INTRODUCTION TO ANIMAL SCIENCE



Deanne Pawlisch
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Introduction to Animal Science

Deanne Pawlisch

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Detailed Licensing

Detailed Licensing

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CHAPTER OVERVIEW

1: Introduction to Animal Science

1.1: Let's Begin



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1.1: Let's Begin

Introduction

Welcome to the captivating and diverse world of animal science. Whether you envision a career in livestock production, equine management, companion animal care, research, or any of the numerous other fields related to the animal kingdom, a solid foundation in the principles of animal science is essential.

This open educational resource guides you through the core concepts underlying our understanding of domestic animals and their interactions with humans. We will explore the fundamental biological processes that govern animal life, delve into the practical aspects of their management and production, and examine the crucial roles animals play in society, the economy, and culture.

We will integrate scientific principles with real-world applications, encouraging you to think critically and develop a comprehensive perspective on animal science. Throughout this resource, you will discover the intricate relationships between genetics, nutrition, physiology, health, behavior, and the environment that shape the lives and productivity of animals.

Understanding the historical roots of animal science helps us appreciate its current state of development. Let's begin our journey by exploring the domestication of animals.



Image information: Title: 1887P956 Pigs Description: 1887P956 Pigs, 1775-1800 Artist: George Morland Keywords: Birmingham Museums Trust/Birmingham Museum & Art Gallery, Oil Painting, Animal/Pig, Farming dams.birminghammuseums.org.uk (opens in new window) [dams.birminghammuseums.org.uk]

Exercise 1.1.1

Individual Activity (5 minutes)

Instructions: Without peeking at your phone or laptop, what are the first **three** things that pop into your head when you think about "animal science?" Don't overthink it; just write down whatever comes to mind in the space below.

1. _____
2. _____
3. _____

Group Activity (10-15 minutes)

Instructions: Get into groups of 3-4 students. Share your individual answers with your group members and discuss the following questions. Be prepared to share your group's insights with the class.

1. **Categorization:** As a group, organize everyone's individual answers into logical categories. (For example, you might have categories like "animal products," "animal care," "research," "specific animals," etc.) What common themes emerged?
2. **Patterns and Surprises:** Were there any interesting patterns in the types of answers your group came up with? Were there any answers that the group found surprising or unexpected? If so, why?
3. **Metacognition Moment:** Why do you think you answered the way you did? What experiences, previous courses, or general knowledge might have led you to those initial thoughts about "animal science"? How might your understanding evolve as we delve deeper into this course?

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The Neolithic Revolution: Origins of Animal Domestication

The story of animal science is deeply intertwined with the history of human civilization. From the earliest acts of domestication to the complex scientific disciplines of today, the relationship between humans and animals has shaped societies and economies worldwide. Let's explore the timeline of animal domestication, the evolution of animal science as a field of study, and the diverse contributions of animals to human society, tracing how practical animal husbandry evolved into the multidisciplinary scientific field we know today.

The foundations of animal science lie in the ***Neolithic Revolution*** (circa 13,000 BCE), a pivotal period when nomadic hunter-gatherer societies transitioned to settled agricultural lifestyles. This transition marked the beginning of a profound shift in human-animal relationships.

Domestication is more than just taming a wild animal. It involves several key characteristics:

- **Purposeful Keeping:** Domesticated animals are kept for specific reasons, whether for food, labor, or companionship.
- **Controlled Breeding:** Humans manage the reproduction of domesticated animals, influencing their genetic traits.
- **Dependence on Humans:** Domesticated animals rely on humans for survival, as they may have lost the ability to thrive in the wild.
- **Development of Unique Traits:** Domestication leads to the development of physical and behavioral traits not seen in their wild ancestors.

Early humans recognized the benefits of domesticating animals, which allowed them to:

- Control animal temperament
- Secure a consistent food source
- Utilize animals for companionship, religious practices, and work

In turn, domesticated animals received protection and a reliable food source. Selective breeding, a process of choosing animals with desirable traits and preventing those with undesirable traits from reproducing, played a crucial role in shaping the characteristics of domesticated species.



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2.1: Animal Domestication Timeline

Animal Domestication Timeline

Determining the order and location of the initial domestication of animals reveals insights into the development of early human societies. Here's a summary of key species and their estimated domestication timelines and locations:

- **Sheep:** Among the first animals to be domesticated (11,000-15,000 years ago) in Southeast Europe and the Central/Southwest Asia mountains. This includes areas within modern-day Greece, Kazakhstan, Turkey, Hungary, Uzbekistan, Syria, Yugoslavia, Turkmenistan, Iraq, Romania, Tajikistan, Bulgaria, Afghanistan, and Iran. Sheep were favored for their wool and meat, and are now so reliant on humans that they cannot survive in the wild.
- **Cattle:** Domesticated around 10,000-15,000 years ago near the boundary of Europe, Asia, and/or Southwest Asia. This includes areas within modern-day Russia, Turkey, Ukraine, Syria, Moldova, Turkmenistan, Iran, and Iraq. Initially used for meat, milk, and labor, horses eventually replaced cattle for most draft work.
- **Goats:** Domesticated approximately 8,000-9,000 years ago in Western Asia. Goats can revert to their wild state.
- **Pigs:** Domesticated 5,000-9,000 years ago in the Middle East (Mesopotamia), in regions including modern-day Syria, Iraq, and Turkey, and then spread across Asia, Europe, and Africa. Pigs were more commonly raised in settled farming communities because moving them long distances was challenging.
- **Horses:** Domesticated roughly 5,000 years ago in Eastern Europe and Western Asia, including modern-day Mongolia and Siberia. Initially used for meat and milk, horses became essential for transportation and draft power.
- **Chickens:** Known to have existed in China over 3,400 years ago, as well as in Southeast Asia (China, Laos, Vietnam, Cambodia, Thailand, Indonesia, Malaysia, Philippines, Burma).
- **Turkeys** are the only animal domesticated in North America.

The image below illustrates the information from the bullet points above.



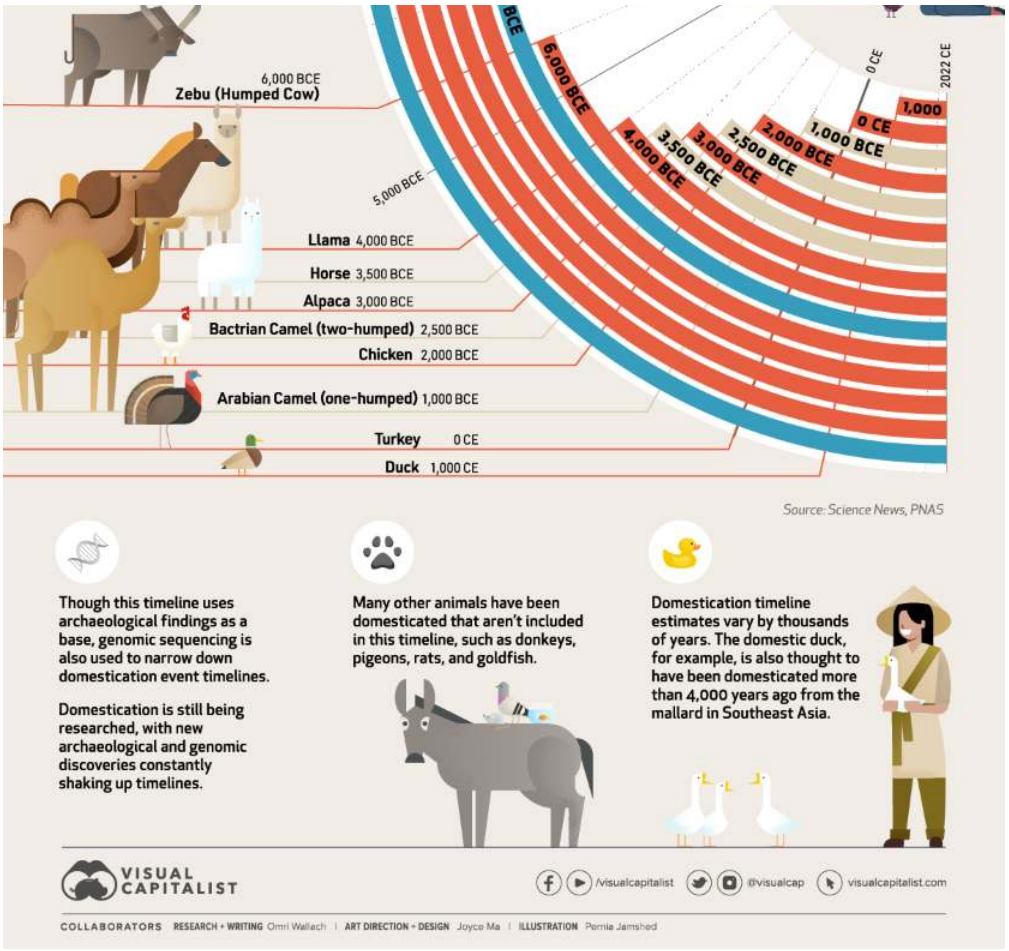


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2.2: Domestication Discussion

Homework:

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2.3: The Classical and Medieval Eras--Laying Intellectual Foundations

The Classical and Medieval Eras: Laying Intellectual Foundations

The classical period in Greece and Rome saw initial forays into understanding animal biology. Philosophers such as Aristotle (4th century BCE) observed animal anatomy and reproduction, though they were not specifically focused on domesticated species for production. The focus remained primarily on practical management.

During the medieval period in Europe, feudal systems and religious institutions largely dictated agricultural practices, including animal husbandry. While advancements in farming technology, such as improved plows, were made, scientific inquiry into animal physiology and breeding remained limited. However, traditional knowledge of animal care and breeding practices continued to evolve within farming communities.



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2.4: The Agricultural Revolution--A Paradigm Shift

The Agricultural Revolution: A Paradigm Shift

The British Agricultural Revolution in the 18th century marked a significant turning point. Individuals such as Robert Bakewell (1725-1795) pioneered systematic selective breeding, emphasizing the inheritance of desirable traits, such as increased size and meat yield, in livestock. Bakewell's work shifted animal breeding from purely observational practices to a more purposeful and directed approach, laying the groundwork for the scientific study of animal genetics.



Image: Robert Bakewell by John Boultbee, oil on canvas, circa 1788-1790. National Portrait Gallery, London. NPG 5949.

The 18th and 19th centuries also witnessed the rise of veterinary medicine as a distinct field focusing on animal health and disease. Establishing veterinary schools and developing disease-control measures were crucial to improving animal productivity and welfare.

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2.5: The Development of Animal Science as a Discipline

The Development of Animal Science as a Discipline

As animal agriculture became more important, the study of farm animals evolved into a distinct scientific discipline:

- **Animal Husbandry:** The art of caring for and managing farm animals. It encompasses the practical skills and knowledge.
- **Animal Science:** This is the scientific study of domestic animals. It applies biology and other scientific principles to understand and improve animal production. It began with acquiring domestic animals and learning to manage, care for, and use them to our best advantage. Meeting those needs led to the development of the discipline of animal science.

The 19th century witnessed the formalization of agricultural sciences, including what would become animal science, within newly established universities and agricultural colleges, particularly in Europe and North America. This era saw the emergence of dedicated research in animal nutrition, physiology, and breeding.

Animal science is a multidisciplinary field, drawing from a wide range of subjects:



? Interdisciplinary Connections 2.5.1

Animal science doesn't exist in a vacuum! It's built on knowledge from many different fields working together. In this activity, you'll become an expert on one contributing discipline and share your discoveries.

Your Mission

You'll research one field that contributes to animal science, then teach your classmates about it through a mini-presentation and group discussion.

Step 1: Choose the Field (5 minutes)

One of the following contributing disciplines is chosen or assigned to all participants:

Biology	Anatomy	Pathology	Law	Embryology

Entomology	**Bacteriology**	**Microbiology**	**Parasitology**	**Ethology**
Ecology	**Agronomy**	**Economics**	**Computer Science**	**Communications**
Chemistry	**Finance**	**Political Science**	**Engineering**	**Genetics**
Nutrition	**Biochemistry**	**Physiology**	**Ecology**	**Statistics**
Engineering	**Economics**	**Veterinary Medicine**	**Reproductive Biology**	**Meat Science**
Dairy Product Science	**Biotechnology**	**Immunology**	**Bioinformatics**	**Animal Husbandry**

Step 2: Research Phase (20 minutes)

Grab your laptop or phone and dive into research! You'll need to find:

A. Definition (5 minutes)

Write a clear, simple definition of your field in your own words. Think: "How would I explain this to a friend who's not an animal person?"

B. Connect the Dots (10 minutes)

Brainstorm and list at least 3-4 specific ways your field contributes to animal science. Ask yourself:

- What problems does this field help solve?
- What tools or methods does it provide?
- How would animal science be different without it?

C. What's Happening Now? (5 minutes)

Find one current event, recent discovery, or trending topic that shows your field in action within animal science. This could be:

- A news article from the past year
- A recent research breakthrough
- A current controversy or debate
- New technology is being developed

Step 3: Share Your Findings (20 minutes)

You'll have 3 minutes to share your findings with a small group of 4-5 classmates. Prepare to cover:

1. Your field's definition (30 seconds)
2. How it contributes to animal science (1.5 minutes)
3. Your current event example (1 minute)

Pro tip: Think of one memorable example or story that ties everything together!

Step 4: Share and Learn (25 minutes)

After each presentation:

- Ask one clarifying question
- Share if you've heard of similar examples
- Discuss how different fields might work together

Pro tip: Think about what would help build a generative conversation.

Step 5: Wrap-Up Reflection (5 minutes)

Write down:

- Which field surprised you the most and why?
- What connections did you notice between different fields?
- How has this changed your view of animal science?

What You'll Turn In

A brief summary (1-2 paragraphs) including:

- Your field's definition and contributions
- Your current event example
- One interesting connection you discovered between your field and another classmate's field

Grading Criteria

- **Participation** (40%): Engaged in research, presented clearly, asked thoughtful questions
- **Content** (40%): Accurate information, clear connections to animal science, relevant current event(s)
- **Reflection** (20%): Thoughtful summary showing understanding of interdisciplinary connections

Need Help?

- Stuck on current events? Try Google News, ScienceDaily, or your field's professional organization website
- Can't find connections? Think about what animal scientists actually do day-to-day
- **Remember:** The goal isn't to become an instant expert, but to appreciate how many different fields contribute to animal science

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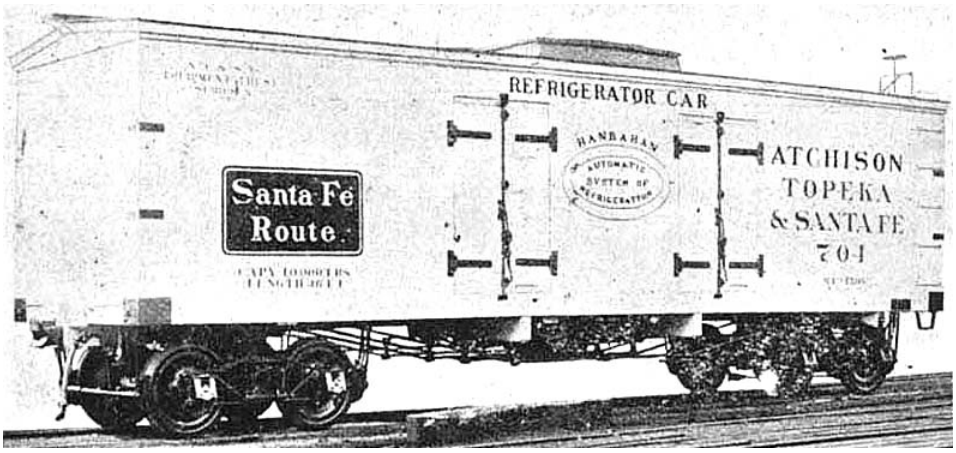
2.6: The History of Animal Agriculture in the United States

The History of Animal Agriculture in the United States

The development of animal agriculture in the United States has its unique timeline:

- **1493:** Columbus brought livestock to the West Indies.
- **1519:** Hernando Cortez introduced cattle and sheep to Mexico.
- **1539:** Hernando de Soto brought horses and hogs to Florida.
- **1641:** William Pynchon of Massachusetts became the first meat packer to export salt pork.
- **1760:** Robert Bakewell in England began breeding animals for specific purposes, developing distinct breeds.

The Civil War (1861-1865) brought significant changes to animal agriculture in the U.S.:



- The expansion of railroads reduced the need for horses and mules and allowed for livestock to be raised further from where they would be consumed.
- Refrigeration in railcars enabled the shipment of meat carcasses to population centers. This allowed animals to be raised in one location, processed in another, and consumed elsewhere.
- Beef became more popular than pork due to improved preservation methods.

Image credit: *https://en.wikipedia.org/wiki/Refrigerator_car#/media/File:Reefers-shorty-ATSF-CM-type-1898-cyc_ACF_builders_photo.jpg*

Government initiatives also played a key role in advancing animal science:

- **1862:** The Land Grant Act provided public lands for universities to teach agriculture.
- **1872:** The Hatch Act established agricultural experiment stations.
- **1914:** The Smith-Lever Act created the Cooperative Extension Service.

These initiatives facilitated research and the dissemination of findings to farmers and ranchers, bridging the gap between scientific discovery and practical application.



Image credit: *https://umdarchives.wordpress.com/2014/05/08/maryland-4-h-and-the-centennial-of-smith-lever/*

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2.7: The 19th and Early 20th Centuries--Key Developments

The 19th and Early 20th Centuries: Key Developments

This period saw fundamental advances in several key areas:

- **Animal Nutrition:** Early research focused on determining the basic nutritional requirements of farm animals and the feeding value of different feedstuffs. The work of scientists in the late 19th and early 20th centuries established the importance of proteins, carbohydrates, fats, and, later, vitamins and minerals in animal diets.
- **Animal Breeding and Genetics:** Following the rediscovery of Mendel's laws of inheritance in the early 20th century, significant progress was made in understanding the genetic basis of economically important traits. Scientists like Jay Lush are considered foundational figures in modern animal breeding and genetics, advocating the use of quantitative statistics and genetic information in breeding programs rather than relying solely on subjective appearance.
- **Animal Physiology:** Research expanded into understanding the internal functions of farm animals, including reproduction, lactation, and growth. This knowledge was crucial for optimizing management practices and improving animal efficiency.

The image below is a table with characteristics of pea plants, such as seed type, flower color, pod, and stems that Gregor Mendel used in his inheritance experiments.

