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From the Editor

Gut microbiota, diet, and health: Application to livestock and companion animals

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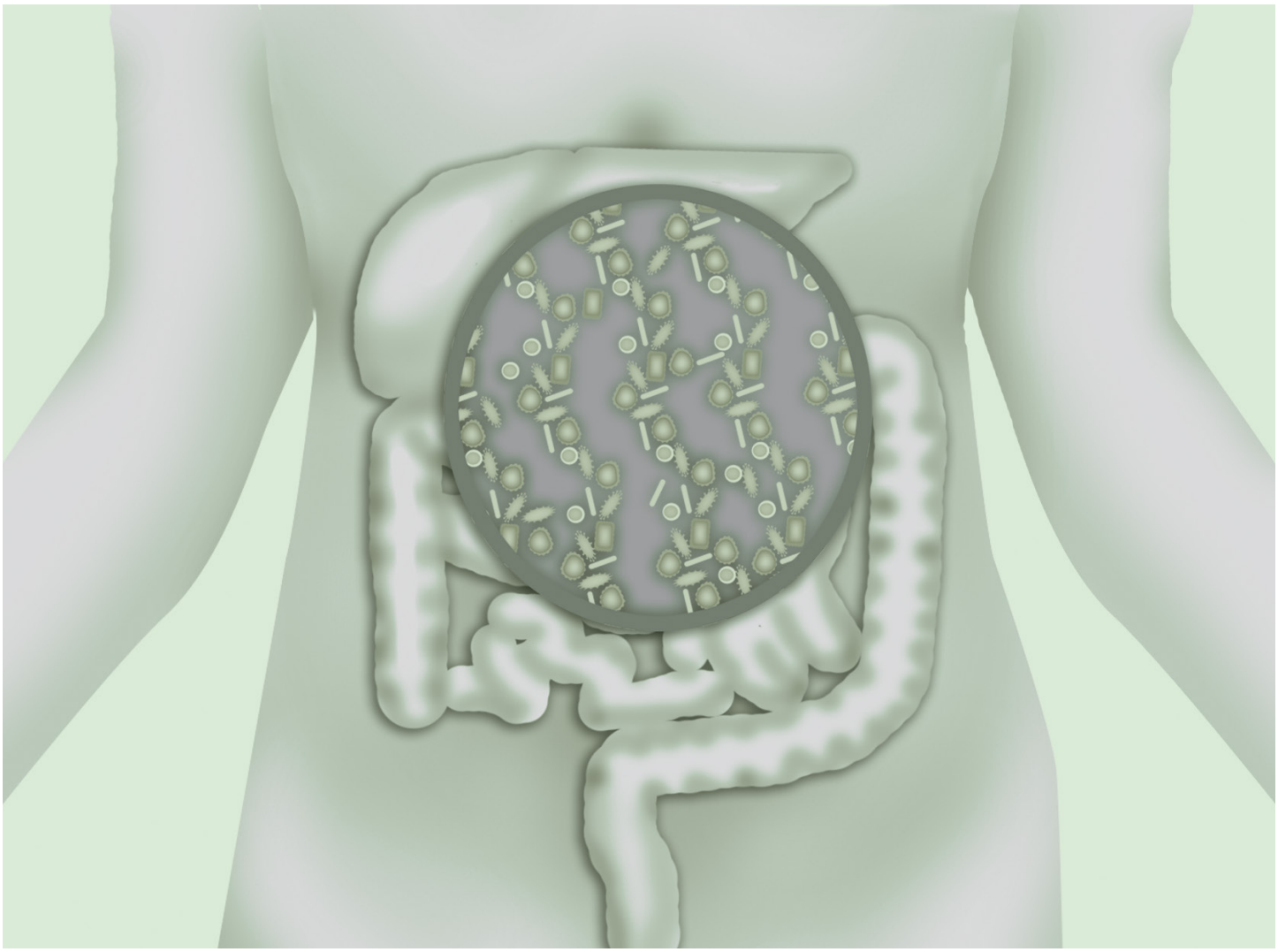

Gastrointestinal (**GI**) microbes play a fundamental role in the health and disease of animals and humans, participating in immune system development, production of bioactive compounds, harvesting energy, and many other processes. For decades, the microbiology field was hampered by the lack of research tools and an inability to culture and study the majority of microbes present in the GI tract. With the advent of high-throughput DNA-based sequencing methods, coupled with new bioinformatic developments that allow for the identification and characterization of microbes and their genes (microbiome) in and on the body, there has been an upsurge in newfound knowledge in the field. A majority of the progress initially came from large international microbiome projects such as the Human Microbiome Project (**HMP**; http://www.hmpdacc.org) and the Metagenomics of the Human Intestinal Tract (**MetaHIT**; http://www.metahit.eu). Initial phases of these projects produced reference genomes and established a framework for subsequent metagenomic analysis and microbiome structure and function studies. These large, multifaceted projects laid the foundation for future microbiome studies that could be conducted by large and small research groups alike and applied to many scientific realms.

