

Agbioscience Sector Review: Animal Health and Nutrition

Prepared by:

Battelle Technology Partnership Practice

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In 2013, the Central Indiana Corporate Partnership (CICP) Executive Committee approved the formation of the Indiana Food and Agriculture Innovation Initiative as a strategic initiative under the CICP parent organization. The entity was launched to focus on the growth and development of innovation in the food and agriculture industry (collectively referred to as the “agbiosciences”) within Indiana. Upon securing support from key state, university, and industry stakeholders for an initial period, the entity was re-named and re-branded as AgriNovus Indiana (AgriNovus) in November 2014 and launched as CICP’s fifth industry sector initiative.

AgriNovus capped its first year with the release of a “first-of-its-kind” report that examined the state of the agbiosciences and agricultural technology ecosystem in Indiana, providing its stakeholders and the public with a detailed examination of key food and agricultural innovation drivers in the State. Drafted by the Battelle Technology Partnership Practice (Battelle), this baseline analysis revealed the type and sources of research-based innovation in Indiana. Battelle identified four Innovation Sectors in which Indiana could leverage an existing industrial base along with private and university research to accelerate economic activity. These four Innovation Sectors include:

- Plant science and crop protection
- Animal health and nutrition products
- Value-added human food and nutrition products
- Agricultural equipment technologies and systems.

Each of these sectors has significant potential for future growth and economic development in Indiana, and will serve as guiding areas of collaborative and strategic opportunity for AgriNovus. The full report can be found at: www.agrinovusindiana.com/resources/

To gain a broader perspective on each sector, Battelle has performed additional research on each Innovation Sector. This white paper, “Agbioscience Sector Review: Animal Health and Nutrition”, provides industry trends on the sector, including market statistics, emerging technologies, leading companies, research and regulatory issues. It is one of four white papers that form an “Agbioscience Innovation Sector Series” that will be used by AgriNovus in discussions with stakeholders to identify and develop strategic initiatives for the organization. AgriNovus is also pleased to make these four white papers available to the public at www.agrinovusindiana.com.



Agbioscience Sector Review: Animal Health and Nutrition

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I. What Does This Sector Do?

The animal health and nutrition market focuses on providing the therapeutics, diagnostics, biologics, and nutrition/feed products to maintain the health and productivity of the more than 3 billion livestock and more than 50 billion poultry found worldwide. It also focuses on ensuring the nutritional value of the food it produces, as well as the health and well-being of companion animals. Although the animal health and nutrition market is large in terms of the volume of livestock and poultry, it should be noted that the human healthcare market is 30 times larger monetarily than the combined market for all nonhuman species.¹ On average, the world spends only about one-fortieth of the amount it devotes to human medicines on animal medicines. Still, animal health-related therapeutics and diagnostics must undergo similar testing and strict regulations found for human health products.²

The animal health and nutrition sector includes industries engaged in all aspects of animal health and nutrition, including medicines and vaccines, diagnostic and testing services, veterinary and breeding services, and animal nutrition products. In contrast to human blockbuster-oriented pharmaceuticals, animal health is dominated by a large number of products with small revenues. Although there are hundreds of products offered in the animal health market, only a couple of dozen products have sales exceeding \$100 million per year.³ In an increasingly risky environment for new product development, the difference between success and failure in the future usually lies in successfully identifying the next growth segment, developing the right product candidates, and being the first to market.

II. Primary Drivers of Growth

The past half-century has seen marked growth in food production, allowing for a dramatic decrease in the proportion of the world's population that is hungry. The innovations that spurred this growth were driven primarily by what is now referred to as the Green Revolution – a series of research, development, and technology transfer initiatives that occurred between the 1940s and the late 1960s that increased agricultural yield worldwide. The initiatives, led by the work of Norman Borlaug – credited as being the "Father of the Green Revolution" – focused primarily on improvements in agricultural production and involved the development of high-yielding varieties of cereal grains, expansion of irrigation infrastructure, modernization of management techniques, distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers.

Even with these significant technological advancements, more than one in seven people today still lack access to sufficient protein and energy from their diet, and even more suffer from some form of micronutrient malnourishment. The Division of the United Nations Department of Economic and Social Affairs (UNDESA) projects that global population, which was roughly 6.5 billion in 2006 and 7 billion in 2012, will grow to 9.6 billion by 2050. At least 3 billion more people are predicted to enter the global middle class by 2030, and as a result of their increase in personal income, will more than likely demand more resource intensive foods such as meats and vegetable oils.

While the demand for food continues to increase, tension is rising as food producers are experiencing greater competition for land, water, and energy, and the environmental impact of some of the Green Revolution's innovations are becoming increasingly clear. A threefold challenge now faces the world: match the rapidly changing demand for food from a larger and more affluent population to its supply; do so in ways that are environmentally and socially sustainable; and ensure that the world's poorest people are no longer hungry. This challenge requires changes in the way food is produced, stored, processed,

¹ BCC Research, Global Markets for Animal Therapeutics and Diagnostics, 2015.

² See <http://www.ahi.org/about-animal-medicines/industry-statistics/>

³ BCC Research, Global Markets for Animal Therapeutics and Diagnostics, 2015.

distributed, and accessed that are as radical as those that occurred during the 18th- and 19th-century Industrial and Agricultural Revolutions and the 20th-century Green Revolution.⁴

It is the global growth of affluence and the middle class that is going to have the greatest impact on the livestock and poultry industry. The World Health Organization puts the challenge succinctly:

There has been an increasing pressure on the livestock sector to meet the growing demand for high-value animal protein. The world's livestock sector is growing at an unprecedented rate and the driving force behind this enormous surge is a combination of population growth, rising incomes and urbanization. Annual meat production is projected to increase from 218 million tonnes in 1997-1999 to 376 million tonnes by 2030.⁵

The animal health and nutrition sector is tasked with the global grand challenge of meeting the demands of a rapidly expanding worldwide population with the purchasing power to afford livestock and poultry product. Ideally, it has to do so without pressing more marginal lands into grazing (causing ecological damage), or forcing more arable land into production to provide livestock feed. To meet demands in a sustainable fashion, advancements need to be made in the breeding, health, and nutrition of livestock and poultry whereby meat yield, milk production, and egg production are increased per animal.

Gaining marginal increases in yield from livestock and poultry is especially important because they consume significant resources. It is reported by the World Health Organization that the number of people fed in a year per hectare ranges from 22 for potatoes and 19 for rice to just 1 and 2, respectively, for beef and lamb.

A series of individual and interrelated factors are evident in driving opportunities and growth in the agriculture sector. Chief among these are discussed in Table 1.

Table 1: Factors Influencing Sector Growth

Factor	Implications for Growth and Development Opportunities
Population growth	Today, the global human population stands at 7.27 billion. In a decade's time (2024), the United Nations projects global population will pass the 8 billion mark, expanding to 9 billion by 2040 and 10 billion by 2062. ⁶ Thus, by 2062 there could be as many as 2.7 billion more people to feed on the planet (yet almost all land on Earth suitable for agricultural and livestock production is already being used).
Wealth growth (expansion of disposable income and per capita consumption)	Increasing incomes, driven largely by global industrialization, are correlated with increasing demand for processed foods, packaged foods, high energy foods and meats. These “developed world” foods consume considerably more resources in their production than basic foodstuffs. Increasing food demand is therefore not only caused by rising population but also increasing per capita consumption. “People who are initially undernourished obtain access to more food calories, they first go through an expansion phase where diets contain more food—typically, grains, roots, tubers and pulses—and then a substitution phase, where the latter are replaced by more energy-rich foods such as meat and those with a high concentration of vegetable oils and sugar. Typically the production of high-energy food requires more resources

⁴ H. Charles J. Godfray. “Food Security: The Challenge of Feeding 9 billion People”. Science, Vol. 327, no. 5967, pp 812–818. Published January 28, 2010.