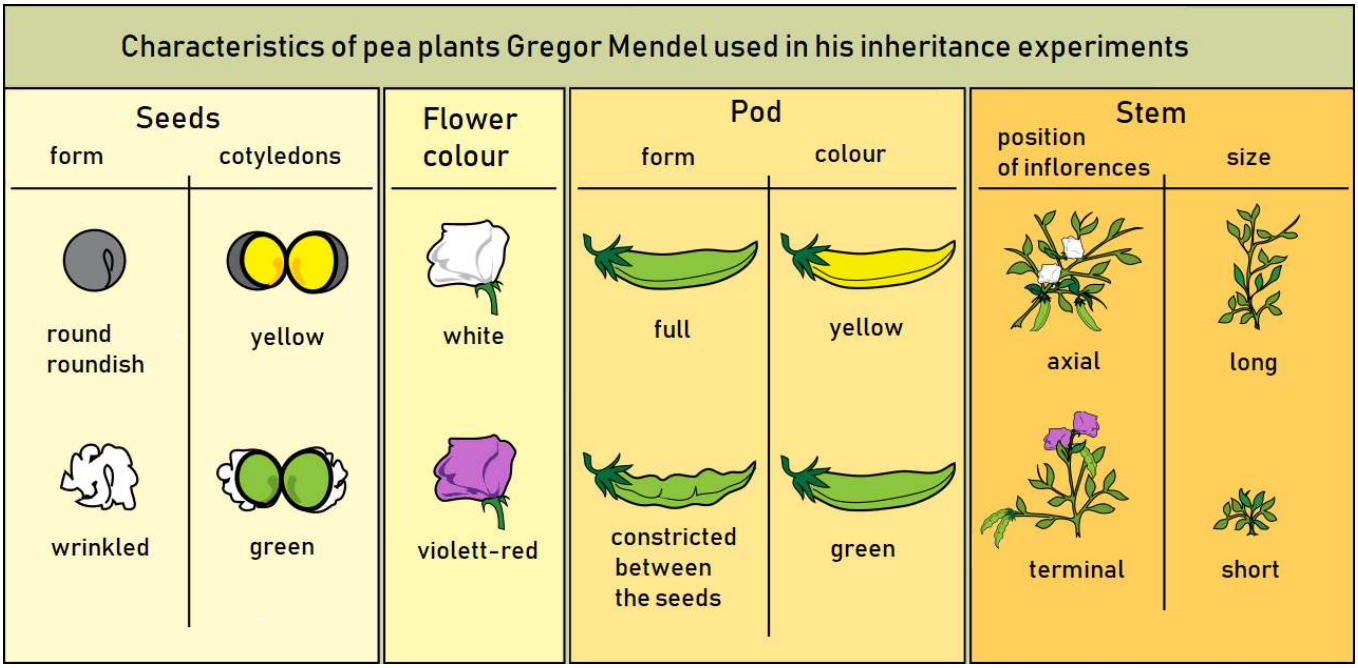


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2.8: Mid to Late 20th Century--Specialization and Technological Advancements

Mid to Late 20th Century: Specialization and Technological Advancements

The mid to late 20th century was characterized by increasing specialization within animal science and the integration of new technologies. Key areas of development included:

- **Intensification of Production Systems:** Driven by increasing global food demand, animal agriculture shifted towards more intensive production systems, such as large-scale feedlots for cattle and confinement housing for poultry and swine. This necessitated advancements in nutrition, disease management, and environmental control.
- **Advances in Reproductive Technologies:** Artificial insemination, embryo transfer, and estrus synchronization became widely adopted, allowing for the more efficient dissemination of superior genetics.
- **Molecular Genetics and Biotechnology:** The latter part of the 20th century witnessed the revolutionary impact of molecular genetics. DNA sequencing, genetic markers, and later, genetic engineering, provided new tools for understanding and manipulating animal genomes, leading to improved breeding efficiency and disease resistance.
- **Animal Welfare Science:** Growing societal concerns about animal welfare led to the emergence of animal welfare as a significant area of study within animal science. Research focused on understanding animal behavior, assessing welfare in different production systems, and developing management practices that promote animal well-being.
- **Meat Science and Food Safety:** Significant advancements were made in understanding the biological and chemical processes that affect meat quality and in developing methods to ensure the safety of animal-derived food products.



Image credit: By Jialiang Gao, www.peace-on-earth.org - Original Photograph, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2926830

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2.9: The Diverse Contributions of Animals to Society

The Diverse Contributions of Animals to Society

Animals make vital contributions to human society in numerous ways:

1. Food - Animals provide a crucial source of nutrition for people around the world:

- Mutton and chevon (goat meat) are consumed worldwide.
- Beef, pork, and poultry are consumed in large quantities worldwide.
- Eggs play a vital role in global food systems and have the lowest environmental footprint among all livestock products.
- Religious practices often influence meat consumption. For example, Hindus do not eat beef, and Muslims, Hindus, and Orthodox Jews do not eat pork.
- Horse meat is consumed in some regions.
- Honey provides nutritious food for people and supports agriculture through pollination.
- Milk and milk products are obtained from various animals, including goats, ewes, cattle, mares, sows, llamas, camels, reindeer, and yaks.

2. Clothing - Animal products have been used for clothing for millennia:

- Wool, hair, hides (leather), and pelts are commonly used.
- In many countries, ruminant fibers like hair and wool are still used for clothing, bedding, housing, and carpets.

3. Shelter - Animal materials can be used for shelter:

- Hides were used to construct teepees, and hair was used in plaster (horsehair plaster).

4. Tools and Utensils - Historically, bones and hides were used for tools. Other animal products, such as bladders, horns, and catgut, have also been utilized.

5. Personal Items - Animal products and by-products are used in jewelry and perfumes.

6. Power - Animals have been essential for draft work, packing, and transportation throughout history:

- In the 1920s, over 25 million horses were used in the United States for draft purposes.
- In developing countries, animals still provide a significant portion of agricultural power, and many of the world's population relies on animals for transporting goods.
- In India, cattle and buffalo, though not typically slaughtered for meat due to religious reasons, are used extensively for fieldwork.

7. War - Animals have been used in warfare for transportation and power.

8. Religion - Some cultures incorporate animals into religious practices, including animal worship.

9. Recreation - Animals provide companionship and are involved in hobbies and sports like horseback riding.

10. Health - Animals play a crucial role in medical research:

- Laboratory animals are used extensively in research.
- Miniature pigs are valuable in research due to their physiological similarities to humans.
- Cattle and sheep have been used to test artificial organs before human trials.
- Animal products and by-products are used in pharmaceuticals.

The image below illustrates the intersection of food nutrition, the environment, livelihoods, and health with livestock.

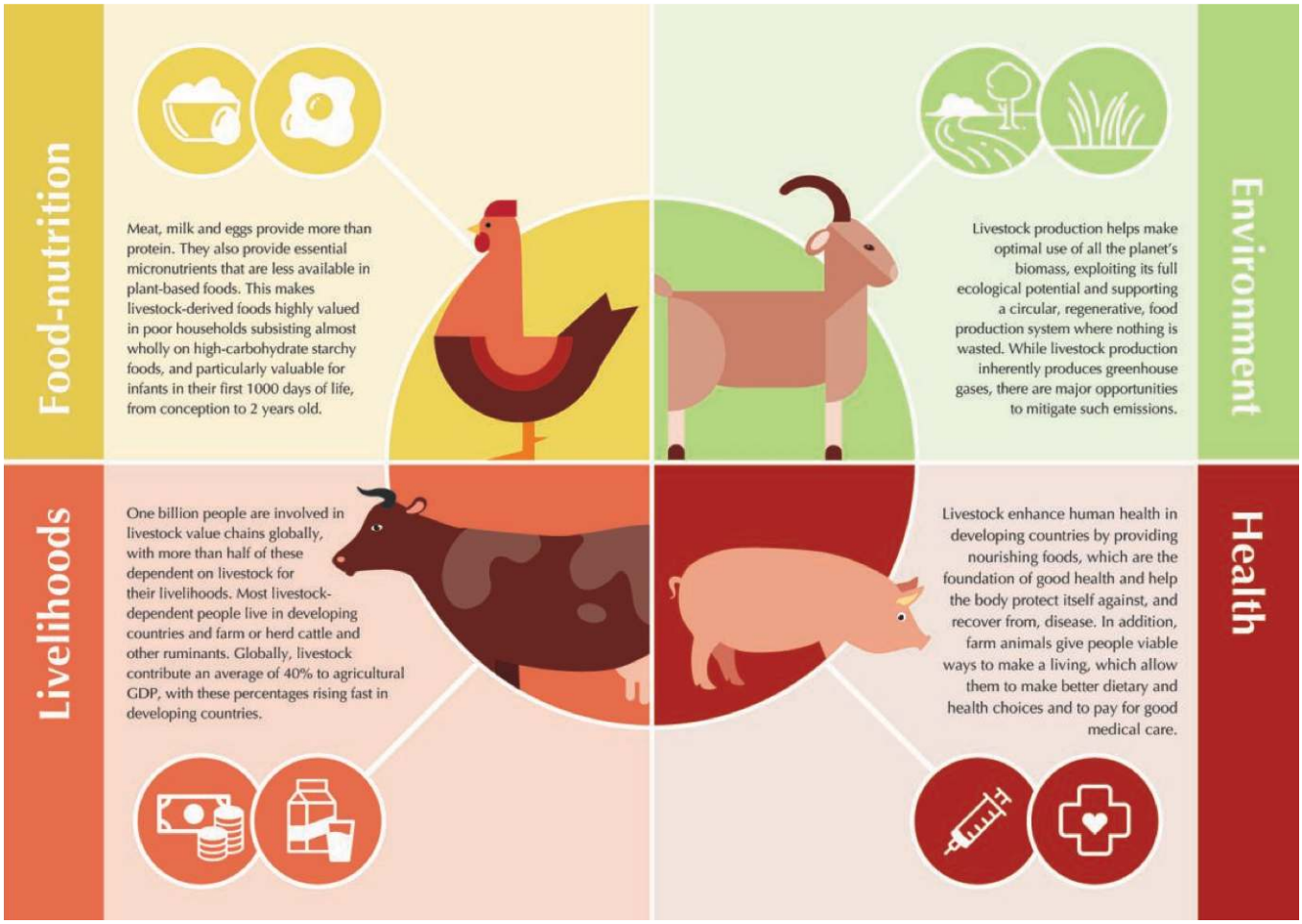


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2.10: 21st Century--Sustainability, Precision Agriculture, and One Health

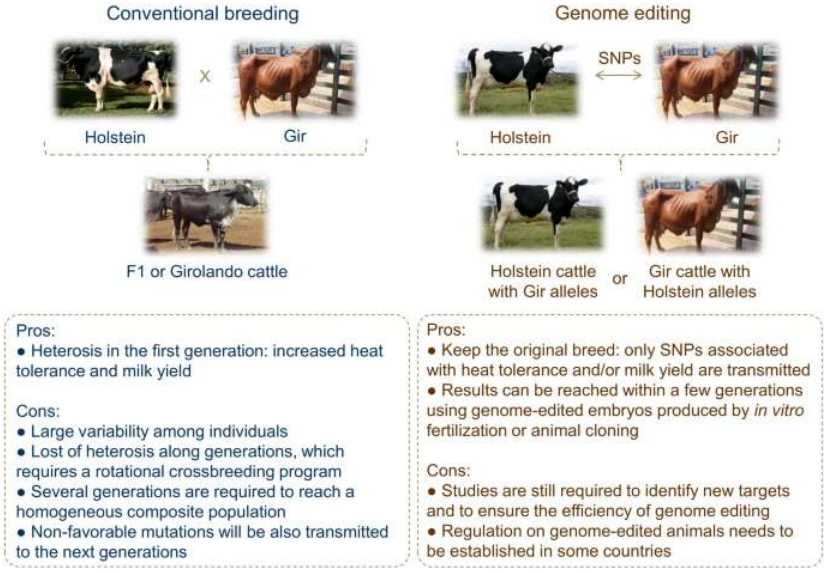


Image credit: https://cabiagbio.biomedcentral.com/...70-022-00075-w

The image above illustrates the pros and cons of conventional breeding and genome editing.

Today, animal science is a dynamic and interdisciplinary field addressing complex global challenges. Key trends include:

- **Sustainability:** A primary focus is on developing more sustainable animal production systems that minimize environmental impact, conserve resources, and address climate change. This includes research on feed efficiency, waste management, and alternative protein sources.
- **Precision Agriculture:** The application of sensor technologies, data analytics, and automation enables more precise management of individual animals or groups, optimizing resource use and improving animal health and productivity.
- **Animal Health and Disease:** Research continues to prevent and control animal diseases, including zoonotic diseases that can impact human health, emphasizing a One Health approach that recognizes the interconnectedness of human, animal, and environmental health.
- **Animal Behavior and Welfare:** A deeper understanding of animal behavior and the development of science-based welfare standards remain critical areas of research and application.
- **Genomics and Gene Editing:** Advances in genomics and gene editing technologies present unprecedented opportunities to enhance animal traits related to productivity, disease resistance, and environmental adaptation, while also raising significant ethical considerations.
- **Companion Animal Science:** The study of companion animals, encompassing their nutrition, behavior, health, and the human-animal bond, has experienced significant growth, reflecting their increasing importance in society.

? Exercise 2.10.1

Let's examine the pivotal role that livestock domestication played in the evolution of agriculture and its subsequent impact on human societies. Through these scenarios, you will analyze various stages and aspects of this historical transformation.

Discussion Instructions:

1. Divide into five groups. Each group is assigned a scenario.
2. Each group should carefully read through the provided scenario. Pay close attention to the historical context, the challenges presented, and the specific ways livestock are integrated into each setting.
3. As a group, discuss and answer the three critical thinking questions together. Aim for thorough, well-reasoned answers that demonstrate a deep understanding of the concepts.

4. As a group, synthesize the key insights and answers for your scenario. Be ready to share your conclusions and elaborate on any particularly interesting points or divergent opinions that emerged during your discussion. You will be asked to present your findings to the class.
5. Elect one spokesperson from your group to summarize your key insights and answers for each question during our full-class discussion. Be ready to share any particularly interesting points or differing opinions that arose within your group.

We will spend approximately 30 minutes in group discussions, followed by a full-class debrief where each group will share its findings.

Scenarios

Scenario 1: The Dawn of Sedentary Life

Setting: Imagine a nomadic hunter-gatherer band in Southeastern Europe, around 13,000 BCE. They are on the cusp of the Neolithic Revolution, a pivotal period during which societies transitioned to settled agricultural lifestyles. They have observed wild sheep frequently grazing near their seasonal camps, attracted by discarded plant matter. The band has been struggling with unpredictable food sources and the constant need to relocate in search of sustenance.

Your task is to consider how the purposeful keeping and controlled breeding of these sheep, initially for meat and wool, would allow the band to secure a more consistent food supply and reduce their reliance on hunting. This newfound stability could then pave the way for a sedentary agricultural lifestyle, allowing them to invest time and effort in cultivating crops.

Critical Thinking Questions:

1. How would securing a consistent food source from domesticated sheep alter the daily lives, labor allocation, and social structure of this nomadic band?
2. What significant challenges might this early community face in transitioning from a mobile hunting and gathering lifestyle to a more settled life centered around agriculture and animal husbandry?
3. Beyond food, what other immediate benefits would the domestication of sheep provide that would directly support a more settled existence?

Scenario 2: Powering Agricultural Expansion

Setting: It's approximately 8,000-9,000 years ago, and you are in a village in Western Asia. Early agriculturalists here cultivated grains, but their fields were relatively small and labor-intensive, relying solely on hand tools. They have domesticated goats for their milk and meat [cite: 19], and have also begun to domesticate cattle, initially primarily for meat and milk. Expanding their cultivated land requires immense manual labor.

Your group observes the villagers beginning to train their domesticated cattle for draft work, specifically for pulling plows. This shift dramatically increases the efficiency of land preparation, enabling larger cultivated areas and higher food production. Consider how the ability to use animal power allows them to expand their agricultural footprint and potentially cultivate more challenging terrain.

Critical Thinking Questions:

1. How does the introduction of animal traction fundamentally change the scale and intensity of agricultural production compared to relying solely on manual labor?
2. What potential long-term societal implications might arise from the ability to produce a significant agricultural surplus due to animal power?
3. What significant practical and behavioral challenges would early agriculturalists have faced in training and managing large animals like cattle for draft work, and how might they have overcome these obstacles?

Scenario 3: The Integrated Farm System

Setting: Your group is observing a thriving Bronze Age settlement in Mesopotamia, around 5,000-9,000 years ago. The community has successfully domesticated pigs, cattle, sheep, and goats, and agriculture is well-established. They face the ongoing challenge of maintaining soil fertility over time in their continuously cultivated fields.

Your task is to analyze how livestock are deeply integrated into the entire agricultural system. You observe animal manure being collected and spread on fields as fertilizer, ensuring sustained crop yields. You also note that animals provide a

continuous source of other resources, such as wool, hides, and milk. Pigs, being more challenging to move over long distances, are especially well-suited for these settled farming communities. This creates a more resilient and productive agricultural economy.

Critical Thinking Questions:

1. Beyond providing direct food sources (meat and milk), how did the use of animal by-products (specifically manure and other materials like wool and hides) create a more sustainable and productive agricultural ecosystem in this ancient settlement?
2. What advantages did having multiple domesticated species (pigs, cattle, sheep, goats) offer this community in terms of resource diversity, dietary variety, and overall agricultural resilience?
3. How might the reliance on such an integrated animal-agriculture system have influenced the settlement's long-term environmental impact compared to a hypothetical system solely reliant on continuous crop cultivation without animal inputs?

Scenario 4: Specialization and Selective Breeding

Setting: It is the 18th century in England, during the British Agricultural Revolution. Farmers have been raising livestock for centuries, but their breeding practices are mainly traditional, based on observation rather than systematic principles. Robert Bakewell (1725-1795) began implementing groundbreaking systematic, selective breeding techniques on his farm.

Your group observes Bakewell's pioneering work. He is not just randomly breeding animals; he is purposefully selecting animals with desirable traits, such as increased size and meat yield in livestock, and managing their reproduction to enhance these characteristics in future generations. This systematic approach transforms animal husbandry from an observational practice into a more purposeful and directed scientific endeavor, laying the groundwork for modern animal genetics and leading to the development of distinct, improved livestock breeds.

Critical Thinking Questions:

1. How did Robert Bakewell's "purposeful and directed approach" to selective breeding fundamentally differ from the more traditional, observational animal husbandry practices common before his time?
2. What economic incentives or societal pressures of the 18th century might have driven the intense focus on developing livestock with "increased size and meat yield"?
3. Beyond direct economic benefits to farmers, how might the development of distinct and improved livestock breeds through systematic selective breeding influence the broader scientific understanding of genetics and inheritance?

Scenario 5: The Industrialization of Animal Agriculture

Setting: You are in the United States in the mid-to-late 19th century, a period significantly shaped by the Civil War (1861-1865). The expansion of railroads and the introduction of refrigeration technology are rapidly transforming how food is produced, processed, and distributed across the country.

Your group observes that these technological advancements, particularly refrigerated railcars, reduce geographic constraints on where livestock can be raised and processed. This new capability enables the separation of animal rearing, processing (including slaughterhouses), and consumption into distinct locations. You also note that beef has become more popular than pork due to improved preservation methods. This marks a significant step toward the intensification and specialization of animal agriculture systems that characterized the 20th century.

Critical Thinking Questions:

1. How did the advent of railroads and refrigeration fundamentally alter the traditional, more localized models of animal agriculture and food consumption in the United States?
2. What are the major economic and logistical benefits, as well as potential drawbacks or new challenges, of separating animal production from consumption, as enabled by these new technologies?
3. Consider the long-term implications of this industrialization. How did it pave the way for modern, large-scale, and intensive animal production systems, and what associated challenges emerged as a result?

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2.11: Summary and Flashcards

The history of animal science is a dynamic and evolving story that reflects the long and complex relationship between humans and animals. From the early days of domestication to the sophisticated scientific advancements of today, animals have played an indispensable role in shaping human societies, providing food, clothing, labor, and companionship, and contributing to advancements in medicine and other fields.

Scientific inquiry and technological innovation have driven the journey from rudimentary husbandry practices to a sophisticated, multidisciplinary field. As we move forward, animal science will continue to be essential for ensuring the sustainable and ethical management of animal resources to meet the needs of a growing global population while addressing emerging challenges related to environmental sustainability, animal welfare, and international food security.

Flashcards for Key Terms

YouTube Resources for this chapter

HEAS, Dec 27, 2023, *Episode 2: The Case Against Domestication and Paleoarcheological Revelations, [Video], YouTube*, *https://youtu.be/0Mmx2UuY8wg?si=w9EkTFiankbXq3DX*

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CHAPTER OVERVIEW

3: A Global Perspective

3.1: The Fundamental Role of Animals in Global Food Systems
3.2: The Impact of Animals in Your Life--A Personal Inventory
3.3: Non-Food Uses of Animals--A Broader Perspective
3.4: Animals and Religion
3.5: Animals in Health Research and Conservation
3.6: The Value of Animals Discussion
3.7: Global Trends in Livestock Production
3.8: Animal Relationships Activity
3.9: Summary and Flashcards

Since the earliest days of domestication, animals have been deeply intertwined with human civilization, contributing far beyond just food. This chapter explores the diverse ways animals enrich our lives, from providing essential nutrition and raw materials to supporting economies and shaping cultural practices worldwide. We will examine the global impact of animal agriculture, considering both developed and developing nations and analyze the complex relationship between humans and animals throughout history and in contemporary society.

