanced)

Symbiotic co-existence of host & microflora

Beneficial



Dysbiosis (unbalanced)

Diseased interaction between host and microflora

Pathogenic

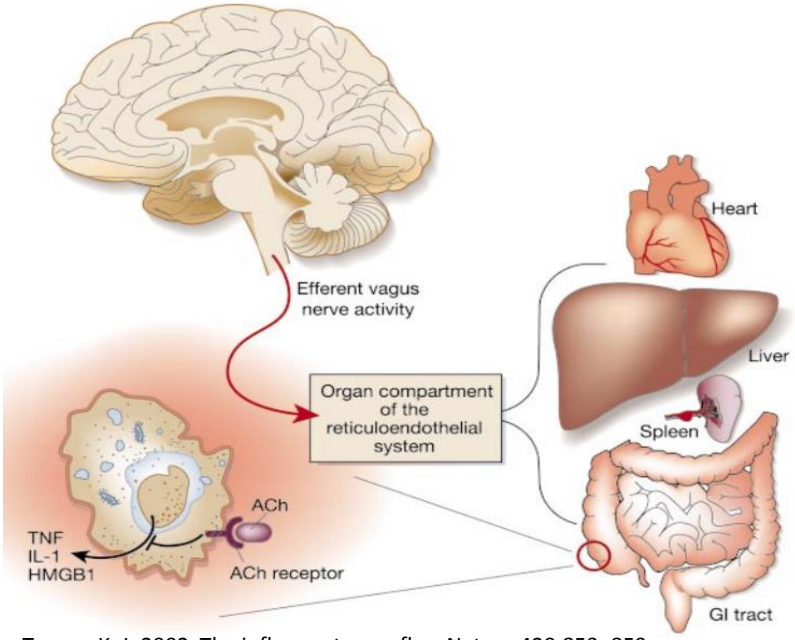
- Protected mucus membrane
- Competitive exclusion
- Balanced stimulation of immune system
- Nutritional benefits

- Damaged epithelium
- Toxins
- Unbalanced increased immune response
- Increased cellular turnover
- Decreased nutrient absorption

Adapted from: M. Mohnl (2007) www.Engormix.com

Factors Affecting Eubiosis

- Nutritional changes
- Feed withdrawal
- Transportation
- Overcrowding
- Climate stress
- Vaccination
- Disease – infectious or noninfectious



Tracey, K. J. 2002. The inflammatory reflex. Nature 420:853–859

STRESS!

Probiotics and Health

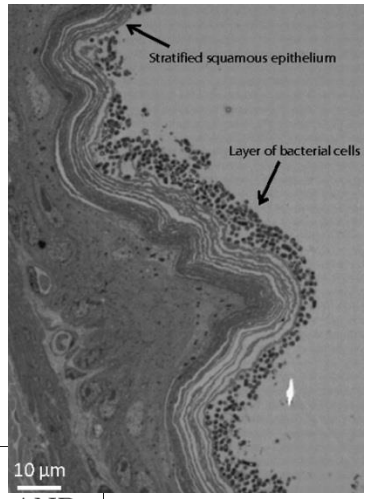
- The use of lactic acid bacteria as feed supplements goes back to pre-Christian times when fermented milks were consumed by humans.

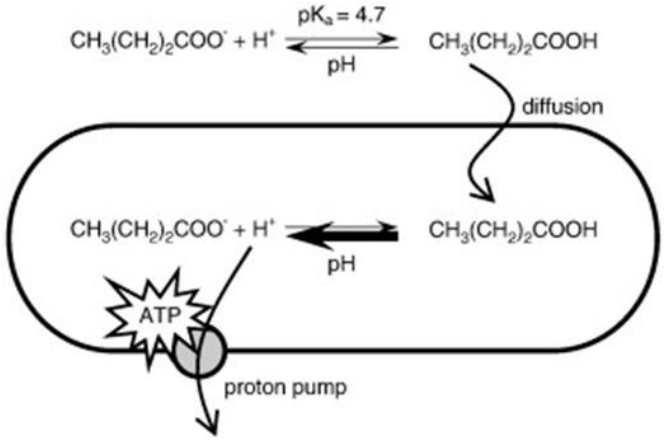
Metchnikoff cited the observation that Bulgarian peasants consumed large quantities of soured milk and also lived long lives.