⁵ World Health Organization. Programmes and Project: Availability and change in consumption of animal products.” Accessed online at: http://www.who.int/nutrition/topics/3_foodconsumption/en/index4.html

⁶ Statistics accessed at <http://www.worldometers.info/world-population/>

	(for example, instead of grain being directly consumed by humans, it is used as animal feed for livestock production which is then consumed by humans.) ⁷ It takes approximately 8kg of grain to generate 1kg of beef, 6kg for 1 kg of pork, and 2kg for 1 kg of chicken meat. ⁸
Climate change	Agriculture and livestock production contributes to global climate change (via deforestation, carbon dioxide emissions, and methane emissions), and agricultural production yields are directly impacted by changing climatic conditions likely to exacerbate extreme weather, droughts, and the geographical range of crop pests and diseases. Innovations are required to reduce the climate change exacerbation factors associated with agriculture and to adapt crops to changing biotic and abiotic stress factors associated with climate change.
Environmental protection	The vast majority of available cultivable land globally is already in production. Most of the unexploited land is either too steep, too wet, too dry, too cold ⁹ or too ecologically important for agriculture. In addition, poor farming practices in much of the developed world are degrading existing farmland – in terms of direct soil erosion, soil nutrient depletion, and soil salinity increases. The pressing of more marginal lands into agricultural and livestock production causes natural habitat losses and reductions in global biodiversity. (Scientific American reports 80,000 acres of tropical rainforest and 135 species of organisms lost daily). In addition, non-sustainable agricultural practices generate significant water pollution, aquifer depletion, and greenhouse gas emissions.
Resource use efficiencies	There is a need for crops that are able to produce the same yield or even enhanced yield with reduced application of inputs (such as water, light, fertilizer, and crop protection chemicals). Demand in this regard is driven by the related factors of needing to reduce the environmental impacts of agricultural chemicals, reduce to sustainable levels the use of scarce water resources, and provide solutions for resource poor developing world farmers who may be unable to afford modern agricultural chemicals. Water use efficiency is a particularly important goal. The UN FAO reports that 70 percent of freshwater resources are consumed by agriculture annually (whereas 19 percent is consumed in industrial processes, and just 11 percent is used for municipal consumption). ¹⁰ Freshwater withdrawals have tripled in the last 50 years, and current usage levels are unsustainable in much of the world.
Evolving and emerging diseases and pests	Because agriculture is an inherently biological production system, it is subject to the laws of nature that govern processes of organismal evolution and adaptation. Seed and crop protection solution providers are in a constant innovation race against the emergence of pests (e.g. insects, weeds, and pathogens) resistant to current chemicals and control strategies. It is

⁷ H. Charles J. Godfray, et al. "The future of the global food system." Phil. Trans. R. Soc. B (2010) 365, 2769–2777.

⁸ Jonathan Watts. "More wealth, more meat. How China's rise spells trouble." The Guardian, May 29, 2008.

⁹ Human Appropriation of the World's Food Supply.
http://www.globalchange.umich.edu/globalchange2/current/lectures/food_supply/food.htm

¹⁰ United Nations Food and Agriculture Organization http://www.fao.org/nr/water/aquastat/water_use/index.stm

	anticipated that climate change will exacerbate pressures as it will likely shift the geographic range of a broad variety of crop pests.
A need for healthier foods	Poor diets and unhealthy food choices by consumers lead to negative health outcomes: both in terms of malnutrition at one end of the spectrum and obesity at the other. Many in the developed world eat unbalanced diets, high in sugars and fats – diets that contain far more calories than are required to provide sustenance resulting in obesity and other health disorders (such as diabetes and cardiovascular disease). In the developing world, it is estimated that over 800 million people suffer from malnutrition, whereby their readily available food supply provides an insufficient nutrient profile for health. Both behavioral changes and technological solutions are required to combat the evident nutrition profile gap that exists across the globe. The development of “foods for health” – foods with robust nutrition characteristics associated with a healthy diet are needed, and in some instances this may require the development of staple crop plant-based foodstuffs with enhanced nutrient and vitamin content. Similarly, technologies that improve the taste, smell, and other sensory inputs during human consumption can also enhance utilization of more healthy foods.
Reduce food waste	Technologies and practices that would reduce food loss and waste could significantly increase food supplies and provide significant environmental and economic benefits. Currently loss and waste of food occurs along the entire post-harvest value chain. The UN FAO estimates that approximately 32 percent of food (by weight) is lost ¹¹ or wasted in the current global food system. The World Resources Institute (WRI) estimates that this translates into 24 percent of all available food energy being lost or wasted overall. The WRI notes that cutting food waste and loss in half by 2050 could close 20 percent of the projected food gap. ¹²
Changes in consumer behavior	The agbiosciences is driven, at the end of the day, by ever evolving human consumption patterns, which at times are in conflict with the other global challenges detailed above. Whether it is the desire for a local food movement (localvore movement) in towns across the nation, the growing negative sentiment towards the use of antibiotics in livestock production, the organic food movement that has been a market force since the 1970s but growing ever stronger, or the growing desire by many consumers to better understand how to impact their health through the food choices made, the bottom line is that how agricultural commodities are grown, processed, and manufactured into final food products will continue to be driven by the evolving nature of consumer preference.

¹¹ Loss” refers to food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer. “Waste” refers to food that is of good quality and fit for consumption, but is not consumed because it is discarded after it reaches consumers—either before or after it spoils. Source: UN FAO.

¹² World Resources Institute. 2013. “Creating a Sustainable Food Future.”

These global challenges are further exacerbated by the fact that the global livestock sector is highly dynamic. In developing countries, as noted above, it is evolving in response to rapidly increasing demand for livestock products. In developed countries, while the overall demand for livestock products is quite high, it is also beginning to stagnate. At the same time, production systems are increasing their efficiency. Global livestock production has increased substantially since the 1960s. Beef production has more than doubled, while over the same time, chicken meat production has increased by a factor of nearly 10, made up of increases in both number of animals and productivity. Carcass weights increased by about 30 percent for both chicken and beef cattle and by about 20 percent for pigs. Increases in milk production per animal have amounted to about 30 percent for cows' milk, and egg production per chicken has experienced the same level of increases in productivity.¹³

Livestock systems occupy about 30 percent of the planet's ice-free terrestrial surface area and are a significant global asset with a value of approximately \$1.4 trillion. The livestock sector is increasingly organized in long market chains that employ more than 1.3 billion people globally.

Historical changes in the demand for livestock products have been largely driven by human population growth, income growth, and urbanization. The increased production response has been driven by advancements in science and technology as well as increases in animal numbers. In the future, efficiencies gained through developments in breeding, nutrition, and animal health will increasingly be affected by competition for natural resources, particularly land and water, competition between food and feed, and by the need to operate in a carbon-constrained economy. Livestock production will likely also be increasingly affected by environmental and animal welfare legislation. Demand for livestock products in the future could also be heavily moderated by socio-economic factors such as human health concerns and changing socio-cultural values. There is considerable uncertainty as to how these factors will play out in different regions of the world in the coming decades.

Another challenging aspect of the animal health and nutrition market is found within the animal feed and primary production industries as consumers continue to express concern about the conditions under which their daily food is produced. Furthermore, consumers are becoming more health conscious, and demanding healthy and balanced diets. The growing trend of natural and organic food is creating a niche market opportunity for suppliers. By implementing a feeding plan that provides vitamins and supplements, consumers enjoy additional nutritional benefits. Additionally, healthy feeding results in minimized impact on the environment.