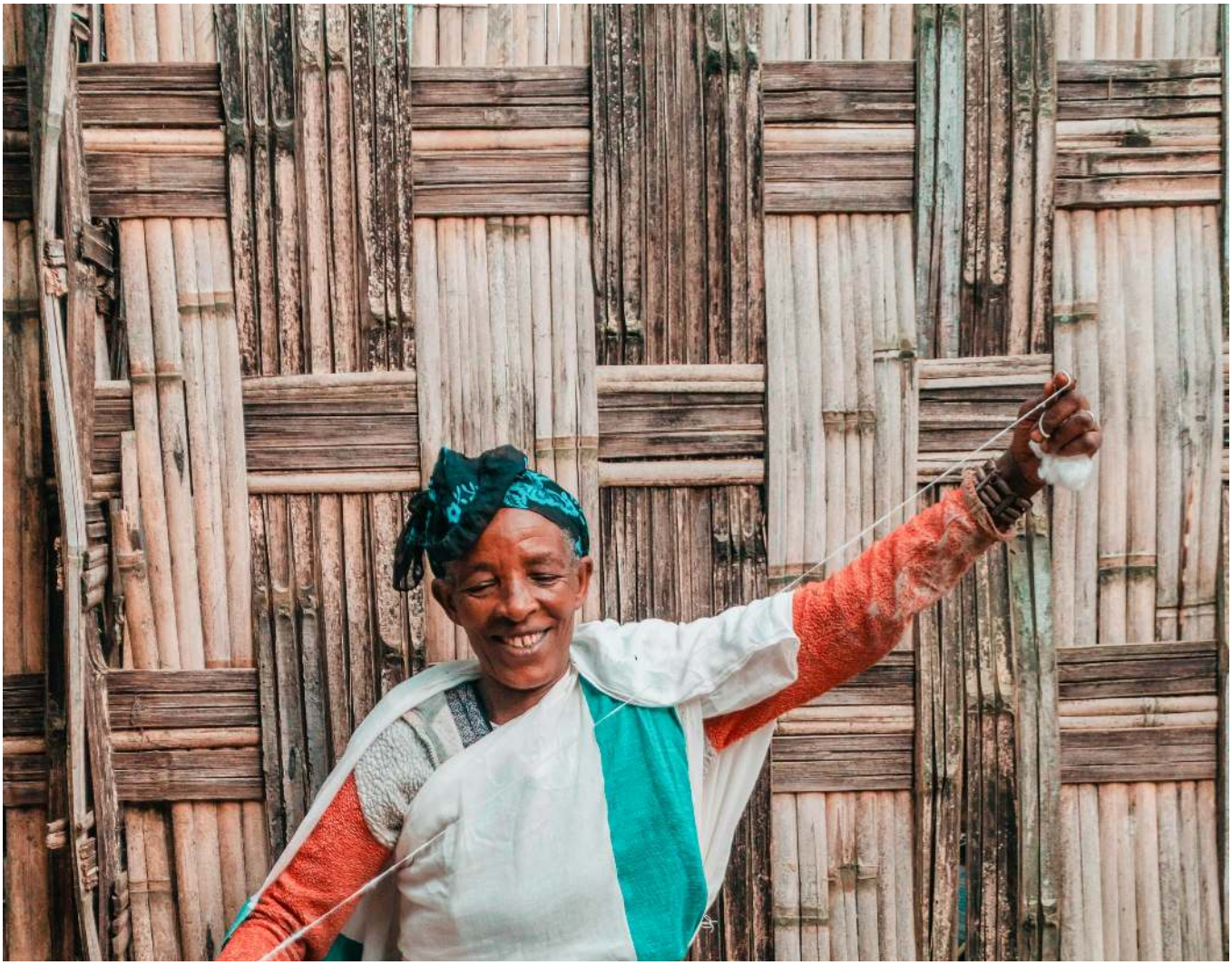




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3.1: The Fundamental Role of Animals in Global Food Systems

Animals are a cornerstone of global food systems, providing critical nutrients for human health. Their contribution to human nutrition has evolved significantly from early domestication to modern production systems, shaped by cultural preferences, economic factors, and technological advancements.

Meat represents a significant source of protein, energy, vitamins, and minerals in human diets worldwide. Global meat consumption patterns vary considerably, primarily influenced by economic development, cultural preferences, and religious practices. As economies develop and incomes rise, meat consumption typically increases, reflecting its status as both a nutritional staple and a valued food commodity.

Globally, pigs serve as the primary source of meat production, although poultry production has experienced rapid growth in recent decades due to improvements in efficiency and shifting consumer preferences. This shift reflects the changing demands of consumers and economic factors in the global meat industry.

In many regions, religious and cultural practices influence meat consumption patterns. For instance, Hindus typically avoid beef, while Muslims, Hindus, and Orthodox Jews do not consume pork. These cultural factors give rise to diverse regional patterns in meat production and consumption, which in turn shape local agricultural systems.

Milk is another vital food product derived from livestock, providing essential nutrients such as calcium, protein, and vitamins. Cattle contribute the majority of global milk production, though goats, sheep, buffalo, camels, and other species are significant sources in specific regions.

Dairy products take various forms across cultures—from fresh milk and cheeses to fermented products like yogurt and kefir—each representing adaptations to local conditions, preservation needs, and taste preferences. The development of refrigeration and modern processing has transformed dairy from a highly perishable local product to a global commodity.



Image credit: Simon Berger from Pexels: https://www.pexels.com/photo/white-a...rasses-704145/

Eggs from poultry are a significant global food source, rich in protein and fat, with high nutritional value. Chicken eggs dominate global production, though duck, quail, and other poultry eggs are significant in various regional cuisines.

Beyond these major products, animals provide other food sources, such as honey from bees and, in some cultures, various by-products and organ meats that are considered delicacies. Though less common in Western diets, organ meats often contain higher concentrations of specific nutrients than muscle meat and remain essential in many traditional food systems.

Animal products are nutritionally valuable, offering high-quality protein, energy, minerals, and vitamins with good nutrient availability and density. Proteins from animal sources contain all essential amino acids in proportions that closely match human requirements, making them highly bioavailable.

Animal products provide several nutrients that are difficult to obtain in adequate amounts from plant sources alone, including vitamin B12, heme iron, and zinc. This nutritional profile makes animal products particularly important in addressing malnutrition, especially in vulnerable populations such as children, pregnant women, and the elderly.

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3.2: The Impact of Animals in Your Life--A Personal Inventory

Personal Animal Inventory 3.2.1

The 24-Hour Challenge

To become more aware of the significant and often unseen ways that animals, animal products, and byproducts influence our daily lives, over the next 24 hours, you will keep a detailed log of every instance in which you encounter or use an animal or an animal byproduct. This can be a list, a journal, or a series of notes on your phone. Be as thorough as possible and think beyond the obvious. This activity is designed to challenge your assumptions and reveal the intricate ways in which animals are part of our daily lives. Have fun with it!

What to Document:

For each entry, please include the following:

- **Time of day:** Approximately when the encounter occurred.
- **Item/Animal:** What was the specific item or animal?
- **Category:** Classify the item into one of the following categories:
- **Live Animal:** An animal you saw, interacted with, or heard (e.g., your pet, a squirrel, a bird).
- **Food Product:** Any food or drink derived from an animal (e.g., meat, milk, cheese, eggs, honey).
- **Clothing/Personal Item:** Any clothing, accessory, or personal care product made from animal materials (e.g., leather shoes, wool sweater, silk scarf).
- **Medicine/Medical Product:** Any medication or medical supply that contains animal-derived ingredients (e.g., gelatin capsules, certain vaccines).
- **Other By-product:** Any non-food or non-clothing item derived from an animal (e.g., candles made with beeswax, paint brushes with animal hair, soap with tallow).
- **Reflection:** Briefly describe the context of the encounter and reflect on its significance. How often do you think about this item's connection to an animal?

Example Log Entry:

- **Time of day:** 7:15 AM
- **Item/Animal:** Bacon
- **Category:** Food Product
- **Reflection:** I eat this almost every morning for breakfast, but I don't often think about the pigs it comes from.
- **Time of day:** 1:00 PM
- **Item/Animal:** Leather wallet
- **Category:** Clothing/Personal Item
- **Reflection:** My wallet has been in my pocket for years. It's made from cowhide, and its durability is something I take for granted.

Deliverables:

- Please submit an organized log of your 24-hour inventory.
- The log should contain at least 25 unique entries.
- Your submission should be in a text file or PDF.

Follow-up Questions (to be discussed in class):

1. Which category had the most entries for you, and why do you think that is?
2. What was the most surprising animal product you documented?
3. Based on this activity, how would you describe the relationship between humans and animals in modern society?
4. Were there any items you encountered that you weren't able to categorize, and what does that suggest about the complexity of our relationship with animals?

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3.3: Non-Food Uses of Animals--A Broader Perspective

While food production often dominates discussions of livestock's role in society, animals contribute to human welfare in numerous other ways that vary widely across different economic and cultural contexts.

Animals provide fiber for clothing and other products, with renewable resources like wool, cashmere, and mohair being particularly valuable. These natural fibers offer unique properties that synthetic alternatives often cannot match, including temperature regulation, moisture management, and durability.

Wool from sheep remains the most widely produced animal fiber globally, with variations in fiber diameter, length, and crimp determining its suitability for different textile applications. Specialty fibers, such as cashmere from goats, mohair from Angora goats, and silk from silkworms, command premium prices due to their distinctive characteristics.

In developing countries, animals remain essential power sources for agriculture and transportation, used for plowing, hauling, and packing. Despite mechanization in many regions, animal power remains crucial in areas where terrain, economics, or infrastructure limit the use of machinery.

Cattle, water buffalo, horses, donkeys, and camels are among the most common draft animals, each adapted to specific environments and work requirements. The continued reliance on animal power in many regions represents both cultural tradition and practical adaptation to local conditions.

Animal waste products are valuable resources in many agricultural systems. Manure serves as a vital fertilizer, replenishing nutrients in the soil and enhancing soil structure and water retention. In some regions, dried manure also functions as a fuel source for cooking and heating.

Beyond manure, other animal by-products find various applications. Urine has been utilized in traditional agricultural practices and in certain industrial processes. These uses of animal waste represent important aspects of sustainable farming systems, creating closed nutrient cycles that reduce dependence on external inputs.



Image credit: ATEEQ-PHOTOS from Pexels: https://www.pexels.com/photo/farmer-...-sky-32409510/

Animals can play an effective role in pest and weed control, offering alternatives to chemical methods. Grazing animals, such as sheep and goats, can effectively manage unwanted vegetation in cropping systems and landscapes. Additionally, ducks have been utilized to control pests in rice paddies.

These biological control methods represent traditional knowledge that is finding renewed application in sustainable agriculture systems, offering environmental benefits while maintaining productivity.

In many economies, especially in developing regions, livestock functions as a form of stored capital and food reserve. Animals represent a reliable store of value that can be liquidated during times of need, providing economic security for households without access to formal banking systems.

Animals are also integrated into cultural practices through exhibitions, sports, companionship, and social structures. From rodeos and equestrian events to the symbolic importance of cattle in pastoral societies, animals hold cultural significance that extends beyond their economic value.

Slaughter by-products find uses in various industries, including pharmaceuticals, cosmetics, and industrial applications. These include:

- Pharmaceutical products derived from animal glands and tissues
- Gelatin and collagen from hides and bones are used in food and pharmaceutical industries
- Tallow and other fats are used in soap making and industrial lubricants
- Bone meal and other by-products are used in fertilizers

The utilization of these by-products improves the efficiency and sustainability of animal agriculture by creating value from all parts of the animal.

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3.4: Animals and Religion

Humans and animals have long-standing relationships that go beyond practical and economic benefits. Animals are deeply ingrained in human culture, influencing our thoughts, dreams, and fears, and giving rise to myths, legends, and fables. To understand an animal's meaning, we must consider its cultural representation. Animals are often used as metaphors or allegories for human traits, a practice that constructs their cultural significance. This cultural importance is evident throughout history in art, literature, music, mythology, and religion.

The significance of animals in human cultural expressions stretches from ancient societies to the modern day. It's essential to acknowledge that the artistic representation of animals is often intertwined with their utilitarian value, and understanding both is crucial to comprehending our perceptions of them.

Religious beliefs have a significant and long-lasting influence on how humans perceive and interact with the natural world. From ancient times to the present, animals have played a critical role in religious practices globally, embodying a supernatural dimension in their relationship with humans. In ancient religions, animals were revered as ancestors and protectors, and some scholars have suggested that the cult of animals, known as **totemism**, was the earliest form of religion.

Over time, human-like gods and goddesses began to replace animal deities, but animals remained present as companions or alternative forms for these new figures. For example, Athena was associated with an owl, Zeus with an eagle, and Odin with ravens and wolves. In ancient Egypt, figures blending human and animal features, such as a human torso with an animal head, were common, reflecting the transition from a hunter-gatherer to an agricultural society. The Egyptians also developed animal cults, viewing certain animals as gods or their representatives. These sacred animals were bred in temples, mummified after death, and buried with their owners. This practice included a variety of animals, such as bulls, cats, and ibises.

The spiritual importance of animals persists today, though it varies greatly across cultures and religions. Sacred animals are still worshipped and used in rituals, and their parts are used to decorate religious spaces. Animals are also used in sacrificial offerings, and their body parts are integrated into magical amulets and other symbolic items. One notable practice is the religious release of captive wild animals, particularly in eastern and southern Asia, known as "merit release." This act, rooted in Buddhist teachings, is believed to enhance personal karma and lead to enlightenment by relieving suffering. However, this has created a commercial trade where animals are captured solely for this purpose, raising concerns about animal welfare and the introduction of non-native species that can harm local ecosystems.

Animals are also prominently featured in the architecture and ornamentation of religious temples worldwide. Figures of real and imaginary animals, such as gargoyles, are often incorporated into church designs, serving both functional and symbolic roles.



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3.5: Animals in Health Research and Conservation

Animals play a vital role in human health research, contributing to medical advancements in numerous fields. Laboratory animals have been essential for understanding disease mechanisms, testing new treatments, and advancing surgical techniques.

Some examples include:

- Miniature pigs in research due to their physiological similarities to humans
- Cattle and sheep are used to test artificial organs before human trials
- Animals in the development and testing of vaccines and pharmaceutical products

While ethical considerations surrounding animal research continue to evolve, controlled and humane research protocols have made significant contributions to advancements in human health.

Animal agriculture is a significant source of income, particularly in developing countries where livestock may represent both household wealth and livelihood. Globally, the livestock sector employs over a billion people and contributes significantly to agricultural GDP in many nations.

In rural areas, livestock production often provides opportunities for women and youth to participate in economic activities, contributing to household food security and well-being. The economic multiplier effects of livestock production extend to feed industries, processing, transportation, and retail sectors.

Animals contribute to conservation efforts and sustainable agriculture in several ways:

- Grazing animals can maintain grassland ecosystems and prevent the encroachment of woody vegetation
- Traditional livestock breeds represent critical genetic resources for adaptation to changing conditions
- Integrated crop-livestock systems can improve nutrient cycling and reduce environmental impacts

The relationship between livestock and conservation is complex, with both potential conflicts and synergies depending on management practices and local contexts.





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3.6: The Value of Animals Discussion

Discussion 3.6.1

Humans have used animals for thousands of years, shaping our civilization, economy, culture, and daily lives. From the earliest domestication of dogs and livestock to modern biotechnology applications, our relationship with animals spans an incredible range of purposes and practices.

As animal science students, it's crucial to understand not only *how* we use animals but also to critically examine *why* we use them, what alternatives exist, and what ethical considerations arise from these practices. Different cultures, societies, and individuals hold varying perspectives on what constitutes appropriate animal use, and these viewpoints continue to evolve as our understanding of animal welfare, environmental impact, and human needs develops.

This activity challenges you to explore the breadth and complexity of human-animal relationships. You'll investigate both the practical realities and ethical dimensions of how humans utilize animals, encouraging you to think critically about practices you may have never considered before.

Each group will be assigned **three different ways** in which humans utilize animals. Your task is to research and thoroughly analyze each assigned category, then present your findings to the class.

Group Assignments

Group 1: Meat, Body Coverings, Cultural Uses

Group 2: Edible By-products, Power Sources, Human Health Research

Group 3: Milk & Other Dairy, Body Wastes, Inedible By-products

Group 4: Eggs, Pest & Weed Control, Income

Group 5: Miscellaneous Food Uses, Storage of Capital & Food, Conservation

For **each** of your three assigned categories, your group must address the following questions:

1. Prevalence and Common Practices

What are the most common ways animals are utilized in this category? How prevalent is this use in the United States compared to the rest of the world? Include specific examples and, where possible, statistics or data. (Cite your sources)

2. Arguments for Animal Use

What are the strongest arguments supporting the use of animals in this capacity? Consider economic, practical, cultural, nutritional, medical, or other benefits. Consider both the human benefits and the potential benefits to the animals themselves.

3. Arguments against Animal Use

What are the most compelling arguments against using animals in this capacity? Consider animal welfare concerns, environmental impacts, ethical objections, health considerations, or alternative solutions.

4. Unusual or Unexpected Uses

What is one surprising, unusual, or unexpected way that humans use animals in your assigned category? This should be something most people wouldn't immediately think of.

5. Personal Ethical Reflection

How do you personally feel about the ethics of using animals in these ways? Is it acceptable or unacceptable? Is it appropriate in some circumstances but not others? What factors influence your opinion?

- **Use credible sources:** Academic journals, government databases, industry reports, reputable news sources
- **Consider multiple perspectives:** Don't just look for sources that confirm one viewpoint
- **Include global perspectives:** How do practices vary between different countries and cultures?
- **Be specific:** Use concrete examples, species names, and quantitative data when available
- **Think critically:** Question assumptions and consider the complexity of these issues

Time: 15 minutes per group

In your group, create a summary of the following:

- Brief overview of your three categories (2 minutes)
- Detailed analysis of each category addressing all five questions (4 minutes each)
- Group reflection on patterns or insights across your categories (3 minutes)

Reflection Questions

After all groups have shared their summaries, we'll engage in a class discussion addressing:

- What patterns did you notice across different types of animal use?
- Which use surprised you the most? Why?
- How do cultural, economic, and geographic factors influence animal utilization?
- Where do you see the most potential for change or improvement?
- How has this activity influenced your thinking about human-animal relationships?

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3.7: Global Trends in Livestock Production

The livestock sector is undergoing rapid transformation globally, driven by population growth, urbanization, and changing consumer preferences. Key trends include:

- Increasing demand for animal products, particularly in emerging economies
- Intensification of production systems, especially for poultry and pigs
- Growing concerns about environmental impacts, including greenhouse gas emissions and land use change
- Increasing focus on animal welfare and sustainable production methods
- Development of alternative protein sources, including plant-based and cell-cultured products

These trends present both challenges and opportunities for the livestock sector, requiring adaptive strategies that balance production efficiency, environmental sustainability, and animal welfare.

The global livestock sector faces significant challenges in meeting growing demand while addressing concerns about environmental sustainability, animal welfare, and human health. Key challenges include:

- Reducing environmental impacts, particularly greenhouse gas emissions and water use
- Addressing antimicrobial resistance associated with livestock production
- Improving animal welfare in intensive production systems
- Ensuring equitable access to animal-source foods in food-insecure regions
- Adapting livestock systems to climate change impacts

Addressing these challenges requires interdisciplinary approaches that account for the complex interactions among livestock production, human nutrition, environmental sustainability, and economic development.