The buzz surrounding the microbiome field has led to significant research investments by federal agencies, private foundations, and industry. Recent microbiome studies in humans have not only associated micro-

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biota with GI diseases (Dicksved et al., 2008), but also with a wide range of other diseases, including obesity (Ley, 2010), diabetes (Larsen et al., 2010), and allergies (Round and Mazmanian, 2009). A similar investment has been made into livestock and companion animal species. This research is providing a better understanding of the taxonomy, dynamics, and functions of GI microbial communities, the relationships between microbial members, the substances produced and consumed by microbes, the influence of environmental factors on microbial activity, microbe–host interactions, and the differences between healthy and diseased animal populations. Most of this work has animal health implications. Given the exchange of microbes among humans, pets, and livestock, however, such research may have relevance to human health as well.

This issue of *Animal Frontiers* explores the importance of the GI microbiota of several livestock and companion animal species as well as humans, with application to host metabolism, growth performance, and overall health. Depending on the situation, GI microbiota may enhance or hinder performance and/or host health. While ruminants and large herbivores rely heavily on microbial fermentation to meet energy and nutrient needs, the resources required to protect the body from pathogenic bacteria and the toxins they may produce can be quite costly. To ease this burden on the body, sub-therapeutic antibiotic growth promoters have been effectively used in the livestock industry for more than 60 years. Due to the concerns over antibiotic-resistant bacteria and possible transmission to humans, medicated feeds have been phased out in Europe and are now being phased out in the US. This issue begins with Cox (2016), who discusses the use of sub-therapeutic antibiotic growth promoters in livestock production, including the reasons for their use and the concerns that come with them. In addition to a brief history of their use in livestock species, recent research using rodent models is presented and discussed. This work shows that the timing of antibiotic administration may shape host metabolism and have lasting effects over generations. The article ends with its application not only to food animals, but human health, and includes economic considerations and alternative strategies for growth promotion.

Whether it is due to its relevance to global warming, the energy harvest of livestock species, or human gastrointestinal disease, methane production is always a popular topic of debate. Hoedt et al. (2016) review the importance of methane production in the agricultural, environmental, and biomedical sectors of society. Although the global demand for milk and meat continues to increase, with beef and dairy cattle contributing greatly in this regard, the environmental impacts of these industries are highly scrutinized. The production of methane, which is the principal method by which ruminant livestock dispose of hydrogen, is often the reason cattle are painted in such a negative light when it comes to the environment. Although agriculture's contribution to greenhouse gases is typically overblown, researchers are exploring novel approaches to manage livestock methane emissions. Because energy is lost through the production of methane, these strategies may not only reduce the carbon footprint of ruminant livestock production, but may increase productive efficiency. Methanogens also are present in the human GI tract and have been associated with several disease states, including constipation, colorectal cancer, and inflammatory bowel diseases. Looking forward, a comparative research approach that considers a variety of animal species, dietary strategies, and human disease conditions, may have wide-reaching implications to animal agriculture and human health.

Despite the recent excitement surrounding the GI microbiome as it pertains to human health, livestock producers, ruminant nutritionists, and rumen microbiologists alike have appreciated the importance of host–microbe symbiosis for decades. Loor et al. (2016) discuss the dietary impacts on rumen microbiota, with application to both beef and dairy production. Given the highly-fibrous nature of their diet, the host–microbe symbiosis that exists in ruminants is crucial for meeting energy and essential nutrient needs. Forage quality, forage:concentrate ratios, and ionophores have long been studied to improve productive efficiency and growth performance. Those relevant topics and specific topics of interest, including dairy calves, transition (peripartum) cows, subacute ruminal acidosis, and milkfat depression, were discussed. Microbial methodological advancements and how a systems biology approach may be used to fill in knowledge gaps, also were highlighted.