Many of the challenges and demand-side factors noted in Table 1 have a direct relationship to potential solutions that may be derived from innovation in animal health and nutrition. Examples are discussed in Table 2.

¹³ Philip K. Thornton. "Livestock production, recent trends, future prospects." *Phil. Trans. R. Soc. B* (2010) 365, 2853–2867.

Table 2: Potential Animal Health and Nutrition Solutions to Agbioscience-Related Challenges

Challenge	Animal Health and Nutrition Platform – Potential Solutions
Population growth	The development of high productivity livestock species able to meet demands under conditions of increasingly constrained inputs (such as feed and water) is required. Breeding livestock that grow faster, gain weight faster, or convert feed into leaner meat can contribute to yield enhancements. Modern gene editing techniques can be used to accelerate breeding for enhanced production traits.
Wealth growth (expansion of per capita consumption)	The animal health and nutrition sector is working to meet the predicted consumer consumption patterns of the 3 billion more people who are predicted to enter the global middle class by 2030, and as a result of their increase in personal income, will more than likely demand more protein intensive foods.
Climate change	The development of livestock breeds that have lower levels of methane emissions is a strategic goal for a number of research groups. Methane is produced from the digestive processes of livestock, and also is generated from manure stored in lagoons and holding tanks.
Environmental protection	Multiple environmental issues are associated with livestock and poultry production and require R&D-based solutions. Issues are associated with the handling of livestock manure such as: nutrient runoff; antibiotics excretion; pathogen distribution; and air quality.
Resource use efficiencies	Increased water use efficiency in livestock agriculture is an important goal. There is also a distinct need to improve the feed use efficiency of livestock and poultry, thereby reducing the volume of agronomic land dedicated to producing feed.
Evolving and emerging diseases and pests	The animal health sector plays a critical role in developing antibiotics, therapeutics, vaccines, parasite, and pest control strategies that are highly important to sustaining and increasing animal agriculture yields. Research is also taking place in products to address the emergence of livestock-related zoonotic diseases that pose a threat to human health.
A need for healthier foods	Livestock breeding and genetics can be used to develop breeds with leaner meat that is lower in fat and cholesterol content. In the future, genetically modified animals may be used to produce products with enhanced downstream health benefits for humans, such as increased omega-3 fatty acid content.
Reduce food waste	Animal health products (vaccines, diagnostics, therapeutics, etc.) play a crucial role in sustaining livestock and poultry health and reducing on farm losses due to disease. Post-harvest processing and packaging technologies also serve to reduce product spoilage and food waste.
Changes in Consumer Behavior	Consumer demands for healthier lower fat meats, livestock and poultry produced in organic production systems, non-traditional meats (e.g. expanding demand for meat goats in the U.S.) each require agbioscience-based R&D.

The varied challenge factors and potential technological-solution categories outlined above combine to provide for a bright future for companies with significant R&D and new product innovation capabilities in these market spaces. Battelle has access to a broad library of proprietary market research resources, and some key data points evident in a review of market projections are highlighted in the next section.

III. Market Statistics, Growth Trends and Projections

Global demand for animal health and nutrition products is projected to continue along a growth trajectory based upon both an expanding human population and increasing purchasing power (which is correlated with an increasing demand for livestock products). As with crops, the vast majority of sustainably utilized land for livestock worldwide is already in production. Achieving significant growth in the industry to meet rising demand will require the production sector to increase productivity. Innovations in livestock productivity will come through three primary channels:

- **Breeding and genetic improvement of livestock** – Livestock producers in the developed world are using both traditional breeding and modern molecular genetics techniques to identify livestock with enhanced productivity traits and to increase the production of lines with the positive production traits. Widespread adoption of artificial insemination techniques greatly facilitates the procreation of improved lines.
- **Enhanced nutrition and feed products** – Meeting the energy, protein, mineral, and vitamin needs of ruminant and non-ruminant livestock is another key technological focus. Advanced knowledge of livestock digestion, gut metagenomics, and other factors are promoting the development of highly accurate and customized feed and nutrition supplement regimens.
- **Veterinary medicine** – Animals contracting diseases or parasites have to use feed energy resources to fight their illness, instead of using these energy resources to grow. Productivity is lost to livestock illnesses, and a considerable volume of antibiotics and other drugs are used in livestock production to counteract disease and parasite-driven productivity losses. In addition major disease outbreaks (e.g. BSE, Foot and Mouth, Avian Influenza, etc.) can lead to the culling of entire herds/flocks and large-scale economic losses. As such, veterinary medicine is an integrated component of modern animal agriculture.

These drivers of animal health and nutrition are comprised of four primary markets¹⁴:

- **Pharmaceuticals** account for the largest percentage of animal health and nutrition revenues with nearly 42 percent of the market. Pharmaceuticals include a number of drug classifications, including allergy treatments, anti-infectives, anti-inflammatories, metabolic drugs, parasite control, and other specialized drugs. Sales for animal pharmaceuticals were estimated at \$15.9 billion for 2014. The growth of this segment is expected to remain steady at roughly 3.7 percent CAGR through 2019 when the market is anticipated to reach \$19 billion.
- **Feed additives** are the second-largest market segment due to demand from production animal producers. The market increased in value in 2014, reaching an estimated value of \$13.4 billion. Amino acids represent the largest share of this market with other sub-segments such as nutritional additives, medicinal additives, and vitamins contributing to this growing market. By 2019 sales are projected to increase to nearly \$16.3 billion, a CAGR of 4.0 percent.
- **Vaccines**, including prophylactic vaccines, therapeutic vaccines, immunotherapies, and other biologics, is a smaller market segment but with strong growth. In 2014, vaccine products were estimated to be valued at almost \$6.2 billion. The growth of this segment is expected to remain strong at roughly 5.3 percent CAGR through 2019 when the market is anticipated to reach \$8 billion.
- **Diagnostic products**, which account for the smallest share of the market with nearly \$2.4 billion in estimated sales in 2014, is also the fastest growing segment of the market. The market segment is expected to grow at a CAGR of 6.2 percent, increasing to nearly \$3.2 billion in 2019. Products in this segment include rapid testing products, clinical laboratory equipment, and imaging equipment. This segment excludes laboratory services and fees.

¹⁴ BCC Research, Global Markets for Animal Therapeutics and Diagnostics, 2015.

The animal health and nutrition market can also be divided into the production animal and companion animal market segments:

- The **production animal market** segment overall has shown steady growth over recent years. In 2014, the market for production animal health and nutrition products was valued at nearly \$23.7 billion, increasing by \$1.1 billion compared to 2012. The market is expected to show healthy growth through 2019, reaching \$28.6 billion, or a 3.9 percent CAGR. Driving this market segment will be the demand by consumers for safe and healthy meat products and a growing industry in developing markets.
- The **companion animal market** segment is experiencing steady growth. In 2014, the companion animal market was estimated at nearly \$14.1 billion, growing by nearly \$1.0 billion over the past three years. The market is expected to generate approximately \$17.8 billion in revenues by 2019, a CAGR of 4.7 percent from 2014 through 2019. Companion animal sales represent the fastest growth segment in the animal health and nutrition market.¹⁵

It is also important to understand the size of the overall animal feed industry. The International Feed Industry Federation places the size of the global commercial feed production industry at \$370 billion.¹⁶ IBISWorld, in its December 2012 report on the U.S. farm animal feed industry, shows industry revenues of \$31.7 billion with annual growth between 2012 and 2017 projected to be 1.4 percent.¹⁷ The IBISWorld report projects that 39.8 percent of U.S. feed production is for dairy and beef cattle feed; 37.7 percent for poultry; 21.5 percent for swine; and one percent for other livestock species.