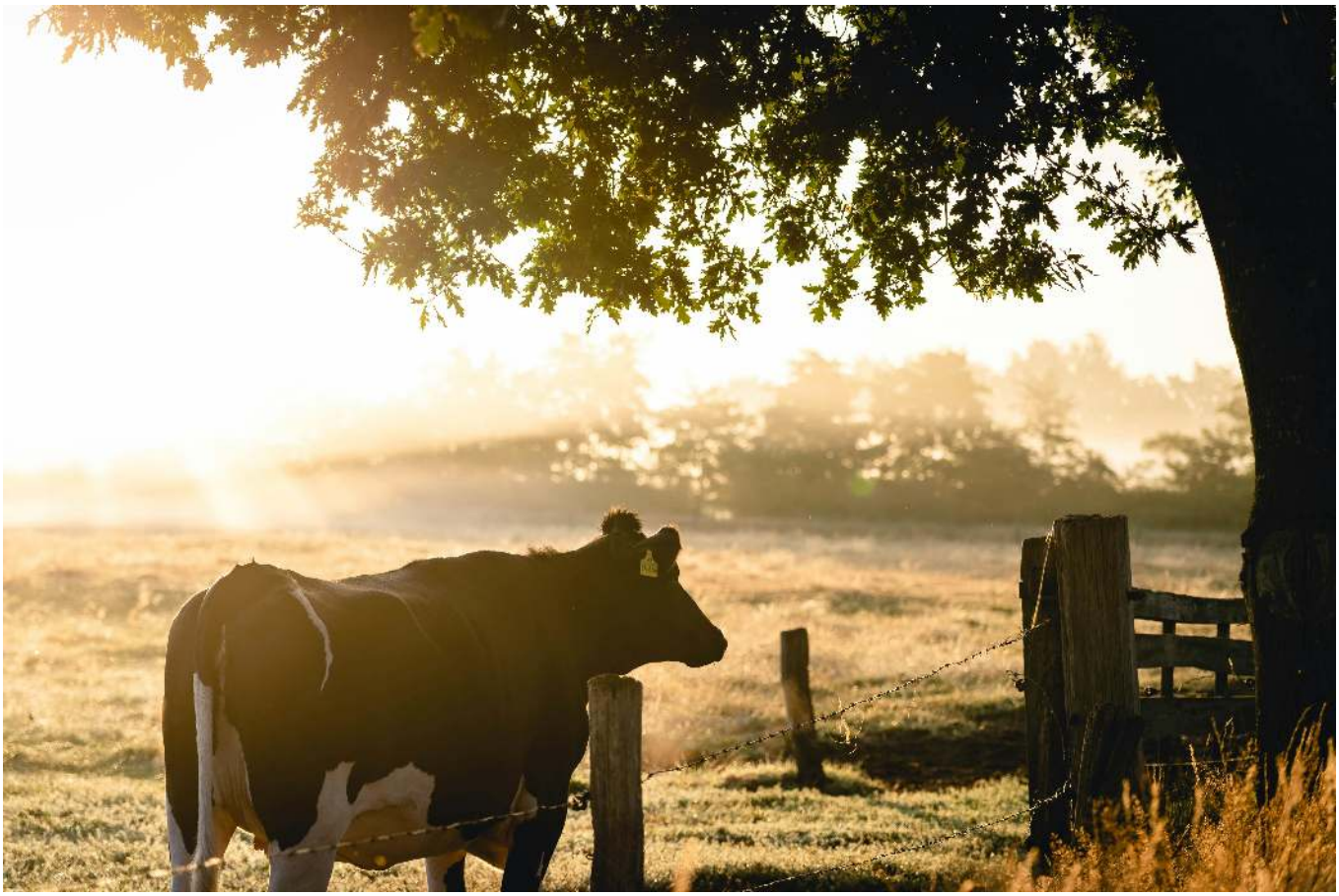


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3.8: Animal Relationships Activity

Activity 3.8.1

Throughout human history, we have developed complex and varied relationships with animals. These relationships range from the intimate bonds we form with companion animals in our homes, to the practical partnerships we maintain with domestic livestock for food and resources, to our more distant interactions with wild animals through conservation efforts, research, or simply sharing the same planet.

Each type of relationship involves a unique exchange--sometimes obvious, sometimes subtle. While we might immediately think of what animals provide for us (companionship, food, labor), these relationships are multifaceted. They involve costs and benefits for both humans and animals that aren't always apparent at first glance.

Today, we'll examine these relationships more deeply by considering multiple perspectives: what we gain, what we give up, what animals sacrifice, and what they receive in return. This analysis will reveal the complexity of human-animal interactions and help you think critically about the ethics and sustainability of these relationships.

Setup (5 minutes)

1. Form groups of **3 students each**
2. Each group member selects ONE animal category:
   - **Student A:** Companion animal (pets: dogs, cats, birds, etc.)
   - **Student B:** Domestic animal (livestock: cattle, pigs, chickens, etc.)
   - **Student C:** Wild animal (any non-domesticated species)
3. Each student chooses a specific animal within their assigned category

Individual Reflection (10 minutes)

Each student completes the following for their chosen animal:

Fill out these four categories:

1. **What WE get from this animal:**
   - The benefits, products, and services humans receive
2. **What it COSTS US:**
   - Resources, money, time, and effort we invest
3. **What it COSTS THE ANIMAL:**
   - What the animal sacrifices or loses in this relationship
4. **What THE ANIMAL GETS:**
   - The benefits, care, and protection the animal receives

Group Discussion (15 minutes)

1. **Share findings** - Each student presents their four points to their group members.
2. **Compare patterns** - Look for similarities and differences across the three animal categories.
3. **Discuss relationships** - Are these relationships balanced? Fair? Mutually beneficial?

Reflection Questions for Class Discussion

Which type of animal relationship seems most balanced? Why?

What surprised you about the costs and benefits?

How do these relationships reflect broader human-animal interactions?

What ethical considerations arise from your analysis and discussion?

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3.9: Summary and Flashcards

Animals provide essential food, materials, labor, and diverse services that significantly contribute to human well-being and cultural development. The global impact of livestock extends far beyond simple production metrics, encompassing complex social, economic, and environmental dimensions.

Understanding this multifaceted value is crucial for promoting sustainable and ethical animal agriculture practices globally. As we face the challenges of feeding a growing population while preserving environmental resources, the livestock sector will continue to evolve, striking a balance between tradition and innovation to meet changing societal needs and expectations.

The Value of Animals to Humanity Flashcards

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CHAPTER OVERVIEW

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4.1: Introduction

Global agricultural systems are shaped by a combination of factors, including climate, topography, soil type, and socioeconomic conditions, such as a region's level of economic development. The choice to devote land to livestock rather than crops is often due to the area being too dry, too rough to cultivate, too high in elevation, or too far from markets to make crop production profitable.

Animals play a vital role in these systems, but their ability to thrive depends on their adaptation to both natural and artificial environments. Adaptation is the total of an organism's adjustments that promote its survival and well-being in a specific environment. This includes morphological (anatomical), physiological (biochemical), and behavioral changes. Stresses on agricultural animals can be climatic, nutritional, internal (like pathogens), geographical, and social.



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4.2: Adaptation

Animals live in conditions shaped by natural forces (climate, geography, pathogens) and artificial influences (human management, housing, and cultural practices). The ability of animals to adapt is fundamental to their survival, domestication, and productivity.

Adaptation is the sum of changes an animal makes in response to environmental stimuli to promote its survival and welfare. These changes can be morphological, physiological, or behavioral. However, animals are constantly challenged by stressors—forces or conditions that disturb their normal function. Let's take a look at how animals adjust to their environments by watching the following video.



BBC Earth, May 13, 2020, *Top 5 Animal Adaptations, [Video], YouTube*, https://www.youtube.com/watch?v=ZT8YswmQuAg

Morphological (Anatomical) Adaptations

Morphological adaptations involve changes in form or structure that help an animal survive in its environment.

- **Heat dissipation**: Cattle breeds in hot climates may have light-colored coats to reflect sunlight, long ears to increase heat loss, or skin muscles that enable them to flick insects off.
- **Cold tolerance**: Animals in cold regions often grow thick fur or develop insulating fat layers.
- **Feeding structures**: The beak of a chicken or the muzzle shape of a cow is adapted to the type of feed it consumes.

Physiological Adaptations

Physiological changes occur at the biochemical and systemic levels inside the animal's body.

- **Thermoregulation**: Sweating, panting, and shivering are mechanisms to regulate body temperature.
- **Metabolic flexibility**: Animals can adjust their digestion to different feedstuffs or alter reproductive cycles in response to feed availability.
- **Disease resistance**: Some breeds have evolved stronger immune responses to local parasites and pathogens.

Behavioral Adaptations

Behavioral adaptations may be instinctive or learned. They are crucial for coping with environmental challenges.

- **Seeking shade or water** in hot climates.
- **Huddling together** for warmth in cold conditions.
- **Grazing patterns** that follow seasonal forage availability.
- **Social behaviors** that reduce conflict or establish dominance hierarchies.



Photo credit: Erwin Bosman: Link to rooster image [www.pexels.com]

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4.3: Environmental Stressors

Animals face multiple categories of stressors in their environments. Stress can reduce productivity, compromise health, and impact overall well-being.



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1. Climatic Stressors

Climate refers to long-term weather patterns, whereas weather refers to the immediate conditions. Key climatic stressors include temperature, humidity, wind, solar radiation, and precipitation.

- **Heat stress** can lower feed intake, slow growth, and reduce fertility.
- **Cold stress** increases energy demands for thermoregulation.
- **Rainfall and drought** affect feed and water availability.
- **High winds and storms** can lead to erosion, exposure, and injuries.

2. Nutritional Stressors

Feed quantity and quality are directly tied to climate and land productivity.

- Inadequate protein, energy, or micronutrients can stunt growth and reduce reproductive success.
- Drought reduces pasture growth, while excessive rainfall may lower forage quality.
- Intensive systems may reduce stress through balanced diets, but feed shortages remain a global challenge.

3. Internal Stressors

Internal stressors are biological agents that invade or disrupt an animal's body.

- **Pathogens** (viruses, bacteria, fungi) cause diseases.
- **Parasites** (internal worms, external ticks) drain nutrients and weaken hosts.
- **Toxins** (natural or artificial) can poison animals and impair function.

4. Geographic Stressors

These are stresses linked to location and terrain, independent of climate.

- **Altitude** reduces oxygen availability, making respiration more challenging.
- **Rugged terrain** can increase energy expenditure and increase the risk of injury.
- **Isolation** of regions may limit genetic diversity or access to feed resources.

5. Social Stressors

Animals interact with members of their own species, with members of other species, and with humans. These interactions can be stressful.

- **Competition** for feed or mates can lead to aggression.
- **Dominance hierarchies** may increase tension among groups.
- **Human handling and management** practices—such as overcrowding, transportation, or inadequate housing—can increase stress and compromise welfare.

Humans modify natural environments to enhance animal productivity and welfare. These artificial environments—such as housing systems, feeding facilities, or controlled climates—reduce specific stresses while sometimes introducing new ones. For example, confinement housing may limit exposure to predators and extreme weather, but it can also create social or behavioral stress if the space is too restrictive.

Animals adapt to survive and thrive in their environments through morphological, physiological, and behavioral changes. However, they are constantly challenged by environmental stressors, which fall into five main categories: climatic, nutritional, internal, geographic, and social. Understanding these adaptations and stressors is essential for improving animal welfare, management, and productivity.

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4.4: Animal Adaptations Activity

Evolution is happening all around us, and understanding how animals adapt to their environments is crucial. Recognizing different adaptations will help you understand why animals look and act the way they do.

? Adaptation Analysis 4.4.1

In this activity, you'll investigate adaptation by discovering real animals that have evolved fascinating solutions to survive and thrive in their environments. You'll see how a bird's beak shape can tell the story of its diet, how some animals have developed incredible internal superpowers to survive extreme conditions, and how behavioral changes can be just as significant as physical ones for survival.

As you explore, you'll get to recognize the three main types of adaptations and figure out how they're different from each other. You'll dig into real-world examples of how animals have evolved to solve environmental challenges, then piece together the "why" behind these adaptations by identifying what environmental pressures made these changes necessary. At the end, you'll share what you've discovered with your classmates so everyone can learn from each other's findings.

Instructions

1. Form groups of three students

2. Each group will research an adaptation type (morphological, physiological, or behavioral adaptation)

3. Determine roles within your group:

- Research Coordinator: Manages sources and fact-checking
- Content Specialist: Focuses on accuracy and terminology
- Summarizer: Organizes information for a clear summary

Deliverables

At the end of class, submit your research summary and source list to the discussion forum on Brightspace.

Research Phase

For your group's adaptation type, find one real-world animal example and gather the following information:

A. ***Species Information*** (name, geographic distribution, and general ecological niche)

B. ***Adaptation Details*** (specific adaptive trait or characteristic, an explanation of how the trait helps the animal survive in its climate, and why the adaptation fits into your assigned adaptation)

C. ***Selective Pressures*** (environmental challenges or stresses that led to this adaptation, survival, or reproductive advantages gained, and any ongoing pressures that maintain this trait)

D. ***Natural vs. Artificial Selection*** (identify whether this adaptation resulted from natural or artificial selection, if natural: describe the environmental factors involved, if artificial: explain human involvement and breeding objectives)

E. ***Before and After Comparison*** (what did the species look like before the adaptation, description of the current adapted condition, and what are the specific differences between the two states)

Research Guidelines

1. Use quality sources (peer-reviewed journals, reputable websites, and scientific organizations) avoid Wikipedia
2. Keep track of all sources (note authors and publication dates)
3. All group members should participate in preparing a succinct summary of your group's discussion to communicate to the class.

Helpful Tips

Research Strategies

1. Start with broad searches, then narrow down to specific examples
2. Look for case studies in animal behavior and evolution textbooks
3. Consider both well-known examples and lesser-known ones

Avoid These Common Pitfalls

1. Don't confuse learned behaviors with inherited behavioral adaptations.
2. Ensure your physiological examples involve *actual internal changes*, not just physical structures.
3. Make sure you can clearly explain the selective pressure for each example.
4. Avoid examples where the adaptation process is still theoretical or heavily debated.

Research Summary Template

Species: *Scientific name and common name*

Adaptation Type: *Is it Morphological, Physiological, or Behavioral?*

The Adaptation: *Provide a brief description of the specific trait*

Selective Pressure: *What environmental challenge drove this adaptation?*

Selection Type: *Explain if it's natural or artificial*

Ancestral condition: *Before the current adapted condition*

Current adapted condition:

Explain how this adaptation helps the animal. *Does it provide a survival or reproductive advantage?*

List 2-3 credible sources:

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4.5: Agricultural Development

There are three primary levels of agricultural development: developed, subsistence, and primitive. The livestock systems in an area are primarily determined by its agrarian system.

In this system, almost the entire population is involved in food production because no one produces a surplus. It is characterized by food scarcity, low nutritional status, and minimal use of animal or mechanical power. Primitive agriculture often supplements subsistence farming with non-agricultural food sources, such as hunting and gathering. Examples include nomadic herding, transhumance, and shifting cultivation.

Subsistence Agriculture

About half of the population is engaged in farming, with each farm family producing roughly what it consumes and only a small surplus for sale or barter. It relies heavily on manual and animal labor and has little mechanization. This level of agriculture is associated with a low per capita income and literacy rate. Examples include subsistence crop and livestock farming (also known as peasant grain, tuber, and livestock farming), paddy rice farming, and urban agriculture.

This system's goal is to *earn a profit* from agriculture. It is highly specialized, with each unit producing only one or two products. Less than 10% of the population is engaged in farming, which is highly mechanized and uses little to no animal or hand labor. Developed agriculture is associated with high per capita income and literacy rates.



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4.6: Livestock and Crop Production Types

Within each development level, various agricultural systems are practiced:

- **Pastoralism:** a form of animal husbandry that involves herding grazing animals.
- **Nomadism:** Characterized by irregular, opportunistic movement in search of food for herds, with no permanent base. The goal is subsistence, not profit.
- **Transhumance:** Pastoralists who move seasonally to take advantage of shifting water and grazing conditions. They maintain a permanent base where some plant cultivation may occur. An example is moving cattle from high elevations in the summer to lower elevations in the winter in the western U.S.
- **Shifting Cultivation:** Also called slash-and-burn agriculture, farmers clear small plots of land, use them until the soil's fertility is depleted, then move to a new area. The objective is subsistence, often supplemented by hunting and gathering.
- **Rudimentary Sedentary Tillage:** Farmers stay in one location and use primitive farming methods, primarily hand labor and simple tools. This requires fertile land and can fail if the population becomes too dense.
- **Paddy Rice Farming:** Concentrated in South and East Asia, this system is highly labor-intensive for both humans and animals and relies on sufficient water to outyield other grains.
- **Peasant Grain, Tuber, and Livestock Farming:** Small farms with a few head of livestock, also known as subsistence crop and livestock farming. The primary goal is self-sufficiency rather than sales, and multipurpose animals are often kept for work, food, and fiber.



Image credit: Julia Volk from Pexels: Link to picture of sheep walking on a hill [www.pexels.com]

- **Ranching:** A commercial, extensive system of agriculture where animals are spread over a wide area. It is the dominant system in the world's dry regions, with a permanent location that ranchers either own or lease.
- **Commercial Crop and Livestock Farming:** The primary enterprise is crop production, with livestock being secondary. This is an intensive method where animal movement is restricted to maximize production and utilize technology.
- **Commercial Livestock Finishing:** A highly specialized system where producers rarely raise their own crops, instead purchasing feed for their livestock. This system is standard for cattle, chickens, and swine.

- **Commercial Dairy Farming:** An intensive system that needs to be near a population center if milk is being produced. Drylot systems, where feed is brought to confined cows, are replacing traditional pasture use.
- **Commercial Grain Farming:** Focuses on producing grains like corn, wheat, and rice in areas with 20 to 30 inches of yearly rainfall. It may involve a small number of livestock.
- **Market Gardening:** These specialized farms sell products to large urban areas and do not raise livestock. This is a labor-intensive system that relies on seasonal farm laborers.
- **Commercial Plantation:** Focuses on raising a single crop on a large area of land, usually owned by large corporations or the government, with the goal of profit.
- **Urban Agriculture:** A method integrated into the urban economic and ecological system, practiced in backyards, community gardens, and on rooftops. Over 800 million people depend on urban agriculture for food and income.
- **Aquaculture:** The raising of aquatic animals and plants in controlled environments. Large-scale aquaculture now produces half of the world's seafood.



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4.7: Contrasting Developed and Developing Countries

The livestock industries in developed and developing countries differ notably. Both have very few large operations. However, moderate-sized operations are typical in developed countries but almost nonexistent in developing countries.

Small livestock operations are common in both types of countries, but their purpose differs greatly. In developing countries, small units are typically subsistence farms that are often the sole source of income for the owners. In developed countries, these small units are frequently considered hobby farms rather than businesses and are not the primary source of income.

In developing countries, livestock are kept for reasons beyond food alone, and their performance is often suboptimal. Primitive and subsistence systems have been successful for centuries because of their low initial investment in animals and equipment. Animals are also used for power because they are renewable and easier to obtain and replace than machines. This employs a large number of laborers.



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4.8: Agricultural Systems Review and Case Studies

Agricultural production systems have evolved in response to the world's complex environmental, cultural, and economic conditions. Farming systems are shaped by climate, topography, soil type, and socioeconomic factors, including economic development level, product demand, political systems, and religious beliefs. The most critical factors are climate—particularly rainfall and temperature—and the level of economic development.

Table of primitive, subsistence, and developed agriculture traits

Agricultural System	Goal	Animal Use	Characteristics
Primitive	basic subsistence, supplemented with hunting and gathering	few animals, not used for draft or meat, primarily hunting or fishing supplies	everyone farms, little surplus, no mechanization, very low literacy, and income levels
Subsistence	produce enough for the family with a small surplus	draft animals, milk, and manure are used; pigs and poultry are used as scavengers	~50% farming population, small surplus, low mechanization, and low literacy and income levels
Developed	commercial farming for profit	profit-driven, intensive or extensive systems, specialization	<10% farming population, high specialization, high mechanization, and high literacy and income levels



Image credit: Jan Kopřiva on Unsplash

? Agricultural System Case Studies 4.8.1

1. Divide into five groups and assign a case study to each group.
2. Within your group, discuss the scenario together and decide which agricultural system it represents.