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The nutritional strategies of non-ruminants differ substantially from that of ruminants, but the GI microbiota are still of critical importance when it comes to the immunological development, physiological function, and nutritional and health status. Fouhse et al. (2016) discuss the importance of the GI microbiota in regards to swine health and production. The increased emphasis on the GI microbiota comes at an interesting time in the history of swine production, a time when medicated feeds have recently been or are currently being phased out throughout the world and a wide variety of highly fibrous byproduct feeds are available for use. Many of the great challenges facing today's swine producers, such as minimizing dysbiosis and post-weaning diarrhea, maximizing growth performance and feed efficiency, and maintaining human food safety, pertain to the GI microbiota and their management and/or manipulation. Potential solutions may include prebiotics and dietary fibers, probiotics/direct-fed microbials, and possibly others but require significant investment in regards to research and may be met with stringent regulatory agencies in many countries around the world.

Dogs and cats evolved as members of Carnivora and have traditionally relied on high-protein, high-fat diets containing relatively low fiber concentrations. Despite having a relatively simple GI tract designed to digest such diets, a rich microbial community exists. Today's pet dogs and cats live in close proximity to humans and have similar environmental exposures, serving as potential vectors for pathogen exposure. Dogs and cats are also afflicted by many of the same complex diseases present in

humans, including obesity, diabetes, inflammatory bowel diseases, and cancers, all of which may be influenced by diet and GI microbiota. Given their proximity to humans, similar disease incidence and etiology, and unique metabolism, microbiome research in dogs and cats may not only lead to improved pet nutrition and veterinary care, but may increase our understanding of host–microbe interactions, with relevance to human metabolism and diseases and public health at large. Blake and Suchodolski (2016) review the existing microbiome literature pertaining to dogs and cats. Like other host species, the composition and activities of the canine and feline GI microbiota are impacted by dietary macronutrient profile, including protein:carbohydrate ratio and the type and amount of dietary fiber. As is done in non-ruminant livestock species, the inclusion of specific ingredients such as prebiotics and probiotics is common as a means to improve gastrointestinal health but come with mixed results experimentally. Finally, the GI microbiota shifts associated with disease have been studied recently, with many of the phylogenetic and functional changes of dogs and cats being similar to that noted in humans, suggesting a core microbiome among host species.

The issue wraps up with a review of a host species viewed to be both livestock and companion animal, depending on the audience. Venable et al. (2016) discusses the recent microbiome literature applied to equine health and disease. Horses rely heavily on microbial fermentation to meet energy needs but are hindgut fermenters that have an enlarged cecum for this purpose. Despite the importance of the GI microbiota to the horse, a relatively small number of studies have been performed in this species using high-throughput sequencing techniques. The impact of dietary ingredient and/or nutrients on GI microbiota have been measured but have typically focused on fecal populations that may or may not have relevance to the composition and activity in the cecum. Although performance in horses is typically not measured in terms of growth or feed efficiency as it is for the livestock species mentioned above, numerous stressors and challenges exist. Laminitis, travel stress, and GI diseases such as colic, all of which may contribute to or be affected by GI microbiota, are major sources of morbidity and mortality in horses and economically important to the equine industry. Gastrointestinal microbiota populations are known to change with increased age, something that is shared with dogs, cats, and humans, but rarely of concern in the production livestock species. Probiotics and other medications have been used to improve or stabilize equine GI microbiota populations, but results have been inconsistent and may soon be scrutinized by regulatory bodies.

In closing, this timely issue of *Animal Frontiers* focuses on the characterization and importance of the GI microbiota in several livestock and companion animal species as well as in humans, touching on several important agricultural, environmental, and biomedical issues. The microbiome field is a buzz, and for good reason, but it is still in its infancy stage. Given the financial investments being made by federal agencies, private foundations, and industry, and the high-throughput and molecular experimental tools and bioinformatics strategies that are now available, it should continue to be an exciting field to watch in the coming years.