Among the key market drivers involved in animal health and nutrition are:

- Increased consumer interest about the conditions under which their food is produced, and requiring improved feeding plans and more proactive approaches on disease control.
- Increased FDA scrutiny on food safety.
- Growing concerns about antibiotic resistance and its impact on humans.

While the market for animal health and nutrition is generally considered to be competitive and fragmented, divisions of major pharmaceutical companies do dominate across all segments of the market, and a number of acquisitions and mergers over the years has consolidated the industry among the top competitors. As previously noted, the animal health and nutrition industry is dominated by large numbers of products with relatively small revenues. Although there are hundreds of products offered in the animal health market, only a couple of dozen products have sales exceeding \$100 million per year.¹⁸

IV. Technologies and Emerging Opportunities

The animal health and nutrition sector presents opportunities and demands for innovation and new technology development across a range of sub-platforms. Chief among these, are likely to be:

- Breeding and genetics
- Enhancing nutrition
- Disease prevention, detection and treatment.

¹⁵ Ibid.

¹⁶ <http://www.ifif.org/pages/t/The+global+feed+industry>

¹⁷ IBISWorld. December 2012. "IBISWorld Industry Report OD4613: Farm Animal Feed Production in the U.S."

¹⁸ BCC Research, Global Markets for Animal Therapeutics and Diagnostics, 2015.

A. Breeding and genetics

Description	Breeding and genetics improvement aims to enhance the desirable characteristics of livestock and poultry. It may include traditional selective breeding, marker assisted selection, and molecular breeding techniques, and draws upon analytical disciplines such as population genetics, quantitative genetics, biostatistics, and molecular genomics. Targeted goals for livestock and poultry improvement may be varied, including: enhanced animal growth rates; increased muscle mass; feed use efficiency; meat quality; disease resistance; or the production of specific animal products such as milk, wool, or eggs.
Examples	<p>Breeding and molecular genetics can be utilized in various applications within livestock agriculture, including for example:</p> <ul style="list-style-type: none">• Traditional selective breeding and marker-assisted breeding of livestock and poultry with traits associated with enhanced yield.• Traditional selective breeding and marker-assisted breeding of livestock and poultry with traits associated with quality or meat characteristics (such as enhanced marbling in beef).• Animal transgenics and/or gene editing to transfer genes associated with desired traits (such as hornless cattle, or disease resistance) from one species to another or within a species.• Analysis of livestock digestion, rumen microbiota, and breeding of livestock for reduced methane production.• Development of high value “zoopharming” whereby high value proteins or medical compounds are produced in genetically modified livestock species. <p>In the companion animal space, breeding may be deployed to “create” varieties of companion animals with desired aesthetics or behavioral characteristics or, in the case of “working” animals (such as dogs, racehorses, etc.) desired performance characteristics.</p>

B. Enhancing nutrition

Description	<p>An animal feed additive is defined as an ingredient or combination of ingredients added to the basic feed mix or parts thereof to fulfill a specific need. The additive is usually used in micro quantities requiring careful handling and mixing. In modern livestock production, animals are normally kept under environmental conditions that are as balanced as possible to assist health protection and growth. This means that there are often a large number of livestock in the same protective environment.</p> <p>Significant research is ongoing in the prediction of animal growth, body composition, feed requirements, and the outputs of waste products from the animal as it relates to production costs. Such work helps improve the efficiency of livestock production and meets the expectations of consumers and the demands of regulatory authorities. Advances in genomics, transcriptomics, proteomics, and metabolomics will continue to contribute to the field of animal nutrition and predictions relating to growth and development. Better understanding of the processes involved in animal nutrition could also contribute to improved management of some of the trade-offs that operate at high levels of animal performance, such as those associated with lower reproductive performance.</p>
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Examples	<ul style="list-style-type: none"> • Nutritionally enhanced feed supplements and additives to provide a balanced profile of vitamins, trace elements and minerals (organic and inorganic), proteins and amino acids to assist in areas such as increasing daily gain and feed conversion efficiency. • Probiotics for amendment or optimization of livestock digestion and feed conversion efficiency. • Milk fortifiers (containing balanced vitamin, mineral and other diet enhancements) for young livestock. • Forage treatment products for increasing fermentation efficiency in various forms of silage operations. • Special feed mixes and formulations optimized for use at various animal development stages (such as for lactating dairy cows, feedlot cattle, weaning rations, rapid recovery of animal post-shipping, etc.). • Development of alternative feeds based on economically beneficial alternative grains (e.g. sorghum or millet-based feeds) • Evaluation and development of agricultural co-products and biofuel co-products for applications in animal feed. • Advanced pet/companion animal foods with desirable characteristics such as ease of handling, protein and general nutrition content, or specialized applications such as Omega 6 fatty acids or other constituent elements imparting a healthy skin or coat. May also include specialized therapeutic diets for the nutritional management of conditions such as enteritis, gastritis and diarrhea.
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C. Disease prevention, detection, and treatment

Description	<p>This arena comprises the science of protecting livestock from disease causing pathogens and parasites. Approaches to livestock protection are varied, ranging through: disease surveillance; infectious disease diagnostics; prevention of disease via vaccines or vector control; and the development of animal health products such as veterinary biopharmaceuticals. More broadly, it can also incorporate approaches to generally improve the health of livestock thereby strengthening immune systems, and the design of animal production environments to reduce animal stresses and disease-propagating conditions. Livestock protection can also link to animal breeding and genetics, with potential approaches focused on the breeding of livestock for innate disease resistance characteristics.</p> <p>Animal diseases generate a wide range of biophysical and socio-economic impacts that may be both direct and indirect, and may vary from localized to global. The economic impacts of diseases are increasingly difficult to quantify, largely because of the complexity of the effects that they may have, but they can be extremely large: the total costs of foot-and-mouth disease in the UK, for example, may have amounted to \$18–25 billion between 1999 and 2002.</p> <p>The last few decades have seen a general reduction in the burden of livestock diseases, as a result of more effective drugs and vaccines and improvements in diagnostic technologies and services. At the same time, new diseases have emerged, such as avian influenza H5N1, which have caused considerable global concern about</p>
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the potential for a change in host species from poultry to man and an emerging global pandemic of human influenza.

For the future, the infectious disease threat will remain diverse and dynamic, and combating the emergence of completely unexpected diseases will require detection systems that are flexible and adaptable in the face of change. Travel, migration, and trade will all continue to promote the spread of infections into new populations. Trade in exotic species are likely to be increasing causes of concern, along with large-scale industrial production systems, in which conditions may be highly suitable for enabling disease transmission between animals and over large distances.

Examples

Future disease trends are likely to be heavily modified by disease surveillance and control technologies. Potentially effective control measures already exist for many infectious diseases, and whether these are implemented appropriately could have considerable impacts on future disease trends. Recent years have seen considerable advances in the technology that can be brought to bear against disease, including DNA fingerprinting for surveillance, polymerase chain reaction tests for diagnostics, and understanding resistance, genome sequencing, and antiviral drugs. There are also options associated with the manipulation of animal genetic resources, such as cross-breeding to introduce genes into breeds that are otherwise well-adapted to the required purposes, and the selection via molecular genetic markers of individuals with high levels of disease resistance or tolerance.

For both livestock and companion animal species there are multiple areas of potential technology development:

- Rapid disease diagnostic kits
- Sensor systems for detection of pathogens or parasites
- Vaccines for infectious diseases and parasites
- Antibiotics
- Disinfectants and on-farm sanitation products
- Epidemiological tools and decision support systems
- Animal disease treatment products (e.g. cancer therapeutics, arthritis drugs, allergy treatments, respiratory disease therapeutics, etc.)
- Bio-protection products for control of pests and disease vectors (e.g. rats, flies, mosquitoes, ticks, etc.)