3. Record your group's responses to the questions. Be sure to explain your group's reasoning and use specific terms (e.g., *primitive agriculture*, *subsistence farming*, *transhumance*).

4. Share your findings with the rest of the class. Make sure to include the following:

- Identify the agricultural system
- Key evidence from the case study
- Strengths and weaknesses of the system

5. After each group presents, compare the systems' similarities and differences. Discuss as a class how climate, geography, and economic development influence agricultural production worldwide.

Case Studies

1. A community lives in a humid area with more than 30 inches of rainfall per year. Most families farm small plots, grow rice with draft animals, and sometimes sell small surpluses.

Which agricultural system are they practicing?

What are its strengths and weaknesses?

What makes this system one of the world's most sustainable forms of agriculture?

2. A small farming community lives in a mountainous region of Europe. Families keep sheep and goats near their village during the winter, but every summer they move their herds to higher elevations to escape the heat and find better grazing. Some families also maintain small fields of barley and potatoes near their permanent homes.

Which system of livestock management is being practiced?

What advantages does this system provide in mountain regions?

How does this system differ from nomadism?

3. A group of families lives in a desert region with very little rainfall. They move frequently with their herds of camels and goats, seeking areas with water and forage. Their homes are tents that can easily be moved, and farming is rarely practiced because the land is too dry.

What type of agricultural system is being practiced here?

Why is this method considered sustainable in desert regions?

How do the families' housing and movement patterns reflect their environment?

4. In a semi-arid region, large numbers of cattle are kept in confined areas and fed grain until they reach market weight. The farmers do not grow their own crops but instead purchase feed from outside suppliers. The goal is to maximize efficiency and profit in meat production.

What agricultural system is represented in this case?

How does this system reflect the characteristics of developed agriculture?

Why did this type of livestock production emerge only in the second half of the 20th century?

5. In a humid rainforest region, families clear small plots of land by cutting down trees and burning them. The ash fertilizes the soil, and crops are grown for several years. Once the soil loses fertility, the families abandon the land and clear another plot. Hunting and fishing often supplement their diet.

What agricultural system is being practiced here?

Why is the land left to rest for 10–20 years before reuse?

How is this system different from rudimentary sedentary tillage?

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4.9: A Livestock Industry Overview

Today, livestock and poultry production form a critical part of the global economy, accounting for a significant portion of world agriculture. The consumption of animal products is rising, driven by both a growing population and increasing affluence in developing countries. Animal products are a vital source of high-quality protein, vitamins, and minerals that are essential for human health.

The global livestock industry is dominated by beef, pork, and poultry, with production of all three increasing significantly.

- **Beef and Dairy:** Beef and milk production are growing.
- **Pork:** Pork production has seen massive increases worldwide, especially in China and Southeast Asia, largely due to a shift toward intensive, large-scale production systems.
- **Poultry:** Chicken and egg production have been growing rapidly worldwide due to consumer preference for these products and the efficiency of modern production systems. This trend is especially pronounced in countries like Vietnam, India, China, and Brazil.

The increasing production of animal products has met the rising global demand, but it has also led to a more industrialized model of agriculture. This shift has raised questions about resource use, environmental impact, and animal welfare, which remain key discussion points.



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4.10: The Global Significance of Milk and Dairy Products

When you pour milk on your cereal or add cheese to a sandwich, you're participating in one of humanity's oldest and most important agricultural practices. Dairy products aren't just convenient foods—they're nutritional powerhouses that play a critical role in feeding the world's population. Around the globe, humans consume approximately 770 million metric tons of milk each year, in various forms such as fluid milk, cheese, yogurt, and other dairy products. Let's examine the impact of dairy production on global nutrition, economic development, and the fight against hunger.

While you might immediately think of cows when you hear "milk," several species contribute to the global milk supply:

- **Cattle** are the dominant producers, supplying over **80%** of the world's milk
- **Water buffalo** contribute approximately **15%**, making them the second most essential dairy species globally
- **Goats, sheep, and camels** produce the remaining milk supply

Buffalo milk production might surprise you with its significance. In many Asian countries, water buffalo are essential to local dairy industries, providing rich milk that's ideal for traditional products like mozzarella cheese.

Global milk production is growing steadily. However, access to dairy products varies dramatically around the world. In some nations, per capita milk supply exceeds 750 pounds per year, while in others, dairy remains a rare luxury. This inequality in dairy access has essential implications for nutrition and health worldwide.

Dairy products deliver a concentrated package of essential nutrients that are particularly valuable in human diets:

- **High-quality protein** for growth and tissue repair
- **Energy** in the form of carbohydrates and fats
- **Calcium** for strong bones and teeth
- **Vitamin A** for vision and immune function
- **Vitamin B12** for nerve function and red blood cell formation

In many populations, dairy products also serve as a significant source of dietary fat. This combination of nutrients makes dairy especially important for vulnerable groups.



Image credit: Matthias Zomer from Pexels: Link to image of dairy cows grazing by a pond [www.pexels.com]

For decades, international development agencies have promoted dairy farming in developing nations because dairying offers unique economic advantages that extend beyond nutrition.

Unlike crop farming, which follows seasonal cycles of planting and harvesting, dairy farming provides *consistent, year-round employment*. Cows need to be milked every day, regardless of the season. This steady work rhythm translates into regular income for farming families, helping to stabilize household finances and strengthen local economies.

Dairying represents an efficient method for converting animal feed into human nutrition. Dairy animals can utilize grasses, crop residues, and other feeds that humans cannot digest directly, transforming them into nutrient-dense milk. This makes dairy farming a financially viable use of agricultural resources.

The dairy industry represents far more than agricultural production—it's a powerful tool for improving human welfare. As the global population continues to grow and the fight against hunger intensifies, understanding and supporting sustainable dairy development may be crucial to building a healthier, more prosperous world.

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4.11: Eggs as a Global Food Resource

Eggs are among humanity's most accessible and valuable sources of nutrition. While poultry species are widely recognized for their meat, their contribution to global food security through egg production is equally significant.

Eggs stand out as an exceptional food source for several important reasons. They provide high-quality protein that contains all the essential amino acids the human body needs. This complete protein profile makes eggs particularly valuable for growth, tissue repair, and maintaining overall health across all age groups.

Beyond protein, eggs are also an excellent source of fat. While dietary fat is sometimes viewed negatively in affluent societies concerned with obesity, the fat content in eggs serves critical functions. Fats provide concentrated calories—essential for populations facing food scarcity—and supply fatty acids that the human body cannot produce on its own but requires for proper functioning. These essential fatty acids play vital roles in brain development, hormone production, and the absorption of fat-soluble vitamins.

The combination of high-quality protein and beneficial fats makes eggs nutritionally important across all economic classes. For wealthy populations, the protein supports active lifestyles and health maintenance. For impoverished communities, both the protein and calorie-dense fats address fundamental nutritional needs that might otherwise go unmet.

From both a volume and quality perspective, eggs constitute an essential component of the global food supply. Worldwide egg production continues to grow, reflecting both rising demand and the expansion of poultry operations across diverse geographical regions.

The accessibility of egg production makes poultry particularly valuable for improving global nutritional levels. Unlike many livestock operations that require substantial capital investment and resources, poultry can be raised with relatively minimal inputs. Small-scale producers can maintain flocks with modest investments in feed, housing, and equipment. In fact, under subsistence conditions, poultry can produce food for their owners with only minimal resource allocation.

This low barrier to entry means that even economically disadvantaged families and communities can participate in egg production. A household with just a few laying hens can generate a consistent supply of high-quality protein and essential nutrients, either for direct consumption or for sale to generate income. This scalability—from backyard flocks to industrial operations—gives eggs unique potential to address malnutrition and food insecurity across multiple levels of society.



Image credit: Suzy Hazelwood from Pexels: Link to image of a bowl containing different types of eggs [www.pexels.com]

Chickens are by far the most critical species in global egg production, accounting for the vast majority of eggs consumed by humans worldwide. Several factors contribute to the chicken's dominance in this role:

- **High productivity**: Modern laying hens can produce over 300 eggs per year
- **Efficient feed conversion**: Chickens convert feed into eggs more efficiently than most other poultry
- **Adaptability**: Chickens thrive in diverse climates and management systems
- **Size**: Their eggs are an ideal size for individual or family consumption
- **Established infrastructure**: Global supply chains and production systems are well-developed for chicken eggs

While chickens dominate global egg production, several other poultry species make significant contributions, though to a much lesser degree:

Ducks are the second most critical egg-producing species in many regions, particularly in Asia. Duck eggs are larger than chicken eggs and have a richer flavor, making them prized for culinary applications. They also have thicker shells, which can improve storage life in areas without refrigeration.

Geese produce large eggs with high fat content. While goose egg production accounts for only a small fraction of global output, these eggs are highly valued in specific markets and cultural contexts.

Turkeys contribute only modestly to egg production because they are primarily raised for meat. While turkey eggs are considerably larger than chicken eggs, they are not commonly available in commercial markets.

Guinea fowl also produce eggs for human consumption, particularly in Africa, where these birds are indigenous. Their eggs are smaller than chicken eggs but are appreciated for their flavor and nutritional content.

Eggs represent a remarkable food resource with the potential to improve nutrition across all socioeconomic levels. Their high-quality protein and beneficial fat content address fundamental dietary needs, while the accessibility of poultry raising makes egg production feasible for communities regardless of economic status. With chickens leading production and other poultry species making supplementary contributions, eggs continue to play a vital role in global food security. As production increases, eggs will likely become even more crucial in meeting the nutritional needs of a growing world population.

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4.12: Fishing and Aquaculture

Aquaculture and fishing represent the aquatic component of agriculture, providing a significant portion of the world's food supply. Aquaculture involves cultivating aquatic organisms, such as fish, crustaceans, mollusks, and aquatic plants, in controlled environments. Fishing focuses on the harvesting of wild aquatic populations. Both practices are vital for global food security and a supplement to traditional livestock and crop farming.

The demand for seafood has been steadily rising due to population growth and a greater appreciation of its nutritional benefits. Fish is an excellent source of high-quality protein, omega-3 fatty acids, vitamins, and minerals. According to the Food and Agriculture Organization (FAO) of the United Nations, more than half of the fish consumed by humans globally comes from aquaculture. This growth underscores aquaculture's crucial role in meeting the protein needs of a growing population while alleviating pressure on wild fish stocks.

Fishing encompasses the capture of fish and other aquatic animals from oceans, lakes, and rivers. This sector is crucial to the economies of many coastal communities, providing a livelihood for millions of people worldwide. However, overfishing is a significant concern. It occurs when fish are caught at a rate faster than their populations can replenish, resulting in a decline in fish stocks and disruption of marine ecosystems. Sustainable fishing practices, such as setting catch limits, using selective fishing gear to minimize the catch of non-target species, and establishing marine protected areas, are crucial to maintaining the long-term health of these ecosystems.

Aquaculture is a diverse field with various methods and systems. These can range from simple pond culture to highly technological recirculation systems.

Types of Aquaculture Systems:

- **Pond Culture:** One of the oldest and most common methods, pond culture involves raising fish in earthen ponds. This system is relatively low-tech and cost-effective, but it can be susceptible to environmental fluctuations.
- **Net Pens/Cages:** Used primarily in lakes, bays, and open oceans, these systems consist of large net enclosures that hold fish. While they allow for the use of natural water flow, they can also raise concerns about waste buildup and the spread of disease to wild populations.
- **Recirculating Aquaculture Systems (RAS):** These are highly controlled, land-based systems that filter and reuse water. RAS minimizes water use and enables fish farming in any location, regardless of proximity to a natural water body. They are considered a more environmentally friendly option, but require a significant initial investment and energy to operate.

A wide variety of species are farmed globally. Some of the most common include:

- **Fin fish:** Salmon, tilapia, catfish, and trout.
- **Mollusks:** Oysters, mussels, and clams.
- **Crustaceans:** Shrimp and prawns.
- **Aquatic Plants:** Seaweed and microalgae are also cultivated for food, biofuels, and other products.

List of Sustainable Seafood



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4.13: End of the Line

Commercial fishing is one of the oldest and most important human industries, providing food, jobs, and economic growth for communities worldwide. Today, it supplies millions of tons of seafood annually and contributes nearly half of the world's protein intake in some regions. However, commercial fishing has also become one of the most debated industries because of its environmental, economic, and cultural impacts.

"End of the Line" is a documentary that will challenge your perspective on seafood. The film examines how our demand for fish has created a global industry that's fundamentally unsustainable, affecting everything from local fishing communities to international trade, from marine ecosystems to food security.

Watch for Themes

As you watch, pay attention to:

- **The science behind overfishing**: How do we know fish populations are declining, and what does "commercial extinction" actually mean?
- **Global interconnectedness**: How fishing practices in one part of the world affect ecosystems and communities thousands of miles away
- **Economic drivers**: Why do fishing fleets continue unsustainable practices even when they know the long-term consequences?
- **Regulatory challenges**: What makes it so difficult to manage ocean resources that cross international boundaries?
- **Potential solutions**: What approaches are being tested to address these challenges?



Critical Viewing Questions 4.13.1

After watching the documentary, answer the following questions and upload them to the assignment drop in Brightspace.

- What role does consumer demand play in driving overfishing?
- How do short-term economic pressures conflict with long-term sustainability?
- What are the ethical implications of depleting ocean resources for future generations?
- How might climate change complicate the issues presented in the film?
- What three things surprised you about this documentary?
- What two things from the documentary do you wish everyone knew? Why did you choose those two things?
- Did the film change your mind about fishing or eating fish? Explain why or why not.
- If restaurants served endangered mammals on their menus, such as cheetahs or elephants, there would be public uproar. Why do you think there isn't a similar reaction to endangered fish?

Resource for video: The Documentary Channel. Oct 19, 2022, The End of the Line: The Destruction of our Seas, [Video], YouTube, https://www.youtube.com/watch?v=Jmi4MGmKpn4&t=1s

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4.14: Outlaw Ocean

The Outlaw Ocean podcast offers an important window into the challenges of ensuring sustainable, ethical seafood production in aquaculture and global fisheries. After listening to ***episodes two and five from season one***, answer the following critical listening questions ahead of our discussion on this topic.

Outlaw Ocean Podcast (opens in new window)

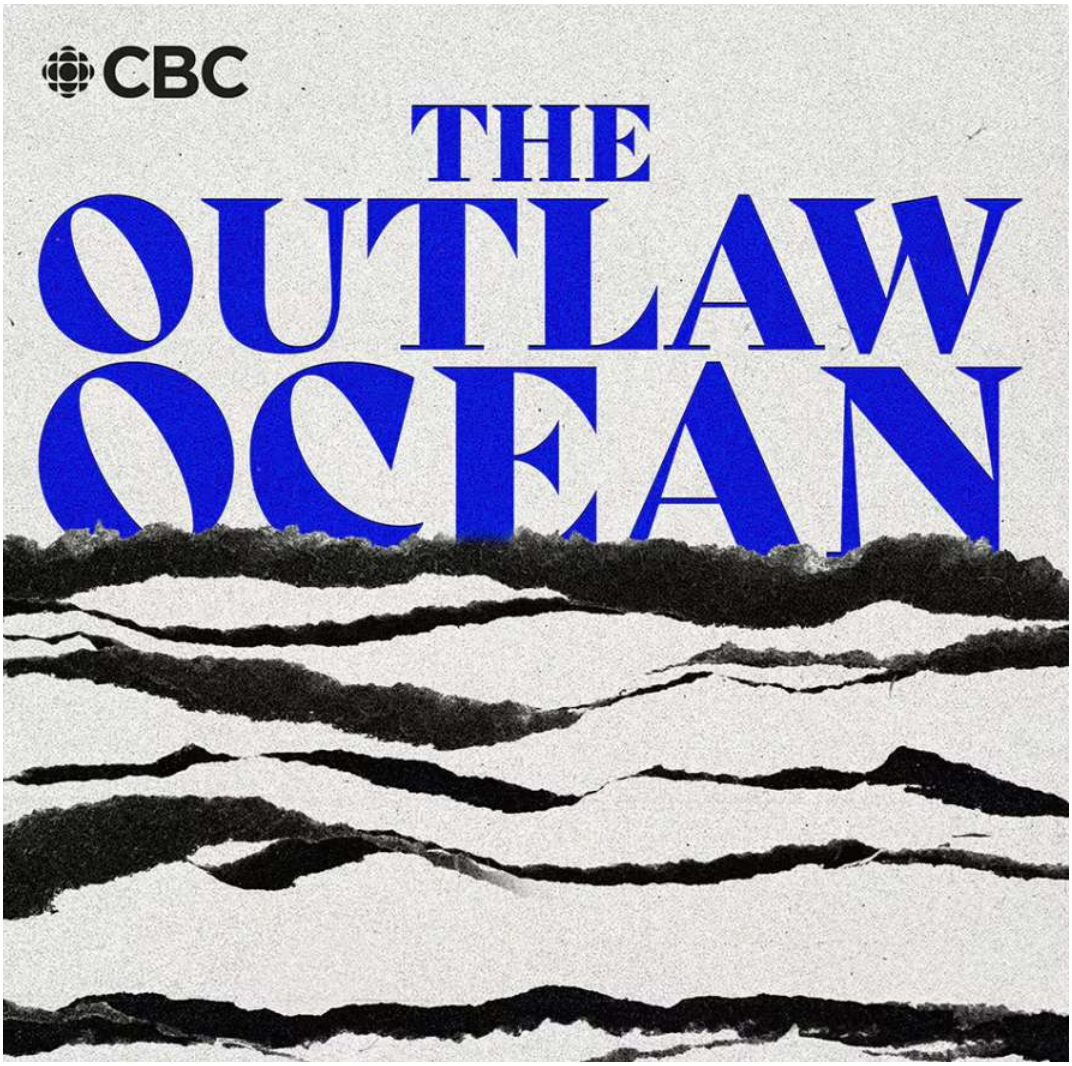


Photo credit: Link to image of the logo for Outlaw Ocean podcast (opens in new window) [www.cbc.ca]

? Critcal Viewing Questions 4.14.1

Season 1 - Episode 2: Dark Fleet

1. What role do “dark fleets” (unregulated, untraceable fishing vessels) play in global seafood markets?

2. How do these fleets exploit loopholes in international law, and why are they so hard to monitor?

3. What are the environmental and economic consequences of unregulated fishing for both marine ecosystems and coastal communities?

4. How does this episode challenge your perception of where seafood on your plate might come from?

Season 1 - Episode 5: Waves of Extraction

1. This episode focuses on deep-sea mining and the extraction of marine resources. How does this form of exploitation compare to industrial fishing in terms of environmental risks?

2. What ethical questions arise when industries treat the ocean as a frontier for resource extraction?

3. How might deep-sea mining impact aquaculture and fisheries in the long run?

4. If you were tasked with drafting international policy, what safeguards would you prioritize to balance economic interests with ecological protection?

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4.15: Aquaculture and Fishing Role-Playing Activity

Let's explore the complex challenges around fishing, aquaculture, and ocean resource management. By stepping into different roles, you'll see how scientific, economic, political, and social perspectives collide in real-world debates about the future of our oceans.

Instructions 4.15.1

1. **Divide students into four groups of five.** Each group will receive a scenario with a set of roles.
2. **Take five minutes to read and understand your role.** Draw on the video and podcast episodes, as well as your own research.
   - Think about your character's priorities, values, and concerns.
     - What motivates them? (profit, survival, science, community, conservation, etc.)
     - What pressures or constraints are they under?
     - What compromises would they resist or accept?
3. **Discuss as a Group**
   - Your group will role-play a meeting, debate, or negotiation based on your scenario.
   - Stay in character as you present your perspective and respond to others.
   - Aim for a *15–20-minute conversation* where each role has a chance to speak.
4. **Reach a Decision (if possible)**
   - Some scenarios ask you to make a collective decision (e.g., whether to allow deep-sea mining, set fishing quotas, or change supermarket seafood sourcing).
   - If your group cannot agree, that's okay—record where the disagreements lie and why.
5. **Reflection**
   - After the role-play, take five minutes to individually answer the follow-up reflection question assigned to your group.
   - Be honest—what did you notice about power, persuasion, or conflict in your group?