- Nobel prize for Physiology 1908, was awarded to Elie Metchnikoff “In recognition of his work on immunity”
- He isolated what he called the *'Bulgarian bacillus'* from soured milk and used this in subsequent trials.
- This organism was probably what became known as *Lactobacillus bulgaricus* and is now called *L. delbrueckii* subsp *bulgaricus.*
- He developed and prescribed to his patients bacteriotherapy, i.e. the use of lactic acid bacteria in dietary regimens.

Nurmi & Rantala. *Nature* 241, 210 - 211 (19 January 1973): Competitive Exclusion

- Proposed mechanisms:
  - Physical obstruction of attachment sites
  - Competition for essential nutrients
  - Protective flora may produce volatile fatty acids that limit the growth of salmonellae





Changing Paradigm

- Probiotics more than simply “compete”
- We know:
  - Stimulate immune function
  - Provide nutrition
- How to select for the “right” probiotics?

Manipulation of Intestinal Microflo

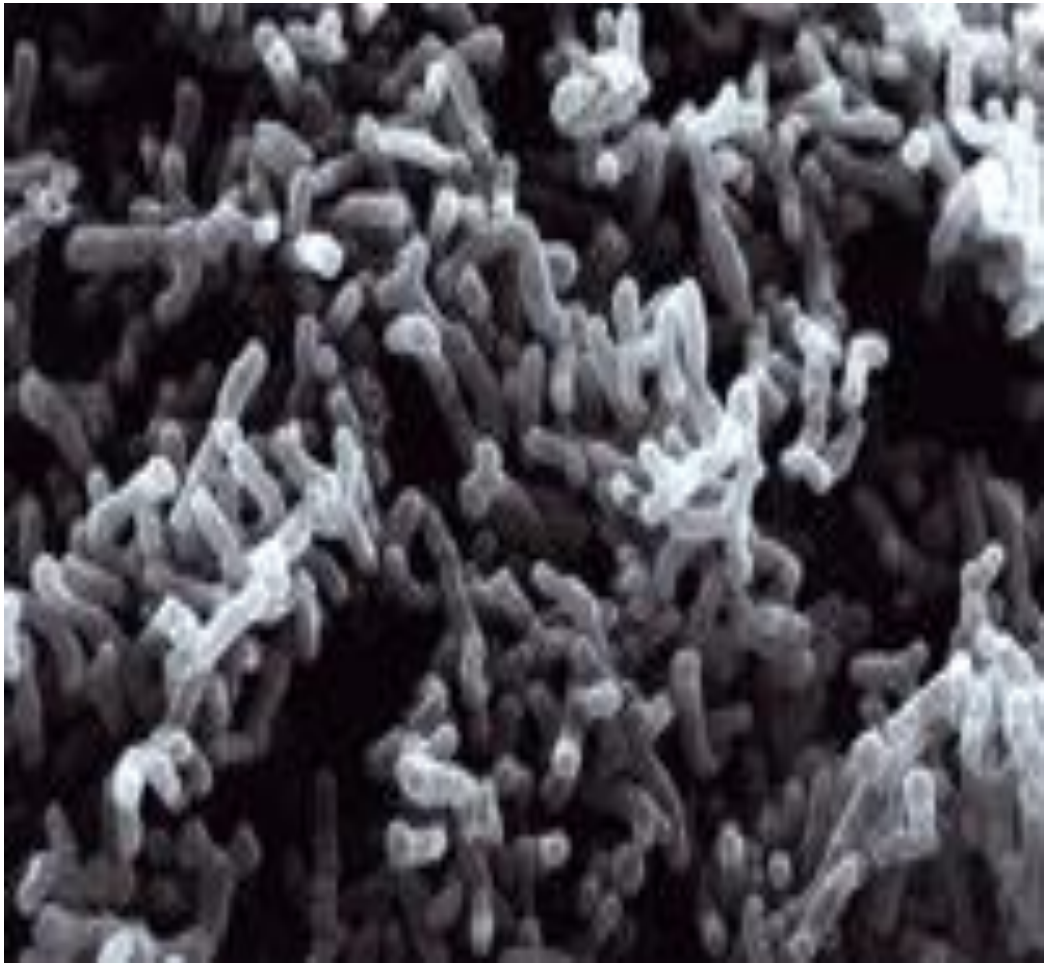
Diet

Prebiotics

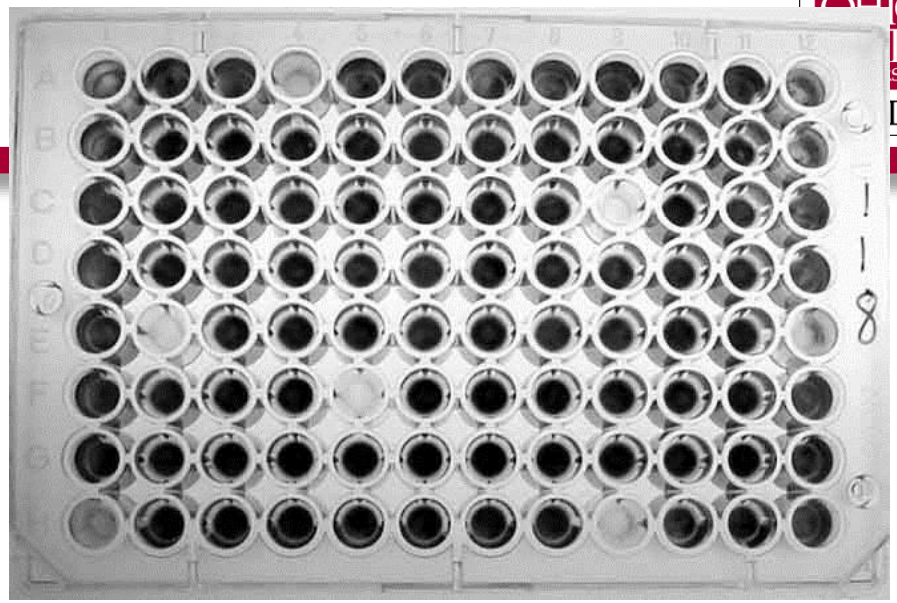
Probiotics

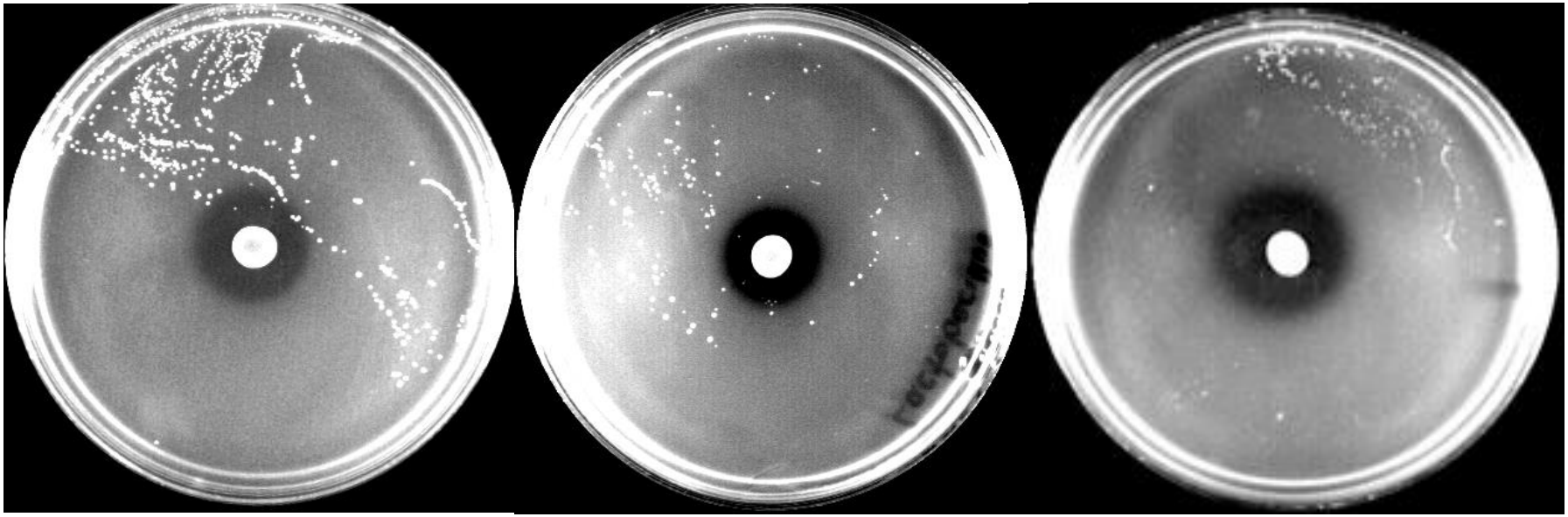
Synbiotics

Intestinal "pathogens"



CE screening methods have worked well against *Salmonella*

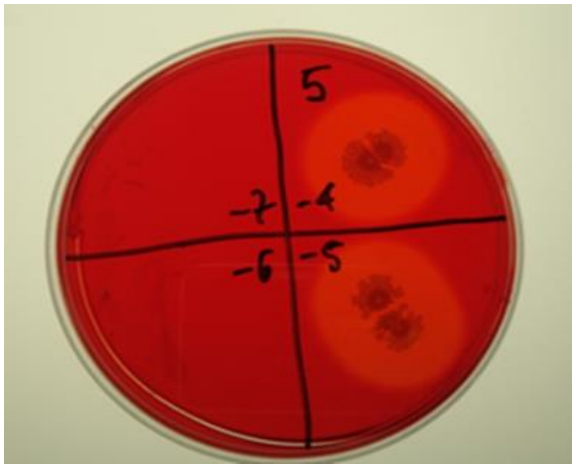




Screening and selection of *Bacillus*-DFM candidates for enzyme production

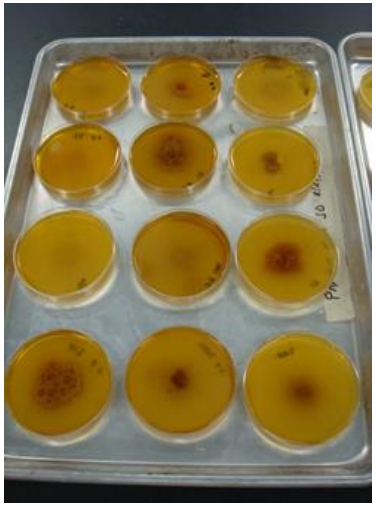
Lipase

Cellulase



Protease

Phytase



Xylanase

In nature…

- Transmission from hen to chick
- Hatched chicks ingest normal microflora in nest or soon after hatch
- Transmission through vaginal inoculation during oviposition or coprophagy has been hypothesized

Reality…

- Eggs are promptly removed from hens and taken to hatchery
- There is no contact between hen and chicks
- Chicks may not receive normal (or minimal) beneficial microbes from hens

Possible Alternatives

- DFM/Probiotics
- Prebiotics
- Vaccines
- Anti-oxidants
- Anti-inflammatory compounds
- Nutrient composition

Is there a single answer?

- Multiple pieces to the puzzle
- Probiotics can be used to control diseases and boost performance, possibly by controlling inflammation and immune response.
- The old idea of competitive exclusion still stands, but is likely more complex than originally thought.
- 100,000X more bacteria in one GIT than people on the planet, and look how complicated our world is, the GIT must be even more so.
- Vaccine technology for control of specific pathogens is advancing