D. Other Critical Needs

Science and technology-based solutions to the global food security challenge, and realizing the opportunities for economic development from animal health and nutrition innovations, unfortunately do not only depend solely upon scientific progress. While a robust scientific R&D infrastructure is a precursor to progress, other important factors also influence development potential. Currently a notable barrier to animal health and nutrition innovation is the lack of risk capital available to small and mid-size firms that are pursuing advancements in this area.

Another critical need is helping to ensure that the political and regulatory framework in the U.S. and within individual states (and in crucial international markets) follows scientific rational methods. The global challenges for which agriculture promises solutions cannot be met if unnecessary barriers, often rooted in unfounded fears and misinformation surrounding advanced life science technologies or environmental impacts, are allowed to proliferate unchallenged. Certainly, intensive livestock agriculture presents environmental and other challenges moving forward, but the unabated growth in worldwide livestock

product consumption predicted for the next three decades or more make it imperative that balanced decisions be reached from a sustainable food systems perspective that can still meet projected demands.

Ultimately, the success of Indiana's efforts to build upon the existing agbioscience cluster in the state will depend not only on the R&D that takes place in Indiana (or the acquisition of external innovations by Indiana companies), but also upon attention being paid to the additional factors that influence the growth of science-based and technology-based innovation ecosystems. The State of Indiana and AgriNovus will need to help ensure that Indiana maintains solid levels of performance on the key factors for agbioscience cluster development noted by Battelle in Table 3.

Table 3: Characteristics for Agbioscience and Animal Health and Nutrition Geographic Hubs

Success Element	Description
Presence of major multi-national agbioscience corporations (especially R&D operations of these companies)	The animal health and nutrition sectors are quite diverse in their industry base, but there are several large global R&D and production companies that have considerable market influence. Examples include Bayer, Boehringer Ingelheim, Elanco, Merck, Merial-Sanofi, Novartis, and Zoetis. The presence of one or more of these agbioscience corporate leaders greatly enhances hub prospects.
Presence of major academic or independent research institutes with a robust program of agbioscience R&D and world-class infrastructure	In the U.S., academic agbioscience R&D is heavily concentrated in major Land-grant Universities and a few specialized independent R&D institutes. It is notable that rather than being a focus of most research universities, agbioscience tends to be a more specialized undertaking concentrated in less than 50 major institutions with a long standing tradition of agricultural research and extension activity. A similar pattern of agbioscience being concentrated in a comparatively compact number of leading institutions is seen globally. In the U.S., the presence of a leading Land-grant University with substantial agbioscience R&D activity is a significant advantage in hub development.
Presence of government agbioscience R&D institutes	Because of the importance of agriculture and livestock production, and the proportion of national land mass dedicated to it, national governments have tended to be active participants in agbioscience research. In the U.S., this is a clear focus of the U.S. Department of Agriculture (USDA) and its Agricultural Research Service. The USDA maintains multiple intensive research sites across the nation with a focus on livestock production and animal health, and the presence of USDA labs is an advantage for these locations.
Diverse agronomic production environment	All other things being equal, a state or nation with a more diverse agronomic, climactic, and soils environment will have an advantage in research and development across a diversity of crops and livestock species. In particular, those locations that possess a significant number of established experiment stations and research farms distributed across a variety of environments have an advantageous position for R&D and the demonstration of new technologies.
Engaged and collaborative stakeholder groups	Technology-based economic development is enhanced by collaborative environments in which academic, industry, government, and other key stakeholder groups cooperate and communicate with one another. Those

	locations that have organizational structures in place to facilitate collaborative engagement have an advantage.
A business environment conducive to entrepreneurial business development	Frontier areas of agbioscience (such as microbiomics, advanced phenotyping, precision agriculture, livestock pharmaceuticals, big data analytics, etc.) present significant opportunities for new business development around the commercialization of innovations. While R&D can lead to innovations anywhere, it requires a special environment to support the establishment and growth of new business ventures. Those locations that are skilled in technology transfer, intellectual property management, entrepreneurial business management, business incubation services, and early-stage capital access have a distinct advantage.
Presence of a science-based regulatory and policy environment that is predictable over the long-term	Politicians and regulators hold considerable influence over the conditions under which business operates and it is imperative that industry experiences a stable and predictable regulatory and policy framework within which it can invest and grow. Unpredictable, ad hoc regulation changes can greatly hamper industry success, and likewise industry needs to be able to trust that policies and regulations will be science-based and not rooted in unrelated political agendas or loose public opinions. This is particularly important in livestock agriculture where concerns over animal welfare, environmental impacts (such as odors, nutrient runoff, and methane emissions), livestock health products (such as antibiotics), the use of growth hormones, and zoonotic disease outbreaks, can promote significant debate.
The presence of a robust education and workforce development pipeline meeting the needs of R&D and industry sectors	Agbioscience, animal science, and veterinary medicine are high-tech, knowledge-based sectors that run on the skills and capabilities of a well-educated workforce. Industry requires PhD trained scientists, skilled technicians, and lab and field workers able to work in a dynamic multi-disciplinary scientific environment. Places with an existing base of workers already employed in agriculture, animal, and veterinary bioscience are at an advantage because knowledge-workers tend to be attracted to locations where clusters of peers exist (providing multiple job opportunities without the need for relocation). Similarly, robust academic programs are required to maintain the workforce pipeline and to support continuing education.

The rewards for getting the economic development equation right for animal health and nutrition growth are likely to be significant. If a state or region achieves a robust position as a major global hub in this sector, it may expect to achieve economic development and job growth via:

- Attraction of significant external funds to support research and development, thereby creating high paying science and technology R&D jobs.
- Attraction of existing industry to the region to undertake R&D and production activities.
- Further growth of existing regional sector industries.
- Growth of new entrepreneurial businesses commercializing R&D outputs.
- Transfer of technologies to regional industry and agricultural sectors that enhance productivity or provide new products and services for sale.
- R&D-based solutions to challenges hampering sector growth and development.

V. Major Companies Operating in this Sector

Although the animal health market is supplied by more than 350 manufacturers and suppliers, there are only about 11 companies that produce sales of \$1 billion or more. These companies are listed in Table 3.

Table 3: Major Companies in the Animal Health and Nutrition Sector

Company	HQ Location	Main Products
BASF Animal Nutrition (BASF SE)	Germany	The animal nutrition division of BASF is a leading provider of innovative, quality animal feed additives. The company provides feed additives to the amino acid, medicinal additive, nutritional supplement, and vitamin segments of the market.
Bayer Animal Health	Germany	Bayer Animal Health, a division of Bayer AG, has two divisions: livestock and companion animals. Products include anti-infectives, vaccines, parasiticides, and pharmacological agents.
Bluestar Group	China	Nutritional additives for animal feed in the areas of amino acids, vitamins, enzymes, minerals, and trace elements. In 2006, Bluestar acquired the leading feed additive developer based in France, Adisseo. In 2014, Bluestar was estimated to be the second-largest producer of feed additives worldwide.
Boehringer Ingelheim	Germany	Boehringer Ingelheim's animal health division, including its U.S. animal health division (Vetmedica located in St. Joseph, Missouri) is focused on biologicals, pharmaceuticals, and natural products for the healthcare of swine, small animals, horses, and cattle. The development of new products, such as vaccines, is a key component of the company's growth strategy.
DSM Nutritional	Switzerland	DSM Nutritional Products provides nutritional and medicinal feed additives to the animal health industry. It was formerly known as Roche Vitamins and Fine Chemicals. Today, DSM Nutritional Products is a world market leader in vitamins, carotenoids, eubiotics, and feed enzymes.
Elanco Animal Health, a division of Eli Lilly & Co.	Indiana, USA	Elanco develops and markets products and services to improve animal health and protein production by focusing on developing treatments for some of the most harmful diseases in animal health, as well as providing products that target common threats and growing medical conditions. In September 2014, Elanco announced a partnership agreement with Dow AgroSciences to research and develop integrated solutions for livestock producers to increase meat and milk production. Also in 2014, the company announced two major agreements to acquire animal health businesses, including the Novartis Animal Health Division. The Novartis deal, worth \$5.4 billion, is for a wide range of animal health products with annual sales