Tips for Success

- Don't worry about "performing" — focus on *representing your role's perspective.*
- Listen carefully to others and respond as your character would, not as yourself.
- Remember: there is no single "right answer." The value comes from seeing how complex these negotiations are.

Role Playing Scenarios

1. The Collapse of Cod

***Context*:** The documentary highlights the collapse of cod fisheries, especially in the North Atlantic, as a case study of overfishing.

***Roles*:**

- Local fishermen who rely on cod for their livelihood
- Government fisheries minister
- Marine biologist studying cod populations
- Restaurant owner whose menu depends on cod dishes
- Journalist covering the story

***Task*:** Role-play a town hall meeting in a coastal community as cod populations near collapse.

***Discussion Goal*:** Explore short-term economic needs versus long-term sustainability, and how science, politics, and livelihoods collide.

***Reflect*:** In your role, how did you balance immediate economic needs with the long-term health of the fishery? What trade-offs felt most difficult, and what does this reveal about the challenges of managing common resources?

2. Bluefin Tuna on the Brink

***Context*:** Bluefin tuna is one of the most overexploited species, driven by global demand, particularly for sushi.

***Roles*:**

- Tuna fisherman
- Representative of the International Commission for the Conservation of Atlantic Tunas (ICCAT)
- Sushi restaurant chain owner
- Consumer advocate promoting seafood guides
- Environmental activist (e.g., Greenpeace)

***Task*:** Simulate an international regulatory meeting where quotas for bluefin tuna are being set.

***Discussion Goal*:** Debate whether economic demand justifies the continued fishing of a species at risk of extinction.

Reflect: How might international politics and market demand shape the outcome of a debate on quotas? Do you think science or economics carried more weight in your group's discussion, and what does that suggest about real-world fisheries management?

3. Supermarket Choices

Context: The film highlights the responsibility of retailers and consumers in driving overfishing.

***Roles*:**

- Supermarket seafood buyer
- Aquaculture industry representative
- Environmental NGO campaigning for sustainable labeling
- A consumer who prioritizes affordability over sustainability
- Policy maker drafting food labeling regulations

Task: Negotiate whether the supermarket chain should only sell sustainably sourced fish, even if it raises prices.

Discussion Goal: Examine the role of consumer choice and corporate accountability in shaping sustainable fisheries.

Reflect: What arguments were most persuasive in deciding whether the supermarket should prioritize sustainability or affordability? How do consumer behavior and corporate responsibility intersect in shaping the future of seafood?

4. Deep-Sea Mining Proposal

Context: "Deep-sea mining is a necessary step for meeting global demand for minerals used in renewable energy technologies (e.g., batteries)." One side defends the practice as essential for progress. The other side argues that the ecological risks outweigh the benefits.

***Roles*:**

- Mining company executive
- Local fishing community leader
- Marine scientist
- Policy maker from an international regulatory body
- Environmental activist

***Task*:** Simulate a public hearing where the mining company seeks permission to begin deep-sea extraction in a biologically rich area.

***Discussion Goal*:** Highlight tensions between economic opportunity, environmental protection, and community survival.

Reflect: What compromises were most complicated to reach? In your opinion, who should bear the responsibility for ensuring that the oceans are used ethically and sustainably (governments, corporations, consumers, or others)? Why?

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4.16: A Growing World and the Challenges of Food Production

The world's population is currently over eight billion people and continues to grow. This growth puts immense pressure on global food production. The world's population reached 1 billion around 1800, and projections suggest it could hit 10 billion by 2050. This rapid increase means that global agriculture has had to feed billions more people. Compounding this, the average caloric intake in developing nations has also increased significantly.

The global livestock sector faces significant challenges in meeting growing demand while addressing concerns about environmental sustainability, animal welfare, and human health.

Key challenges include:

- Reducing environmental impacts, particularly greenhouse gas emissions and water use
- Addressing antimicrobial resistance associated with livestock production
- Improving animal welfare in intensive production systems
- Ensuring equitable access to animal-source foods in food-insecure regions
- Adapting livestock systems to climate change impacts

Addressing these challenges requires interdisciplinary approaches that account for the complex interactions among livestock production, human nutrition, environmental sustainability, and economic development.



Image credit: Barbara Barbosa from Pexels: Link to image of confined pigs eating inside a building [www.pexels.com]

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4.17: The 2050 Food Crisis

The "2050 food crisis" refers to a looming global food security challenge driven by a combination of factors that threaten the world's ability to feed an estimated population of 9.8 to 10 billion people. To meet this demand, food production would need to increase by 56% to 70% from current levels. However, this projected increase in demand is challenged by several environmental, economic, and social pressures.

- **Population Growth and Changing Diets:** The global population is projected to increase by more than two billion by 2050, with most of this growth occurring in developing countries. As these populations become more affluent, their dietary habits are shifting toward more resource-intensive foods, particularly meat and dairy. This change in diet requires a significant increase in grain production for animal feed.
- **Climate Change and Environmental Stressors:** Climate change is a major driver of food insecurity, causing unpredictable weather, droughts, heatwaves, and extreme climate events that lead to failed harvests and livestock deaths. A rise of 1 to 2 degrees Celsius in average global temperatures is expected to reduce crop yields. Climate change also accelerates water loss from plants and soil, and water scarcity is a significant concern for agriculture in many regions.
- **Resource Depletion:** The availability of arable land is shrinking due to urbanization, soil degradation, and the conversion of forests into grazing land. Agriculture currently accounts for 70% of the world's freshwater withdrawals, a demand that could increase by 120% by 2050. This puts immense pressure on already scarce water resources.
- **Inequality and Conflict:** Even with adequate global food supplies, hunger can persist due to limited income opportunities for the poor and a weak social safety net. Conflict and instability in many regions disrupt food production, displace populations, and hinder humanitarian aid, exacerbating food insecurity.
- **Food Waste and System Inefficiency:** An estimated one-third of all food produced for human consumption is lost or wasted annually. This waste occurs throughout the supply chain, from post-harvest losses due to pests and poor storage to consumer-level waste.

Potential Solutions to Avert the Crisis

Averting this crisis requires a multi-faceted approach involving technological innovation, policy changes, and shifts in consumer behavior.

- **Sustainable Agriculture and Technology:** Increasing investment in agricultural research is crucial to developing technologies that enhance crop productivity and resilience. This includes improving the efficiency of photosynthesis in staple crops, developing naturally drought-resistant crops, and promoting nutrient-rich indigenous crops. Techniques like agroecology and the System of Rice Intensification (SRI) can also boost yields while using less water and fewer fertilizers.
- **Changes in Diet and Consumption:** To reduce the environmental footprint of our food system, some experts suggest a radical change in diet, such as reducing meat consumption. Diversifying protein sources with alternatives like edible insects and seaweed is also being explored, as these foods are rich in nutrients and have a smaller environmental impact than traditional meat production. Additionally, initiatives to reduce food waste at both the production and consumer levels are a key strategy.
- **Policy and Infrastructure:** Political will and financial investment are needed to implement these solutions. This involves strengthening infrastructure to improve food storage and transport, which reduces food loss. Policies that support small farmers are essential, as they are often the most vulnerable to climate shocks and food insecurity. Ensuring fair trade practices and securing land rights for women farmers can also improve livelihoods and food security in rural communities.



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4.18: 2050 Food Debate

As the global population approaches 10 billion by 2050, humanity faces one of its most pressing challenges: how to feed everyone sustainably while our planet's resources grow increasingly strained. Climate change threatens traditional agricultural regions, water scarcity intensifies, and arable land diminishes under the pressure of urbanization and soil degradation. Your group will be assigned a potential solution to the global food crisis and will act as advocates for that solution. The goal is to research, present, and debate the feasibility and effectiveness of your assigned solution. The class will then vote on the most convincing argument.

? Debate Instructions 4.18.1

1. ***Divide the class into five teams.*** Each team is assigned one of the following potential food solutions for 2050:

    - Vertical Farming
    - Genetically Modified (GM) Crops
    - Plant-Based Diets
    - Cultured Meats and Cellular Milk
    - Reducing Food Loss and Waste

2. ***Research and Plan Development***

Each team should become experts on their assigned solution. They should prepare a comprehensive argument that addresses the following points:

- *Problem*: What specific aspects of the 2050 food crisis does your solution address most effectively? (e.g., land use, water scarcity, environmental impact)
- *Mechanism:* How does your solution work? What are the key technological or social components?
- *Advantages:* What are the benefits of your solution? (e.g., increased yields, reduced environmental footprint, enhanced nutrition)
- *Feasibility*: How realistic is it to implement your solution on a global scale by 2050? Consider economic costs, consumer acceptance, and regulatory hurdles.
- *Counterarguments:* Anticipate and prepare responses to potential criticisms from other teams. For example, a team advocating for GM crops should be ready to address public skepticism and safety concerns.

3. ***The Debate***

The instructor will moderate the debate. The debate should focus on the merits of each solution, highlighting strengths and weaknesses. Each team has a set time to present its solution. After all presentations, teams can ask each other questions, and the moderator can pose questions to spark conversation.

4. ***Voting and Conclusion***

Following the debate, each student will vote for the solution they believe is the most feasible and impactful for solving the 2050 food crisis. The presentation with the most votes wins the debate. Time permitting, the moderator will then lead a debriefing discussion, summarizing the key takeaways from the debate.

Voting and Evaluation Criteria

Consider the following points when voting for the 2050 food solutions presented during the debate:

- **Argument Strength**: How well did the team support their claims with evidence and logical reasoning?
- **Debate Performance:** How effectively did the team respond to questions and counterarguments?
- **Feasibility Assessment:** Did the team realistically evaluate the economic, social, and logistical challenges of their solution?
- **Citation:** All information must be accurately cited from reliable sources.

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4.19: Summary and Flashcards

Understanding worldwide agricultural systems provides a crucial frame of reference for our own practices. The climate and level of economic development primarily determine the systems found in a given area. Agricultural animals must adapt to both natural and human-made environments, adjusting to stresses that can be climatic, nutritional, internal, geographical, and social.

Global agricultural production can be broadly categorized into three levels of development: primitive, subsistence, and developed. Primitive and subsistence systems, characterized by low capital investment and reliance on hand and animal labor, have proven sustainable for centuries. The goal of these systems is typically self-sufficiency rather than profit. In contrast, developed agriculture is highly specialized, mechanized, and profit-driven, with a tiny portion of the population engaged in farming.

There are also significant differences between the livestock industries in developed and developing countries. While both have a few extensive operations, moderate-sized farms are more common in developed countries than in developing ones. Minor operations are commonplace in both, but in developing countries, they are often the sole source of income, whereas in developed countries, they are typically considered a hobby farm.

Aquaculture and fishing provide essential nutrition and livelihoods worldwide. With aquaculture now supplying over half of global fish consumption and sustainable fishing needed to protect wild stocks, both are critical to meeting rising food demand and supporting food security.

Eggs and dairy are major animal-derived foods, providing complete protein and beneficial fats essential for human nutrition. Their value lies in both nutrition and accessibility, as they can be produced from small backyard setups to extensive industrial facilities with relatively low investment. This scalability allows even resource-limited communities to grow nutritious food, making eggs and dairy vital to addressing malnutrition and improving food security worldwide.

Avoiding the 2050 food crisis will require bold innovation and global commitment to build sustainable, resilient food systems—starting now.

https://bio.libretexts.org/@go/page/182415

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CHAPTER OVERVIEW

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Nutrition examines how organisms use components of food to sustain life, support growth, and enable production. In commercial livestock operations, nutrition represents the single largest variable cost—feed typically accounts for 65-75% of total production expenses. Understanding nutritional principles is therefore essential for both animal welfare and economic viability.

Nutrients are chemical substances that support survival, maintenance, and productivity. They fall into six major classes: water, carbohydrates, proteins, lipids, vitamins, and minerals. These can be further categorized as either dietary essentials (must be consumed) or dietary non-essentials (synthesizable by the body).



Image credit: Los Muertos Crew https://www.pexels.com/photo/cows-in...ting-10041325/

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5.1: Nutrient Requirements and Evaluation

Understanding what animals need to eat starts with recognizing why they need those nutrients in the first place. Every animal's body is constantly working to keep itself alive and functioning, but beyond that, different life stages and activities create additional nutritional demands. A growing calf, a lactating dairy cow, and a horse pulling a plow all have vastly different nutrient requirements because their bodies are doing other things. To properly feed and manage animals, you need to understand how these physiological functions drive what they need to consume and how much they need to consume.

Physiological Functions Dictating Nutrient Needs:

Animal nutrient requirements are determined by maintenance needs plus production demands:

- **Maintenance** supports basal metabolism (cardiovascular, respiratory, and renal function), thermoregulation, and minimal physical activity. This must be met before production can occur.
- **Growth** requires nutrients for tissue accretion, with high-quality protein and balanced mineral supply being critical.
- **Lactation** imposes substantial energy and nutrient demands, often exceeding intake capacity in early lactation, necessitating mobilization of body reserves.
- **Reproduction** encompasses gamete production, fetal development, and parturition, with increased energy, protein, vitamin, and mineral needs, particularly in late gestation.
- **Production/Work** increases energy requirements in proportion to activity intensity, including the output of products (milk, eggs, wool).
- **Finishing** is the final phase for meat animals, focusing on adding fat tissue. Requires high energy but a lower percentage of protein than the growth phase.



Image credit: Mark Stebnicki from Pexels: Link to piglets suckling image [www.pexels.com]

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5.2: Water

Water is the most abundant nutrient in the body, comprising 50-90% of body mass depending on age and physiological state. Despite its critical importance, it is often the most neglected nutrient in animal management.

- Serves as the universal solvent for biochemical reactions
- Transports nutrients to cells and removes metabolic waste
- Regulates body temperature through its high specific heat capacity
- Maintains cell structure and osmotic pressure
- Facilitates digestion through saliva, gastric secretions, and intestinal fluids

Animals obtain water through three routes: direct consumption (drinking water), water from food, and metabolic water produced during nutrient oxidation. Requirements vary substantially with environmental temperature, physiological state (lactation significantly increases demand), diet composition (high salt or protein increases demand), and species-specific water-conservation abilities.

Water restriction rapidly compromises feed intake and productivity. Dehydration causes electrolyte imbalances, elevated body temperature, increased respiratory rate, and behavioral changes. Severe deprivation leads to circulatory collapse and death more quickly than deprivation of any other nutrient.

Total dissolved solids (TDS) below 1,000 mg/L are generally safe for all livestock classes. Concentrations above 5,000 mg/L may reduce productivity, cause diarrhea, or lead to water refusal. Contamination with nitrates (>1,500 ppm), pathogenic organisms, blue-green algae toxins, or pesticide residues poses significant health risks.



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5.3: Water Crisis Discussion

To critically think through, synthesize, analyze, and prepare for our water discussion, please write a Response Essay using the format outlined below. This will not only provide a low-stakes assignment to process concepts but also prepare you for class discussions, upcoming assignments, and exams. Consider this assignment more formal than notes, and a way to discuss and connect ideas with yourself and your classmates.



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? The Response Essay 5.3.1

A Response Essay is a three-paragraph essay meant to:

- Hone your critical reading/viewing skills.
- Demonstrate your understanding of and engagement with the topic.
- Help with writing the formal essays.

Response essays can be used to collect your thoughts and build arguments, evidence, quotations, and questions, but should be written in whole paragraphs (usually five to ten sentences, but no fewer than four).

Answer one of the following questions (unless you feel compelled to write for more than one, which is fantastic):

1. What was most interesting about the video viewing for this topic? Why?
2. What connections do you see between today's video and other topics from this course (or other courses) or conversations we have had earlier in the semester?
3. What was most challenging for you in today's viewing? You may refer to things that are intellectually or emotionally difficult.

Cite a quotation or scene from the video and explain why you find it significant. Is this quotation/scene representative of a point you are making? Is this quotation/scene an example of something in agreement or disagreement with another topic? Is it a passage/moment that moved you, resonated with your own experience, or surprised you?

Create a discussion question for the class, then answer it in paragraph form.

How useful do you think the solutions outlined in the video are in the long run, and how can larger policy changes improve those?

Video **Our Water Crisis is WAY WORSE than You Think...Here's Why (opens in new window)**

Video resource: PBS Terra. Feb 12, 2025, *Our Water Crisis Is WAY WORSE than You Think...Here's Why* [Video], YouTube, https://www.youtube.com/watch?v=7ALeNj7cp_s

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5.4: Carbohydrates

Carbohydrates are organic compounds with the general formula $(CH_2O)_n$, composed of carbon, hydrogen, and oxygen. They represent the primary energy source in most animal diets.



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- ***Monosaccharides*** are single sugar units (glucose, fructose, galactose) that require no digestion and are readily absorbed; Monosaccharides are the simplest forms of carbohydrate.
- ***Disaccharides*** consist of two monosaccharides linked by glycosidic bonds (lactose in milk, sucrose in plants, maltose from starch digestion)
- ***Oligosaccharides*** contain 3-15 sugar units (raffinose, stachyose in legumes)
- ***Polysaccharides*** are long chains of monosaccharides serving either storage (starch, glycogen) or structural (cellulose, hemicellulose) functions

Starch is the primary carbohydrate source in the diet of monogastric animals. Pancreatic amylase makes starch highly digestible for monogastric animals.

Structural Carbohydrates build plant cell walls and include cellulose, hemicellulose, and lignin (which isn't a carbohydrate but is closely linked to the wall). Mammals can't digest these. However, ruminants and hindgut fermenters use cellulases to ferment these carbohydrates into volatile fatty acids (VFAs), which they use for energy.

In monogastrics, starch digestion begins minimally in the mouth (limited salivary amylase in some species) and proceeds primarily in the small intestine via pancreatic amylase. The resulting glucose is absorbed.

In ruminants, dietary carbohydrates undergo microbial fermentation in the reticulorumen before enzymatic digestion occurs. VFAs produced during fermentation provide 70% or more of the ruminant's energy supply.

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5.5: Proteins and Amino Acids

Proteins are long chains of amino acids linked by peptide bonds. While they serve as structural components of muscle, skin, and hair, they also function as enzymes, hormones, antibodies, and transport molecules. When dietary protein exceeds these functional needs, the excess can be broken down and used for energy.

Of the 20 amino acids in animal proteins, approximately ten are classified as essential for monogastric animals—they cannot be synthesized at rates sufficient to meet requirements. The requirement varies by species (e.g., ten for pigs, more for poultry/cats).

The limiting amino acid is the essential amino acid present in the diet at the lowest level relative to the animal's requirement.



Image credit: Lukas Blazek from Pexels: https://www.pexels.com/photo/raw-mea...urface-618773/

Protein digestion starts in the stomach. Where stomach acid converts pepsinogen into pepsin, which begins breaking down protein chains. The process continues in the small intestine, where the pancreas releases enzymes (trypsin, chymotrypsin, and carboxypeptidases) that further break down proteins. Finally, enzymes on the intestinal lining complete the job, creating amino acids and small peptides that the body can absorb.

Absorbed amino acids enter the blood and reach the liver, where they may be used for protein synthesis, converted to glucose, oxidized for energy, or released into general circulation. Excess amino acids are deaminated—the amino group is removed, converted to urea via the urea cycle (or uric acid in birds), and excreted. The remaining carbon skeleton can be used for energy or converted to glucose or fat.

Ruminant protein nutrition differs significantly from that of monogastric animals. Dietary protein is divided into rumen-degradable protein (RDP) and rumen-undegradable protein (RUP, also known as bypass protein). Microbes in the rumen break down RDP into amino acids, then deaminate them to release ammonia. Using the ammonia and carbon skeletons from carbohydrate fermentation, the microbes synthesize microbial protein. Both microbial protein and RUP then move to the abomasum and small intestine for normal enzymatic digestion.

Because rumen microbes can synthesize amino acids from ammonia, ruminants can utilize non-protein nitrogen (NPN) sources, such as urea. However, if RDP exceeds available energy, excess ammonia builds up, is absorbed into the bloodstream, converted to urea in the liver, and excreted—wasting energy and increasing nitrogen loss to the environment.