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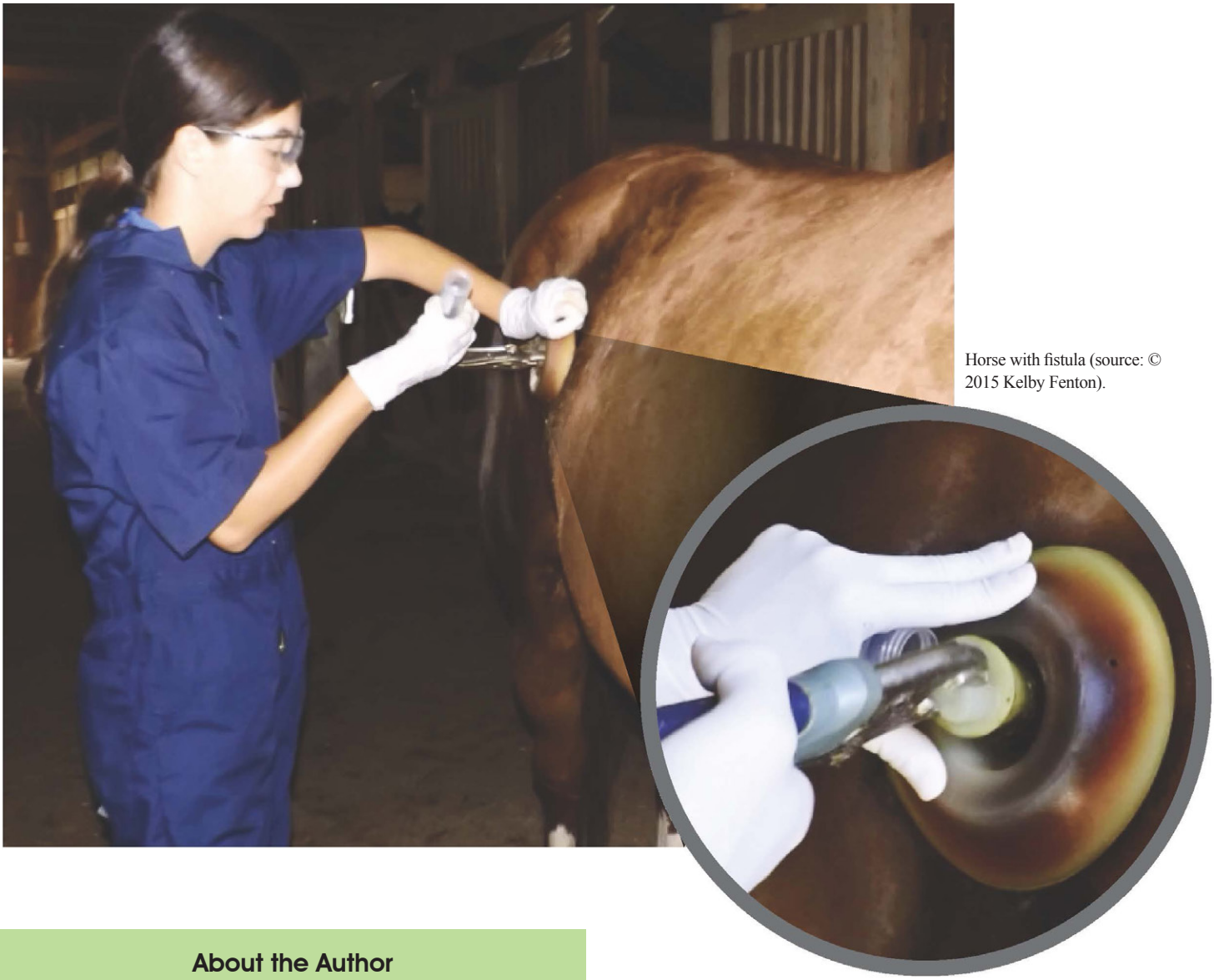

Horse with fistula (source: © 2015 Kelby Fenton).

About the Author

Kelly S. Swanson received his Ph.D. in nutritional sciences at the University of Illinois at Urbana-Champaign (UIUC) in 2002. Following post-doctoral training in functional genomics, he became Assistant Professor at UIUC in 2004 and has since been promoted to Associate (2009) and Full Professor (2014). His lab studies the effects of nutritional intervention on canine and feline health, identifying mechanisms by which nutrients impact gene expression and host physiology, with emphasis on gastrointestinal health and obesity. He has established an internationally recognized research program, highlighted by more than $9 million in research support, 90 invited lectures in 11 countries around the world, 135 peer-reviewed publications, and 11 research and teaching awards. He has trained 24 graduate students and post-doctoral fellows, hosted 11 international visiting scholars/interns, and mentored 23 undergraduate research projects. Dr. Swanson teaches three courses pertaining to companion animal nutrition to veterinary, undergraduate, and graduate students annually and serves on many committees at the departmental, college, and campus level, including the Institutional Animal Care and Use Committee. **Correspondence:** kswanso@illinois.edu

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