		of more than \$1 billion. The other animal health business agreement is for Lohmann Animal Health, a producer of poultry vaccines and feed additives.
Evonik Industries AG	Germany	Evonik's Health & Nutrition Business manufactures and markets amino acids for animal nutrition. It uses an advanced amino acid analysis system it uses to produce animal feeds.
Merck Animal Health	New Jersey, USA	Merck Animal Health is the animal health division of Merck & Co. Merck merged with Schering-Plough in 2009 and retained the Merck name. Company products include: antibiotics, vaccines, anti-inflammatories, production efficiency products, poultry products, ear ointments, anthelmintic (dewormer), and aquaculture products.
Merial, a division of Sanofi	Georgia, USA	Sanofi acquired Merial in 2009 and integrated the company into its business as its dedicated animal health unit in 2011. Merial Animal Health has a history of groundbreaking innovation that includes two blockbuster products—Ivomec and Frontline. Merial reported net sales of animal health products for 2013 of approximately \$2.6 billion.
Zoetis (previously Pfizer Animal Health)	New Jersey, USA	In 2013, Pfizer split off its Animal Health business with the launch of Zoetis Inc. Zoetis currently focuses on the discovery, development, manufacturing, and marketing of animal vaccines and medicines. It provides leading products in both the companion animal and livestock industries.

Source: Global Markets for Animal Therapeutics and Diagnostics. BCC Research report number HLC034D

In addition to the above listed companies generating significant sales in this industry, many of them hold the number one, two, or three position in one of the four market segments discussed below.

As discussed in the market research section, four major market segments comprise the animal health and nutrition industry sector:

- **Pharmaceuticals** account for the largest percentage of animal health and nutrition revenues with nearly 42 of the market. Sales for animal pharmaceuticals were estimated at \$15.9 billion for 2014.
- **Feed additives** are the second-largest market segment due to demand from production animal producers. The market increased in value in 2014, reaching an estimated value of \$13.4 billion.
- **Vaccines** were estimated to be valued at almost \$6.2 billion in 2014.
- **Diagnostic products** accounts for the smallest share of the market with nearly \$2.4 billion in estimated sales in 2014.

Tables 4 through 7 lists top companies in the four market categories.

Table 4: Companies Active in the Animal Pharmaceuticals Sector

Company	HQ Location	2014 Market Share
Zoetis	New Jersey, USA	19%
Bayer Animal Health	Germany	10%
Merial (Sanofi)	Georgia, USA	9%
Merck	New Jersey, USA	9%
Elanco	Indiana, USA	8%
Novartis Animal Health*	Switzerland	6%
Others		39%

*Novartis Animal Health has been acquired by Elanco.

Source: Global Markets for Animal Therapeutics and Diagnostics. BCC Research report number HLC034D

The competitive market for animal pharmaceuticals is highly fragmented with hundreds of companies offering products worldwide. Zoetis has captured the leading market position for 2014, representing one of the most diverse providers of animal pharmaceuticals in the world. While Zoetis currently has a strong position in the market, representing nearly 20 percent of global market share, the remaining industry leaders face strong competitive pressures. The acquisition by Elanco of Novartis will significantly impact the industry segment moving forward as the new company vies for top market position.

Table 5: Companies Active in the Animal Feed Additives Sector

Company	HQ Location	2014 Market Share
DSM Nutritional	Switzerland	21%
Bluestar Group	China	12%
BASF Animal Nutrition	Germany	11%
Evonik Industries AG	Germany	8%
Elanco	Indiana, USA	7%
Others		41%

Source: Global Markets for Animal Therapeutics and Diagnostics. BCC Research report number HLC034D

The feed additive market is moderately competitive among the top five competitors, each with a market share of seven percent or more. However, companies falling under this mark have faced tough competition from both established animal health companies and emerging companies. In 2014, DSM Nutritional Products continued to hold the leading spot in providing animal feed additives with a market share of approximately 21 percent with sales of about \$2.8 billion. Bluestar Group, based in China, is continuing to expand its market presence in the animal feed segment. The 2006 acquisition of the Adisseo Group provided the company with a larger global reach and has allowed the company to grow to be a major competitor in all major world animal health markets. Sales in the feed additive segment are estimated at \$1.6 billion for 2014.

Table 6: Companies Active in the Animal Vaccine Sector

Company	HQ Location	2014 Market Share
Merck	New Jersey, USA	25%
Zoetis	New Jersey, USA	21%
Merial (Sanofi)	Georgia, USA	16%
Boehringer Ingelheim	Germany	12%
Others		26%

Source: Global Markets for Animal Therapeutics and Diagnostics. BCC Research report number HLC034D

The worldwide animal vaccine market involves a diverse range of competitors, offering products for both companion and production animal markets. However, the top four competitors, who include Merck, Zoetis, Merial (Sanofi), and Boehringer Ingelheim, dominated the market accounting for approximately 75 percent of worldwide animal vaccine market share in 2014.

Table 7: Companies Active in the Animal Diagnostics Sector

Company	HQ Location	2014 Market Share
IDEXX Laboratories	Maine, USA	35%
Abaxis	California, USA	6%
Others		59%

Source: Global Markets for Animal Therapeutics and Diagnostics. BCC Research report number HLC034D

IDEXX is the market leader in the animal diagnostics market, with 35 percent market share in 2014. IDEXX holds the number one position without much competition. IDEXX's rapid diagnostic testing products generated sales of approximately \$200 million in 2014. IDEXX also is the leading provider of in-clinic diagnostic testing. A number of much smaller companies compete in the market segment. However, only one company, Abaxis, has been able to capture more than two percent of the market. Abaxis markets reagent kits that are used with its VetScan hematology devices.

VI. Major Research Institutions and Initiatives Focused in this Sector

Animal health and nutrition R&D occurs across a variety of different organizational types. Academic institutions perform basic and applied research, and in the U.S., via the Land-grant Universities, operate proactive extension systems to disseminate technologies and best practices. The Federal Government in the United States is also an important performer of agricultural research through the USDA ARS (Agricultural Research Service), which has a series of research stations and programs across the nation, often operated in close collaboration with major Land-grant Universities. Industry, of course, is a key performer of R&D – just as it is in any sector with large-scale commercial markets. Industry research takes place in the large multi-nationals, and in mid-size and smaller entrepreneurial business ventures.

A. Land-grant Universities

As noted in a 2011 report by Battelle:¹⁹

Helping to drive scientific discovery, innovation and the deployment of new technologies and innovations to enhance industry productivity is a uniquely American system developed by visionaries in the late 1800's—the Land-grant University. "Land-grant University" is the term used to identify a public university in each state that was originally established as a land-grant college of agriculture pursuant to the Morrill Act of 1862. In most states (including all of the North Central states) the original agricultural colleges grew over time into full-fledged comprehensive public universities by adding other colleges (e.g., arts and sciences, medicine, law, etc.). Today these universities stand among the world's premier research and extension education institutions.

Within the national system of Land-grant Universities, Purdue University stands among the premiere providers of agbioscience research. In 2013, the combined research expenditures of Purdue's College of Agriculture, Experiment Station and Extension research system totaled over \$120 million. The basic through applied agbioscience research continuum at Purdue is supported by a robust base of specialized resources and infrastructure, with basic and applied research facilities in West Lafayette supported by 14,697 acres of Purdue University agricultural land distributed across the state to facilitate research and field trial activity (including 11 experiment stations), and Purdue Extension reaching all 92 Indiana counties in provision of research-based education.