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5.6: Fats (Lipids)

Lipids are organic compounds characterized by their solubility. They provide approximately 2.25 times the energy of carbohydrates or proteins on a weight basis. This energy density makes fats valuable for formulating palatable, high-energy diets, particularly for lactating animals or those under thermal stress. Fats also provide omega-3 and omega-6 fatty acids, which animals require for normal physiological function.

Fatty acids are classified by chain length:

- **Saturated fatty acids** contain no double bonds
- **Monounsaturated fatty acids** contain one double bond
- **Polyunsaturated fatty acids (PUFAs)** contain multiple double bonds



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In monogastrics, lipid digestion begins in the small intestine, where bile salts emulsify fats. Pancreatic lipase then breaks triglycerides into monoglycerides and free fatty acids. These combine with bile salts to form micelles, which aid absorption into intestinal cells. Inside the cells, fatty acids are rebuilt into triglycerides, packaged into chylomicrons, and released into the lymph.

In ruminants, rumen microbes first break down dietary fats into free fatty acids and glycerol. Glycerol is quickly fermented to propionate, while unsaturated fatty acids are hydrogenated—microbes add hydrogen to saturate double bonds and reduce fat toxicity. As a result, ruminant body fat and milk fat contain more saturated and fewer polyunsaturated fatty acids than the original diet.

In addition to providing energy, lipids play vital structural and regulatory roles. Phospholipids form the bilayer of cell membranes, while cholesterol contributes to membrane structure and serves as a precursor for steroid hormones, vitamin D, and bile acids. Essential fatty acids give rise to eicosanoids, which regulate inflammation, immune responses, and vascular function.

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5.7: Vitamins

Fats act as important carriers for the fat-soluble vitamins (A, D, E, and K). Vitamins are organic compounds required in minute amounts that function primarily as coenzymes or regulatory molecules rather than providing energy or structural material. They are classified by solubility.

Fat-soluble vitamins are involved in regulating body functions like vision, bone development, blood clotting, and tissue maintenance and can be stored in the body's fat tissue.

Vitamin A is essential for vision, epithelial cell integrity, bone growth, and immune function. Deficiency causes night blindness, keratinization of epithelial tissues, reproductive failure, and increased infection susceptibility. Ruminants generally meet vitamin A needs from carotenes in fresh forage; grain-fed animals require supplementation.

Vitamin D (cholecalciferol in animals) functions as a hormone regulating calcium and phosphorus homeostasis. It promotes intestinal calcium absorption, renal calcium reabsorption, and bone mineral mobilization. Synthesis occurs in skin exposed to UV light; housed animals require dietary sources. Deficiency causes rickets in growing animals (inadequate bone mineralization with skeletal deformities) and osteomalacia in adults (bone demineralization, fractures). Vitamin D is critical in preventing milk fever (parturient paresis) in high-producing dairy cows.

Vitamin E (α-tocopherol) is the primary lipid-soluble antioxidant, protecting cell membranes from peroxidative damage by scavenging free radicals. Deficiency syndromes include white muscle disease (nutritional muscular dystrophy affecting skeletal and cardiac muscle), exudative diathesis in poultry (capillary damage causing subcutaneous edema), and encephalomalacia (cerebellar necrosis in chicks). High dietary levels are used to enhance the oxidative stability of meat and improve immune function.

Vitamin K is required for the synthesis of blood-clotting factors. Deficiency causes prolonged clotting time and hemorrhage. Hindgut microbial synthesis generally meets requirements except in young animals, those on antibiotic therapy, or consumption of vitamin K antagonists (in moldy sweet clover).

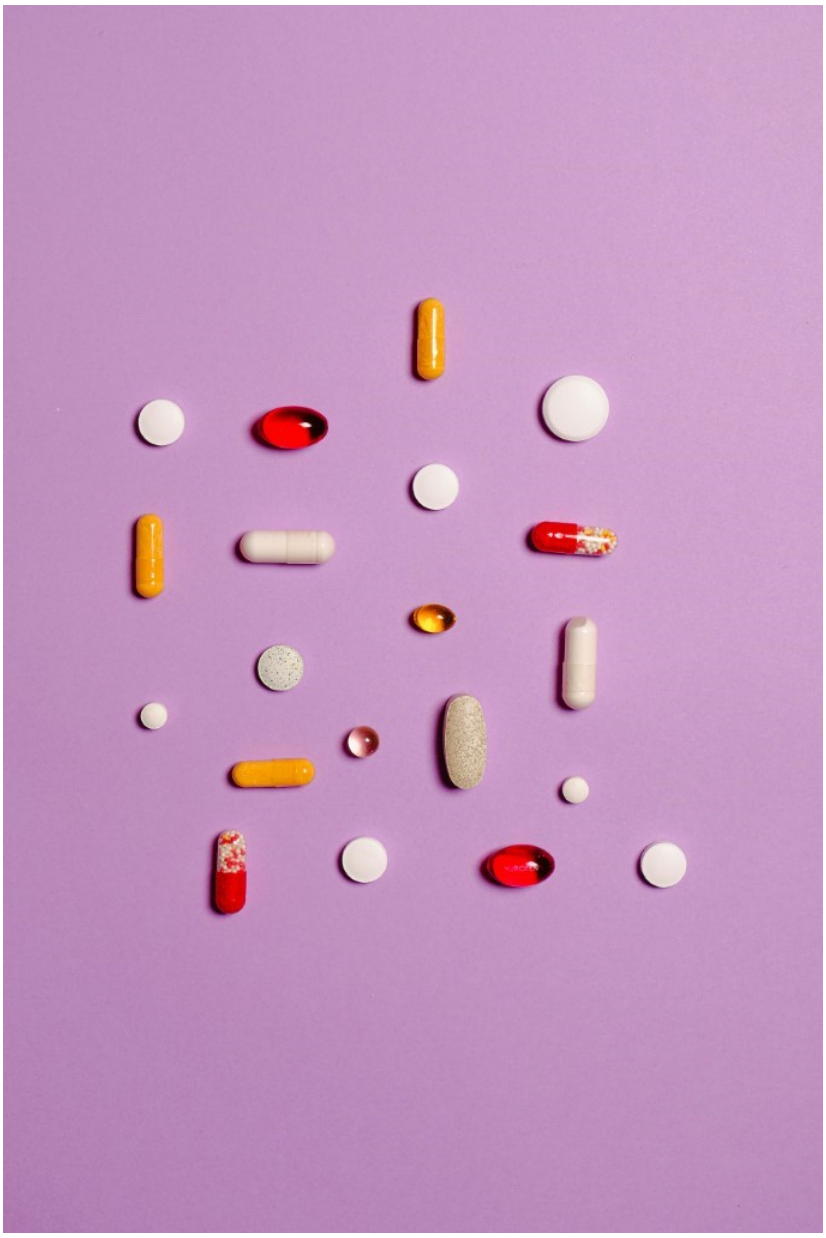


Image credit: Anna Shvets from Pexels: https://www.pexels.com/photo/medicat...round-3683116/

Water-soluble vitamins play essential roles in animal nutrition, serving primarily as coenzymes in metabolism. Unlike fat-soluble vitamins, they are not stored extensively in the body and must be supplied regularly through the diet. These vitamins—including the B-complex group and vitamin C—are vital for energy production, red blood cell formation, nervous system function, and antioxidant defense. Because excess amounts are excreted in urine, consistent intake is necessary to maintain optimal health and performance.

The B vitamins function as coenzymes in energy metabolism, protein metabolism, and cell replication. Because they are not stored appreciably, daily intake is essential for monogastrics. Ruminants and hindgut fermenters synthesize B vitamins through microbial activity.

Vitamin C (ascorbic acid) is synthesized from glucose by most mammals except primates and guinea pigs. It functions in collagen synthesis, as an antioxidant, and in neurotransmitter synthesis. Livestock typically do not require dietary vitamin C, though supplementation during stress may provide benefits.

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5.8: Macrominerals

Minerals are inorganic elements essential for structural and regulatory functions. They are classified by quantitative requirements.



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Macrominerals (>0.01% of diet) are essential minerals required by animals in relatively large amounts to support vital physiological functions. They play key roles in bone formation, nerve transmission, muscle contraction, osmotic balance, and acid–base regulation. The primary macrominerals include calcium, phosphorus, magnesium, sodium, potassium, chlorine, and sulfur. Adequate and balanced intake of these minerals is crucial for growth, reproduction, and overall animal health.

Calcium and Phosphorus account for 99% and 80%, respectively, of these minerals in the body, primarily in bones and teeth. Calcium also functions in nerve transmission, muscle contraction, blood clotting, and enzyme activation. Phosphorus is essential to ATP, nucleic acids, phospholipids, and buffer systems.

Blood calcium is tightly regulated by parathyroid hormone (PTH), calcitonin, and vitamin D. Hypocalcemia stimulates PTH release, which increases bone resorption, renal calcium retention, and renal synthesis of active vitamin D, enhancing intestinal calcium absorption.

Deficiency causes rickets in young animals and osteomalacia in adults, both marked by weak bones, deformities, lameness, and fractures. In dairy cows, milk fever occurs around calving when the demand for calcium in milk exceeds the body's ability to supply it. It is treated with intravenous calcium and prevented by adjusting the pre-calving diet to slightly increase acidity, which helps the cow mobilize calcium more effectively.

Magnesium activates enzymes involved in phosphate transfer and functions in bone structure. Deficiency manifests as grass tetany in ruminants grazing lush, rapidly growing pasture. Clinical signs include hyperexcitability, muscle tremors, tetanic spasms, convulsions, and sudden death. High potassium and nitrogen in spring grass inhibit magnesium absorption. Treatment involves intravenous magnesium sulfate; prevention includes magnesium supplementation.

Electrolytes (Sodium, Potassium, Chloride) help regulate fluid balance, acid–base status, and nerve and muscle function. Sodium is the main ion outside cells, potassium is the main ion inside cells, and chloride is the main negative ion outside cells and is needed

to make stomach acid. The balance of these electrolytes in the diet influences growth, bone strength in poultry, and the risk of milk fever in dairy cows.

Sulfur is a component of sulfur-containing amino acids, vitamins (thiamin, biotin), and structural proteins (keratin in hair, wool, feathers; chondroitin sulfate in cartilage). Requirements are generally met through amino acid intake, though ruminants may benefit from inorganic sulfur when consuming non-protein nitrogen sources.



Photo credit: Wikipedia https://en.wikipedia.org/wiki/Sulfur

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5.9: Microminerals

Microminerals, or trace minerals (<0.01% of diet), are required by animals in small amounts but are vital for many physiological processes. They play key roles in enzyme function, hormone production, immune response, and antioxidant defense. Important microminerals include iron, copper, zinc, manganese, iodine, selenium, and cobalt. Even slight deficiencies or imbalances can impair growth, reproduction, and overall health.

Iron is primarily found in hemoglobin and myoglobin. Deficiency causes hypochromic, microcytic anemia. Piglet anemia is common due to low milk iron, rapid growth, and limited placental transfer; prophylactic iron dextran injection is standard practice.

Copper is required for iron metabolism, collagen cross-linking, melanin synthesis, and antioxidant defense. Deficiency causes anemia, skeletal abnormalities, cardiovascular lesions (aortic rupture), depigmentation, and neurological disorders (swayback in lambs). Sheep are particularly susceptible to copper toxicity due to inefficient biliary excretion.

Zinc is a cofactor or structural component of over 300 enzymes involved in nucleic acid and protein synthesis, immunity, and reproduction. High concentrations occur in hair, wool, skin, and feathers. Deficiency causes parakeratosis (dermatitis with thick, scaly skin lesions), poor growth, impaired immunity, and reproductive dysfunction.

Selenium is a key component of selenoproteins, which protect cells from oxidative damage, and of enzymes that activate thyroid hormones. It works closely with vitamin E as an antioxidant. Deficiency can cause white muscle disease in livestock, exudative diathesis in poultry, and reproductive issues. However, too much selenium is toxic—chronic excess (alkali disease) leads to hoof and hair damage, while acute toxicity (blind staggers) causes nervous system problems.

Iodine is exclusively required as a component of thyroid hormones, which regulate basal metabolic rate and energy metabolism. Deficiency causes hypothyroidism—reduced growth, reproductive failure, hair loss—and goiter (thyroid gland enlargement). Marine sources and iodized salt provide supplementation.

Cobalt functions solely as a component of vitamin B_{12} (cobalamin). Ruminants require dietary cobalt for microbial synthesis of B_{12} in the rumen; monogastrics require preformed B_{12}. Deficiency in ruminants impairs short-chain fatty acid metabolism, causing anorexia, emaciation, anemia, and fatty liver.



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5.10: Animal Nutritional Needs--A Ranking Activity

Understanding how different nutrients support animal health, growth, and productivity is fundamental to effective livestock management. In this activity, you'll work collaboratively to analyze the specific nutritional requirements of different farm animals, considering how their unique physiological demands, production purposes, and environmental conditions shape their dietary needs. By creating nutrient cards and ranking their importance, you'll develop a deeper appreciation for the complexity of animal nutrition and learn to think critically about resource prioritization when constraints arise.

Materials

70 index cards total (14 blank cards per group for 5 groups)

Digital alternatives: If you prefer a digital format, consider using free versions of Padlet, Trello, or your LMS discussion board to create virtual cards.

Instructions

1. Form Groups

Divide the class into five groups of approximately equal size. Each group will analyze the nutritional needs of a different animal production scenario.

2. Receive Your Animal Assignment

Your instructor will assign one of the following animals to your group:

- **Group 1:** High-producing dairy cow
- **Group 2:** Growing piglet
- **Group 3:** Sheep in a cold climate
- **Group 4:** Egg-laying hen
- **Group 5:** Beef steer on finishing diet

3. Create Your Nutrient Cards (14 cards total)

For each of the 14 nutrients listed below, create one card:

Front of card: Write the nutrient name clearly at the top

1. Water
2. Carbohydrates – Starch
3. Carbohydrates – Structural Carbohydrates
4. Protein
5. Lipids (fats)
6. Fat-soluble vitamins
7. Water-soluble vitamins
8. Calcium
9. Magnesium
10. Electrolytes
11. Iron
12. Copper
13. Cobalt
14. Selenium

Back of card: Explain how this specific nutrient supports your assigned animals:

- Survival
- Reproduction
- Growth
- Health

Consider your animal's unique characteristics, production purpose, and environmental conditions when writing your explanations.

4. Rank the Nutrients

As a group, discuss and arrange your 14 nutrient cards in order from ***most important to least important*** for your group's specific animal scenario. Be prepared to justify your ranking decisions based on your animal's physiological needs and production goals.

5. Prepare Your Presentation

Discuss as a group and be ready to explain:

- Why did you rank your top 3-5 nutrients in those positions?
- Why did you rank your bottom nutrients lower?
- What unique factors about your animal's biology, production purpose, or environment influenced your decisions?

6. Class Discussion

Each group will share its nutrient ranking and reasoning with the class. Listen actively to other groups and note similarities and differences across animal species.

Critical Thinking Challenge: When Life Throws a Curveball

After your initial presentation, your instructor will visit each group and **remove one nutrient card to simulate a real-world scenario in which** specific nutrients become unavailable or cost-prohibitive.

Your task:

- Realign your nutrient ranking without the removed nutrient
- Discuss how this deficiency might impact your animal's health and productivity
- Consider what compensatory strategies a producer might employ
- Identify which remaining nutrients become more critical

Be prepared to share how this constraint changed your thinking and what unique factors influenced your adjusted ranking.



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5.11: Feed Evaluation Procedures

Accurate feed evaluation integrates chemical composition with biological availability and productive value. Feed analysis aims to determine the composition, digestibility, palatability, and productive value of feedstuffs.

Animal trials are biological procedures used to determine how a feed affects an animal. Animal trials are a necessary component of animal nutrition research, complementing chemical analyses of feedstuffs to determine their value to animals.

Nutritionists commonly employ three major types of biological trials: *feeding trials* (to test palatability and performance in functions like growth, lactation, or endurance), *digestion trials* (to measure digestibility by quantifying the nutrient difference between intake and excretion), and more advanced *metabolism trials* (which measure the body's total intake and excretion, including losses via urine and gas, to calculate nutrient retention or balance).

Although time-consuming, labor-intensive, and expensive, these methods provide essential data for accurate ration formulation and understanding how animals metabolize and utilize feed components.

This method, developed in the 1860s, provides a standardized way to compare feeds and formulate balanced diets. While not perfect—it doesn't account for digestibility or nutrient quality—proximate analysis remains widely used because it's relatively simple, inexpensive, and provides a consistent baseline for feed evaluation. Proximate Analysis partitions feed into six fractions:

- **Dry Matter (DM)**: what remains after all water is evaporated by oven drying at 105°C
- **Crude Protein (CP)**: calculated from the total nitrogen (N) content multiplied by 6.25 (since protein is roughly 16% N)
- **Ether Extract (EE)**: fat extracted by organic solvents (high-caloric density)
- **Ash**: all mineral content remaining after burning off all organic matter at 500-600°C
- **Crude Fiber (CF)**: insoluble carbohydrates (cellulose, hemicellulose, lignin) remaining after acid/alkali digestion
- **Nitrogen-Free Extract (NFE)**: a calculated estimate of readily available carbohydrates (sugars, starch)



Image credit: RDNE Stock project from Pexels: Link to the graph image [www.pexels.com]

The Van Soest method is a more accurate method for measuring fiber in animal feeds, developed to overcome the limitations of crude fiber analysis. Instead of using harsh acids and bases that dissolve some fiber components, the Van Soest method uses detergent solutions to separate feed into two main fractions:

Neutral Detergent Fiber (NDF): The total cell wall material, including cellulose, hemicellulose, and lignin. This represents the bulkiness of the feed and the amount of space it occupies in the animal's digestive tract.

Acid Detergent Fiber (ADF): The less digestible portion, containing only cellulose and lignin. This indicates how much of the fiber is poorly digestible.

Hemicellulose: Calculated as NDF minus ADF, represents the most digestible fiber fraction.

The key advantage of this method is that it more accurately predicts the digestibility of a feed, especially for ruminant animals. Higher NDF means the animal can eat less because the feed is bulkier. A higher ADF means a lower energy value because more of the fiber is indigestible. This information helps nutritionists formulate more precise diets, particularly for dairy cattle and other ruminants that rely heavily on forage.

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5.12: Feeding Trials

Feeding trials use live animals to evaluate how well they perform on different diets. Unlike laboratory chemical analysis, which only tells us what's in the feed, feeding trials show us how animals actually respond to that feed. Whether they eat it, digest it, and grow or produce well on it.

The simplest type of feeding trial is a growth trial. Animals are fed a test diet for a set period, and researchers track their feed intake and weight gain. From this data, they calculate *feed efficiency*—how many pounds of feed it takes to produce one pound of weight gain. For example, if a pig eats 3 pounds of feed to gain one pound of body weight, the feed efficiency is 3:1. Better diets produce better feed efficiency ratios. However, growth trials don't explain *why* one diet works better than another—they just show the end result.



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5.13: Digestion Trials

Digestion trials go a step further by measuring what portion of the feed is actually absorbed by the animal. Researchers carefully measure both what goes into the animal (feed intake) and what comes out (feces). The difference represents what was digested and absorbed. This gives us a *digestibility coefficient*—for instance, if an animal eats 100 grams of protein and excretes 20 grams in the feces, the protein digestibility is 80%. These trials help identify which feeds provide nutrients in forms animals can actually use, not just what's present in the feed.

Digestibility represents the proportion of ingested nutrients absorbed from the gastrointestinal tract. Digestibility trials determine the degree to which a feed is digested and absorbed by calculating the difference between nutrient intake and fecal excretion (digestion coefficient). Apparent digestibility is calculated as:

Apparent Digestibility (%) = [(Nutrient Intake - Fecal Nutrient) / Nutrient Intake] × 100

This includes endogenous losses (sloughed epithelial cells, enzymes, and mucus), which underestimate the true digestibility. *Ileal digestibility*, measured at the terminal ileum before hindgut fermentation, provides a more accurate assessment for monogastrics, particularly for protein and amino acids. This requires surgically cannulated animals or digesta collection at slaughter.