¹⁹ Simon Tripp and Deborah Cummings. 2011. "Power and Promise: Agbioscience in the North Central United States." Battelle Memorial Institute, Technology Partnership Practice.

Several key Purdue resources were highlighted in the recent Battelle report on agbioscience opportunities in Indiana, with some notable focus areas relating to animal health and nutrition being:

- **The Animal Sciences Research and Education Center (ASREC)**, which provides animals, facilities, technical assistance, and labor to conduct research, provides instruction, and assists in Extension educational activities. Research trials vary from basic to applied and involve many disciplines—nutrition, physiology, behavior, genetics, reproduction, animal health, and product quality. Faculty use the Research and Education Center to teach several animal science courses and to help provide hands-on experience for students. ASREC consists of 1,515 contiguous acres of highly productive prairie soils, and is located ten miles northwest of the Purdue campus.
- **The Center for Animal Welfare Science** is a good example of Purdue's expertise in facilitating cross-disciplinary and cross-college research, teaching, and outreach teams. In this instance, the focus is on addressing contentious social issues in animal behavior and welfare; promoting and exploring the broad effects of the human-animal bond; and bridging the rural-urban divide on understanding animals and their evolving roles in society.

While almost all the Land-grant Universities maintain focus areas in animal health and nutrition to some degree, several stand-out for a significant emphasis in this area. Some notable examples include:

- **Colorado State University** with a focus on beef cattle, horses, food safety, and animal care.
- **Iowa State University** is well-known for its animal breeding and genetics program (especially in quantitative genetics). Animal sciences at Iowa State also has significant research depth in nutrition (both ruminant and non-ruminant), physiology, meat science, and animal behavior (facilitated by the Animal Behavior Lab).
- **Kansas State University** with a historical emphasis on beef cattle, is also increasingly gaining world renown research strength in animal diseases, including foot-and-mouth disease, classical swine fever, African swine fever, and contagious bovine pleuropneumonia (facilitated by the Center for Excellence for Emerging and Zoonotic Animal Diseases as well as recently being named the new site for the Federal National Bio and Agro-Defense Facility).
- **Texas A&M** has the largest animal science department in the nation. Major programs of research are focused in animal genomics, meat science, food safety, as well as projects focusing on the major livestock species in Texas.

Depending on the individual area of animal science or livestock species under consideration, there is great variability in terms of which universities are the most formidable competitors. For example, emphasis in a specific livestock will highlight certain universities (typically those for which that animal is a key production commodity in that state – such as poultry in Arkansas, cattle in Kansas, swine in North Carolina, or equine at the University of Kentucky). Similarly, niche areas will show variability depending on where the top faculty in that individual specialty are located.

Also, of course, directly relevant to this platform is the **Purdue University College of Veterinary Medicine**. The College identifies its signature research areas as being: infectious diseases and immunology; cancer; neuroscience; orthopedics and tissue engineering; and human-animal bond, animal welfare and shelter medicine. The College also operates several research centers, including:

- Center for Human-Animal Bond
- Center for Paralysis Research
- Purdue Comparative Oncology
- Equine Sports Medicine Center.

In addition to offering the Doctor of Veterinary Medicine (DVM) degree, the College also provides associate and bachelor's degrees in veterinary technology, as well as graduate and post graduate programs.

Among Colleges of Veterinary Medicine (of which there are 26 in the U.S.), it is notable that of those institutions ranked in the Top 10 by U.S. News and World Report, almost all are Land-grant Universities (the exceptions being two private universities, the University of Pennsylvania and Tufts University). The top ranked Land-grant University veterinary medicine schools are: University of California – Davis; Cornell University; Colorado State University; North Carolina State University; The Ohio State University; the University of Wisconsin – Madison; Texas A&M; the University of Minnesota; and the University of Georgia.

Across the U.S., the research performed at Land-grant Universities produces a substantial base of new intellectual property (IP) every year. This IP is typically available for licensing (rather than being directly commercialized by the university or start-up companies – although that certainly does occur), and should be monitored for opportunities to in-license technology for commercialization in Indiana.

Battelle notes the emergence of a small, but noticeable, trend among Land-grant Universities to reorganize their traditional structures to better facilitate interdisciplinary agbioscience and plant science research. Cornell University recently reorganized to create the School of Integrative Plant Sciences and North Carolina State University's College of Agriculture and Life Sciences plans a similar reorganization. In addition, some universities are developing interdisciplinary campus-wide strategic initiatives targeting global grand challenges. Both The Ohio State University and the University of Minnesota have identified food and agriculture as key interdisciplinary thrusts.

B. University-based and State-based Agbioscience Economic Development Initiatives

Just as Indiana has recognized the large-scale economic development opportunities associated with agbioscience (embodied in the formation, for example, of AgriNovus), so too have other states and regions within the U.S. Other initiatives around the country represent competition, but they may also represent an opportunity for networking and collaborations. Some notable competing initiatives are evident in:

- **Kansas and Missouri:** The Kansas City Animal Health Corridor and the KC Animal Health Initiative spans a 250 mile linear geography along Interstate 70 from Columbia, Missouri (home to the University of Missouri) in the East through Kansas City and on to Manhattan, Kansas (home to Kansas State University) in the West. It can legitimately claim to be the world's largest hub of animal health and nutrition, containing more than 300 companies operating in the cluster. Currently, companies having a strategic location in the Corridor are claimed by the Initiative to have 56 percent of the total worldwide sales of animal health, diagnostics, and pet food sales. The initiative is a collaborative formed by multiple stakeholders including the Greater Kansas City Chamber, the Kansas City Life Sciences Institute, Kansas City Area Development Council, BioKansas, the Kansas Development Authority, Missouri Technology Corporation, regional research universities, and industry. The advisory board built by the Initiative is impressive, including representation from Merck Animal health, MRI Global, Nestle Purina PetCare, Zoetis, Boehringer Ingelheim Vetmedica, Hill's Pet Nutrition, Ceva, AgriLabs, Merial, Bayer Healthcare Animal Health, and the Deans of the Colleges of Veterinary Medicine at Kansas State and the University of Missouri – Columbia.
- **Michigan.** Michigan has, since 1993, operated the Animal Agriculture Initiative (AAI) that is a partnership between livestock producers, industry groups, Michigan State University, and the Michigan Department of Agriculture. The Initiative is an economic development effort focused on diversifying the state's economy away from and lessen its dependence on the automobile industry. The AAI works to develop more profitable and sustainable farm production practices, environmentally sound manure management systems, efficient new energy sources, safer food products, and more humane animal care systems based on science.

- **North Carolina.** The North Carolina Biotechnology Center – long recognized as perhaps the gold standard in state supported economic development initiatives focused on the life science sector – has formed AgBio[sphere] as an initiative focused on further building the significant cluster of agbioscience companies in the Research Triangle Park area and further statewide. While most of the cluster is currently plant science focused, the importance of the livestock industry in the state, together with the presence of significant biomedical and animal science research capacity, and a growing base of animal health and nutrition companies (such as Advanced Animal Diagnostics), suggests that AgBio[sphere] will incorporate animal health and nutrition as a focus. There is potential in North Carolina to link such an initiative to the human advanced nutrition research cluster at the North Carolina Research Campus located in Kannapolis, which has received significant public and private investment.

Other states have identified agricultural science capabilities and opportunities into statewide bioscience development strategies (strategies that examined not only agbioscience, but also biomedical and industrial life science opportunities). Such strategies have been undertaken in many states, with recent examples including Ohio, Colorado, Mississippi, Iowa, Oklahoma, and Nebraska.

C. Key International Animal Health and Nutrition Hubs

With livestock agriculture being a worldwide industry of great importance to both developed and developing nations, it should come as no surprise that, in addition to the U.S., there are notable hubs of animal health and nutrition activity located around the world. Some key examples include:

- **The United Kingdom.** The UK has an extensive history of work in agriculture and a significant network of major agbioscience research institutes. Internationally recognized centers for agbioscience research in the UK include, for example, the James Hutton Institute, John Innes Center, Rothamstead Research and Moredun. The Moredun Institute in Scotland conducts research on infectious diseases of livestock, developing and selling vaccines, diagnostic tests and treatment strategies. Established by farmers in 1920 as the Animal Diseases Research Association, Moredun became known for its vaccines and treatment strategies for Braxy and lamb dysentery, and later for a Louping Ill vaccine. Also in Scotland, and particularly well-recognized globally, is the Roslin Institute at the University of Edinburgh. Famous for the well-publicized “Dolly the Sheep” cloning, Roslin has an intensive animal research focus with concentrations in:
 - Improved animal health and welfare through knowledge of genetic factors affecting susceptibility and resistance to disease.
 - Improved sustainability of livestock production systems and food supply chains through an understanding of the biological, economic, environmental and social factors that apply, and their interactions.
 - Translation of discoveries into veterinary clinical practice, and translation of veterinary clinical observations and opportunities into basic science discoveries.
 - Improved food safety based upon understanding interactions between disease causing organisms and animals.
 - Improved human health through an understanding basic mechanisms of health and disease through comparative biology of animal species.
 - The identification of new and emerging zoonoses and an improved understanding of how pathogens might cross from animals to humans.
 - Improved quality of life for animals by studying the mechanisms and behaviors associated with optimizing their environment and life experiences.²⁰

²⁰ Roslin Institute website at: <http://www.roslin.ed.ac.uk/research/what/>

Also in the UK, The Pirbright Institute (formerly the Institute for Animal Health) is dedicated to the study of infectious diseases of farm animals. It forms part of the UK government's Biotechnology and Biological Sciences Research Council (BBSRC).

- In **Denmark**, Aarhus University's Department of Animal Science carries out basic and applied research in issues relating to the nutrition, health and welfare of livestock, companion animals, and humans. The Department consists of seven research units and has extensive experimental and laboratory facilities. Approximately 220 people are employed at the Department – half of which are academic staff. The staff have expertise in disciplines such as cell biology, physiology (digestion, reproduction, growth, lactation, stress, organ and production physiology), applied analytical chemistry and biochemistry, nutrition, microbiology, reproductive biology and technology, embryology, immunology, biomarkers in clinical chemistry and biomodelling, pathobiology, pain biology, ethology, veterinary epidemiology, herd diagnostics, production management and animal health economics.
- **China** Agricultural University's College of Animal Sciences & Technology (CAST) consists of three departments: Department of Animal Genetics, Breeding & Reproduction; Department of Animal Nutrition & Feed Science; and Department of Forage & Grassland Sciences. In addition, the University has recently entered in partnership agreements with a number of U.S. institutions including Purdue University.
- **Australia.** The AgriBio Institute located in Melbourne and operated jointly between La Trobe University and the State of Victoria Department of Primary Industries (DPI) is a state-of-the art agbioscience research operation opened in 2012. Animal health and nutrition work is especially concentrated on the dairy industry, which is the largest component of Victoria's agriculture sector. DPI is undertaking significant collaborative research with the national Dairy Futures Collaborative Research Centre (CRC), with programs in areas such as feed conversion efficiency and milk yield enhancement. DPI also conducts research into rumen microbiota, animal digestion and reduction of associated methane emissions. DPI is also working in collaboration with Australia's CSIRO organization in milk systems biology and analytical characterization of milk. Notable for its scale of inquiry, the DPI 10,000 Holstein Genomes project is linking the genotype of cattle to molecular phenotyping (metabolomics and proteomics) – resulting in molecular methods to ID phenotype. This ambitious and large-scale project will likely provide the basis for multiple investigations into the future and is targeting towards identifying new options for increasing the rate of genetic gain in the Australian dairy herd. DPI is also active in improvement of meat animal species, with the application of genetic tools and technologies to enhancing meat quality and carcass yield in beef and lamb. DPI scientists also have some work ongoing in aquatic species improvement. La Trobe University researchers have a long standing reputation in livestock parasitology and are working on livestock vaccines.
- **New Zealand.** Massey University has, since 2003, hosted large-animal facilities and research staff for the NZ Crown Research Institute AgResearch, which closed a standalone facility in Wallaceville. The contemporary announcement called this collocation “a once in a life-time opportunity to form a national center for animal health research of a size that rivals that found anywhere in the world.” This provided an opportunity to group 100 researchers from both organizations, focusing on parasitic and infectious disease in ruminant animals. One of Massey's units called EpiCentre bills itself the largest veterinary epidemiology training and research center in Australasia, and claims to have had impact on control of the last outbreak of foot and mouth disease in the UK, and on study of bird flu and BSE globally. The EpiCentre focuses on understanding and control of diseases in livestock, and their transmission to humans through food products or otherwise. Diseases of specific local interest are Johne's disease in ruminants, mastitis and lameness in dairy cattle, respiratory diseases in pigs and sheep, and tuberculosis in farm and wild life. The center is known for its collaboration in the development and commercial use of animal health software and use of GIS. EpiCentre is contained within the Hopkirk facility which has six labs at PC2 containment level and three at PC3. The facility enables university faculty and AgResearch staff to work on new vaccines and disease-control

strategies for both government and commercial sponsors. Hopkirk's mEpiLab facility and the EpiCentre organization were recently acknowledged as collaborating centers of the World Organization for Animal Health. Massey also hosts the Riddet Institute which works on food structures and digestive physiology.

VII. Conclusion

Animal health and nutrition represents a strong economic growth proposition for Indiana. It is clear that global demographic and wealth trends are highly favorable for continued growth and development of the animal health and nutrition sector. Indiana is favorably positioned to take advantage of these growth opportunities not only as a result of its significant livestock production capacity, including the diversity of its species, but also due to the innovative companies located in the state that are well positioned in the global market and supported by a number of strong research assets.

With nine Indiana businesses focused on animal health and nutrition activities, employing nearly 1,200 workers in the state, including one of the leading global industry drivers, Elanco, in addition to the significant livestock production that occurs in the state, animal health and nutrition is an existing industry cluster to build upon. The growth opportunities are further reinforced by a robust base of animal science and nutrition R&D at Purdue University, which is furthering its already significant concentration in this sector through its industrial research relationships with Elanco.

The sector provides promise for Indiana along several economic development pathways. R&D within industry and academic institutions hold promise for the development of new commercial innovations, and the growing global demand for animal health and nutrition solutions suggests that growth in Indiana companies in the sector is to be anticipated. Purdue's work in animal health and nutrition research will help attract further extramural funding into Indiana from outside sources, and forms the backbone for the education and training of the skilled animal scientists needed for the sector to expand. It is also the case that R&D and associated innovations in Indiana animal and nutrition sciences will not only provide opportunities for exportable products, technologies and services but also provide solutions needed by Indiana livestock producers to improve production and enhance farm profitability across the state.

AgriNovus, by convening key stakeholders in animal health and nutrition from across Indiana, will play a critically important role in facilitating the industry/university and public/private partnerships that can help further advance the sector in the State. Through encouraging dialog and teamwork between key actors in the field within Indiana, and assuring Indiana government and economic developers pay attention to sustaining a healthy ecosystem for agbioscience innovations in the State, AgriNovus can help assure a robust platform for animal health and nutrition growth.

VIII. Suggested Further Reading

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