- **Total Digestible Nutrients (TDN)**: A measure historically used to estimate the digestible energy content of a feed, calculated from the digestion coefficients of the proximate analysis fractions.



Image credit: Helena Lopes from Pexels: https://www.pexels.com/photo/white-h...grass-1996333/

Energy Systems:

- **Gross Energy (GE)**: total heat of combustion measured by bomb calorimetry
- **Digestible Energy (DE)**: GE minus fecal energy losses
- **Metabolizable Energy (ME)**: DE minus urinary and gaseous (methane) losses
- **Net Energy (NE)**: ME minus heat increment (thermic effect of feeding)

Total Digestible Nutrients (TDN) is an older energy system calculated as:

TDN = Digestible CP + Digestible CF + Digestible NFE + (Digestible EE × 2.25)

The 2.25 factor accounts for the higher energy density of fats. TDN remains commonly used for ruminants despite limitations in accurately reflecting energy available for productive functions, particularly from high-fiber feeds.

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5.14: Metabolism Trials

The most comprehensive feeding trials are metabolic trials, which track not only feed intake and fecal output but also urine and, sometimes, gas production. This complete accounting shows exactly how much of each nutrient the animal retains in its body for growth, milk production, or other functions. While metabolism trials provide the most accurate information, they require specialized equipment and are expensive to conduct, so they're typically reserved for research rather than routine feed evaluation.

Feeding trials bridge the gap between feed composition and animal performance, providing practical information that animal nutritionists use to formulate diets that maximize productivity while maintaining animal health.



Image credit: RDNE Stock project from Pexels: To bowl of pelleted animal food picture [www.pexels.com]

In animal science, nutritionists bridge the gap between biochemical theory and practical application by conducting three primary types of animal trials: feeding, digestion, and metabolism trials. While feeding trials are relatively simple experiments used to determine whether animals will consume a feedstuff and how they perform—measuring outcomes like growth, lactation, or egg production—digestion trials offer greater technical depth by calculating a digestion coefficient to determine precisely how much of a nutrient is absorbed. Metabolism trials represent the most advanced stage of evaluation; they track advanced metrics such as urine and hair loss, often through balance trials, to determine the net retention or loss of specific nutrients within the body. Together, these trials allow researchers to analyze how the body's metabolic machinery utilizes chemical entities to meet the varying requirements for maintenance, reproduction, and production.

? Animal Nutrition Trial Comparison 5.14.1

A blank table that can be filled in as a study guide for animal nutrition trials

Trial Type	Primary Objective	Key Measurements
Feeding Trial		
Digestion Trial		
Metabolism Trial		

Nutrition Trial Study Guide Creation

Add texts here.

To differentiate between the three major types of animal trials used by nutritionists to evaluate feedstuffs and animal performance, fill in the table above.

1. For the primary objective column, define the research goal by identifying what an animal nutritionist wants to discover during each type of trial.

2. For the key measurements column, identify specific data points that the animal nutritionist collects during each type of trial.

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5.15: Summary and Flashcards

Effective animal nutrition requires understanding nutrient chemistry, digestion physiology, metabolic utilization, and practical feed evaluation. Species differences—particularly between ruminants and monogastrics—fundamentally affect dietary requirements and feeding strategies. Economic optimization of livestock production depends on precisely matching nutrient supply to physiological demands while maintaining animal health and product quality. The principles outlined here form the foundation for developing scientifically sound, economically viable feeding programs for food-producing animals.



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CHAPTER OVERVIEW

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The type of digestive system an animal possesses fundamentally determines what it can successfully consume and utilize as feed. While nutrient metabolism and metabolic pathways remain essentially the same across different species, animals have vastly different nutritional requirements, consume different feeds, and digest food through remarkably different processes. The digestive tract functions to break down complex feed materials into constituent parts—a process called digestion—so that nutrients can be absorbed and metabolized by the body.

Digestion is accomplished through three integrated mechanisms:

1. Physical and Mechanical Actions

- Mastication (chewing) crushes food into smaller particles
- Peristalsis—progressive muscular contractions—moves material through the digestive tract

2. Chemical Action

- Acids such as hydrochloric acid (HCl) in the stomach denature proteins
- Bases like sodium bicarbonate from the pancreas neutralize stomach acid
- Bile assists in fat digestion and absorption

Enzymes are proteins that catalyze the breakdown of chemical bonds in food. They originate from two sources:

- **Autoenzymatic**: enzymes produced by the animal itself
- **Alloenzymatic**: enzymes produced by microorganisms through fermentation



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6.1: Dietary Categories

Animals are classified by their dietary preferences:

- Carnivore: subsists primarily on meat
- Omnivore: consumes both plant matter and meat
- Herbivore: eats only plant material

These categories correlate with digestive anatomy. Carnivores typically have simple, short digestive tracts suited for readily digestible protein and fat. Herbivores require either complex stomachs (ruminants) or extensive hindgut fermentation chambers (horses, rabbits) to break down plant cellulose.



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6.2: Steps of Digestion

The digestive process follows a sequential pathway from food intake to waste elimination.

This is how an animal "grabs" its food. Different animals have evolved unique strategies:

- Horses and cattle use their flexible lips and tongue to pull grass into their mouths
- Pigs use their snout to root and their teeth to grab food
- Birds use their beaks to peck and scoop
- Cats and dogs use their teeth to tear and bite

Think of prehension as the "capture phase"--without it, no digestion can begin.

Once food is in the mouth, chewing begins the physical breakdown:

- Teeth crush and grind food into smaller particles
- This increases the surface area of the food, making it easier for enzymes to work later
- Different teeth serve different purposes:
  - Incisors cut and nip
  - Molars grind and crush
  - Canines (in carnivores) tear meat

Fun Fact: Birds don't have teeth, so they skip this step in the mouth--their gizzard does the grinding later.

Saliva does much more than just make food wet:

Lubrication Functions:

- Makes food slippery so it can slide down the esophagus easily
- Especially important for horses eating dry, coarse hay

Chemical Functions (varies by species):

- Pigs produce salivary amylase, which starts breaking down starches (though this is minimally effective)
- Horses and cattle produce saliva with NO enzymes--it's purely for lubrication
- Saliva also helps form the food into a bolus--a cohesive ball that's easier to swallow

Fun fact: Cattle can produce 50-80 liters (13-21 gallons) of saliva per day!



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This is the journey from mouth to stomach:

- The tongue pushes the bolus to the back of the throat
- The epiglottis (a flap of tissue) closes over the windpipe to prevent choking
- Muscular contractions called peristalsis push the food down the esophagus
- Food reaches the stomach (or in ruminants, the rumen first)

This process is mostly involuntary once swallowing starts--the body takes over.

This is where serious digestion begins:

In the Glandular Stomach (or Abomasum in ruminants):

Hydrochloric Acid (HCl):

- Creates an extremely acidic environment (pH 1.5-3)
- Denatures proteins, meaning it unfolds their complex structure, exposing bonds that enzymes can break
- Kills most harmful bacteria in food
- Activates pepsinogen (inactive form) into pepsin (active form)

Pepsin (the enzyme):

- Begins breaking down proteins into smaller peptide chains
- Works best in very acidic conditions
- This is just the START of protein digestion--it's completed in the small intestine

Why this matters: Without the stomach's acid and pepsin, proteins would pass through mostly intact and be wasted.

The small intestine is where the magic happens--nutrients finally enter your bloodstream:

The Three Sections Work Together:

Duodenum (The Chemical Factory):

- First 10-12 inches after the stomach
- Receives pancreatic juice containing:
  - Enzymes for breaking down proteins, fats, and carbohydrates
  - Bicarbonate to neutralize stomach acid (pH goes from ~2 to ~7-8)
- Receives bile from the liver/gallbladder to emulsify fats (break them into tiny droplets)
- Food is chemically broken down into its simplest forms here:
  - Proteins → amino acids
  - Carbohydrates → simple sugars (glucose, fructose)
  - Fats → fatty acids and glycerol

Jejunum (The Absorption Powerhouse):

- The longest section (several feet in most animals)
- Lined with millions of tiny fingerlike projections called villi (and even tinier microvilli)
- These create MASSIVE surface area--like turning a bedsheet into a shag carpet
- Most nutrient absorption happens here:
  - Amino acids cross into the bloodstream
  - Simple sugars enter the blood
  - Fatty acids enter the lymphatic system
- By the time food leaves the jejunum, most usable nutrients are gone

Ileum (The Final Checkpoint):

- Shorter section connecting to the large intestine
- Absorbs remaining nutrients, especially:
  - Vitamin B12
  - Bile salts (recycled back to the liver)
  - Any leftover water and electrolytes
- Contains lymphoid tissue that helps with immune function

If food moves too quickly through the small intestine (diarrhea), nutrients aren't absorbed, leading to malnutrition despite eating enough food.

After all useful nutrients are extracted, waste must be expelled:

Defecation (Solid Waste):

- Undigested material, fiber, dead bacteria, and worn-out cells move to the large intestine
- Water is absorbed, forming solid feces
- Feces are stored in the rectum until expelled
- Feces exit through the cloaca (combined opening) in birds
- Feces exit through the anus in mammals

What's in feces?

- Undigested fiber (cellulose in herbivores)
- Dead bacteria (actually about 50% of fecal mass!)
- Bile pigments (give it the brown color)
- Sloughed-off intestinal cells

Micturition (Liquid Waste):

- This is urination--a separate process from digestion, but important for waste removal
- Kidneys filter blood and remove:
  - Urea (in mammals)--formed from breaking down excess amino acids
  - Uric acid (in birds and reptiles)--the white paste you see in bird droppings
  - Excess water, minerals, and metabolic byproducts

Why the difference?

- Mammals can afford to use water to flush out urea.
- Birds evolved to conserve water (uric acid requires much less water to excrete), which helps them fly.



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6.3: Digestive System Classification

Digestive systems are classified based on stomach complexity and the primary method of digestion.

Monogastrics, or nonruminants, possess a single, simple stomach and typically consume energy-dense, easily digestible diets. Digestion relies primarily on the animal's own enzymes (autoenzymatic digestion).

These nonruminant animals utilize plant fiber by housing large populations of fermenting microorganisms primarily in the cecum and large colon—collectively called the hindgut.

These animals utilize roughage and fiber extensively. Their digestion is alloenzymatic, relying on microorganisms for complex breakdown.



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6.4: Understanding Different Digestive Systems Activity

To reinforce your understanding of various animal digestive systems, your group will clearly and engagingly explain them to each other. Your group will become the class's expert on one type of animal digestive system or the differences and similarities between ruminants and non-ruminants.

? Teach Back Instructions 6.4.1

1. Arrange participants into five groups.
2. Assign each group one of the following:
   - Cow (Ruminant)
   - Pig (Monogastric/Omnivore)
   - Horse (Hindgut Fermenter)
   - Bird/Chicken (Avian)
   - Ruminant and Non-ruminant
3. Conduct Research: Use course resources and reliable outside sources to gather detailed information. Your group must become the experts on your assigned topic. (Cite any outside sources.)
   - **Focus Areas:** Anatomy (specific organs), Physiology (how digestion occurs), and unique adaptations.
   - **Key Details to Include:** The food's journey, the types of feed consumed, and the role of key organs.
   - **Compare Systems:** Briefly compare your animal's system to the others, noting similarities and differences.
4. **Develop a Teaching Strategy:** Outline how your group will teach the material. How do your group members like to learn? What about this topic drives your group's curiosity? What gets your group speaking about and interacting with a topic? Use pictures and/or diagrams to illustrate the food's journey from entry to exit. (Cite your image sources.)
5. Each group will deliver a clear, engaging, and thorough presentation to teach the rest of the class about your assigned digestive system.
   - **Goal:** Your presentation should be comprehensive enough that your peers understand this type of digestive system, if it is their only source of information on the topic, and even if they aren't taking this class.
   - **Engagement:** Use your visual aids effectively and ensure every group member participates in the teaching process.
6. After your presentation, your group will facilitate a brief Q&A session.
   - Be prepared for questions on complex concepts, unique features, and comparisons with other systems.
   - Or use this time to clarify any confusing concepts.
7. Before the end of class, each participant will complete a brief written reflection based on the presentations.
   - **Submission:** This reflection must be turned in before leaving class today.
   - **Reflection Prompts:** On a separate sheet of paper, address the following:
8. What was the most surprising or new detail you learned about the digestive system of an animal that wasn't your own?
9. Briefly describe a key anatomical or physiological difference between the ruminant and the horse/hindgut fermenter digestive systems, as presented today.

Key Points to Include

Avians (Poultry)

- **Key Features:** Lack teeth and have specialized upper GI tract organs.
- **Crop:** Stores and moistens food; limited fermentation occurs.
- **Proventriculus (Glandular Stomach):** Secretes HCl and pepsin (gastric juices).
- **Gizzard (Ventriculus):** Highly specialized, muscular organ for grinding food; no enzyme secretion here.
- **Ceca:** Two large ceca digest fiber near the junction of the small and large intestine.
- **Cloaca:** Common orifice for waste elimination, copulation, and egg laying.

Ruminant (e.g., Cow)

- **Key Features:** Alloenzymatic digestion (relying on microorganisms) in a complex, four-compartment stomach. Utilizes roughage and fiber extensively.

- **Rumen (Largest):** Site of anaerobic bacterial fermentation. Microbes produce VFAs (primary energy source, 50−70% of needs), bacterial protein, and vitamins (K and water-soluble).
- **Reticulum (Honeycomb Lining):** Pacemaker for rumen contractions and helps move food.
- **Omasum (Many Folds):** Absorbs water, electrolytes, and VFAs; reduces particle size.
- **Abomasum (True Stomach):** Glandular; secretes HCl and pepsin to digest both feed and microbial protein.
- **Rumination (Chewing Cud):** Regurgitation and re-chewing of food to increase surface area for microbial digestion.
- **Eructation:** Belching of fermentation gases.
- **Trade-offs:** Enables digestion of poor-quality feeds but can decrease the value of high-quality feeds due to fermentation energy cost.

The Horse (Hindgut Fermenter)

- **Key Features:** Monogastric stomach, but the majority of microbial digestion occurs in the hindgut (cecum and large colon).
- **Prehension:** Uses teeth, flexible upper lip, and tongue. Saliva is purely for lubrication (no enzymes).
- **Stomach:** Smaller capacity and reduced muscular activity compared to other mammals, increasing susceptibility to digestive disorders (e.g., colic).
- **No Gallbladder:** Evolved as continuous grazers; no need for bile storage.
- **Cecum & Large Intestine:** Account for over 60% of total gut capacity. Bacteria here ferment fiber into Volatile Fatty Acids (VFAs), the main energy source for forage diets.
- **Protein Limitation:** Bacterial protein synthesized in the hindgut is poorly absorbed as it is beyond the primary absorption site (small intestine).

Pig (Monogastric/Omnivore)

- **Key Features:** Monogastric system with one stomach. Primarily relies on enzymatic digestion in the stomach and small intestine.
- **Stomach:** Contains enzymes (e.g., pepsin) typical of monogastrics. Salivary amylase is present but minimally active due to short retention and low stomach pH.
- **Small Intestine:** Site of most protein and fat digestion and absorption.

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6.5: Monogastric (Nonruminant) Simple Stomach

Pigs are the only common farm animals that secrete salivary amylase in their saliva. This enzyme begins starch breakdown; however, it provides little nutritional benefit because feed passes through the mouth quickly, and the low stomach pH inactivates the enzyme.

The pig's gastric juices contain enzymes typical of monogastrics. Protein digestion begins in the stomach with pepsin but is completed in the small intestine, where most fat digestion also occurs.

Pancreatic juice plays a crucial role by providing:

- Digestive enzymes for carbohydrates, proteins, and fats
- Sodium carbonate and sodium bicarbonate are used to neutralize stomach acid
- Insulin (produced by the pancreas) for carbohydrate metabolism

Bile, formed in the liver and stored in the gallbladder, assists in fat digestion and absorption while aiding in the absorption of fat-soluble vitamins (A, D, E, and K).



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Birds lack teeth and possess several unique digestive structures:

Crop – A dilation of the esophagus that stores and moistens food; some fermentation occurs in certain species

Proventriculus – The glandular stomach equivalent to the mammalian stomach or ruminant abomasum; produces gastric juice (HCl and pepsin) with a pH of 4. Ingesta passes through in seconds, so minimal digestion occurs here.

Gizzard (Ventriculus) – A highly specialized, muscular grinding organ that mechanically breaks down feed. Free-ranging birds may consume grit to aid grinding, but modern preground rations make this unnecessary. No enzymes are secreted in the gizzard, although enzymes from the proventriculus continue to work here.

Ceca – Two large pouches located at the junction of the small and large intestine. Size varies with diet—larger ceca develop when animals consume high-fiber diets. The ceca digest fiber, though modern chickens fed low-fiber diets make minimal use of them.

Cloaca – The common orifice for waste elimination (feces and urine), copulation, and egg laying in females



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6.6: Monogastric Herbivores (Hindgut Fermenters)

Horses digest fiber only about two-thirds as efficiently as ruminants. Soluble carbohydrates are digested and absorbed in the small intestine, while fiber fractions are fermented in the large intestine and colon.

Unique Stomach Features:

- Smaller capacity compared to other mammals of similar size
- Reduced muscular activity compared to other species
- These factors increase susceptibility to digestive disorders such as colic and stomach rupture

No Gallbladder – Horses evolved as continuous grazers and had no need for bile storage between meals

Large Intestine and Cecum – Account for over 60% of total gut capacity. The cecum and large colon harbor bacterial populations similar to those of ruminants. These microorganisms ferment fiber into **volatile fatty acids (VFAs)**, which provide the majority of energy for horses on forage diets.

Limited Protein Utilization – Bacteria synthesize protein in the hindgut, but horses cannot absorb it effectively since it passes beyond the small intestine. Horses on poor diets may practice **coprophagy** (eating feces) to reclaim some of this bacterial protein.



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6.7: Ruminant (Complex Stomach)

Ruminants—including cattle, sheep, goats, and pseudoruminants like llamas—possess complex, multi-compartmented stomachs that enable them to utilize roughage and fiber extensively. Their digestion is alloenzymatic, relying heavily on microorganisms.



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The ruminant stomach consists of four distinct compartments. The first three are collectively known as the forestomachs and have nonglandular linings that produce neither mucus nor enzymes.

- Primary site of anaerobic bacterial fermentation
- Stores food until the animal can remasticate it
- Houses diverse microbial populations that produce:
  - VFAs: provide 50-70% of the animal's total energy needs
  - Bacterial protein: synthesized from dietary protein and non-protein nitrogen (NPN) sources like urea
  - Vitamin K and water-soluble B vitamins (Note: microorganisms do not synthesize vitamins A, D, or E)
  - Essential fatty acids
- Acts as the pacemaker for rumen contractions
- Mixes rumen contents and moves material through the digestive tract
- Absorbs water, electrolytes, and VFAs
- Reduces feed particle size before passage to the abomasum
- Lined with a mucous membrane
- Secretes gastric juice containing HCl and pepsin
- Digests both feed and the microbial protein from forestomach fermentation
- From the abomasum onward, the ruminant digestive tract closely resembles that of monogastrics

Ruminants typically fill the rumen rapidly with minimal chewing, then find a resting place to ruminate. During rumination, the animal regurgitates previously swallowed food (the cud or bolus) and spends time rechewing it. This process increases surface area

for microbial digestion. The amount of rumination is directly proportional to dietary fiber content—more fiber equals more rumination time.

Microbial fermentation produces large quantities of gas (primarily methane and carbon dioxide) that must be expelled. Eructation (belching) removes these gases from the rumen through the esophagus. The gas enters the lungs and is exhaled, which muffles the belching sound. Failure to eructate properly can lead to ruminal bloat (ruminal tympany), a potentially fatal overdistention of the rumen and reticulum.

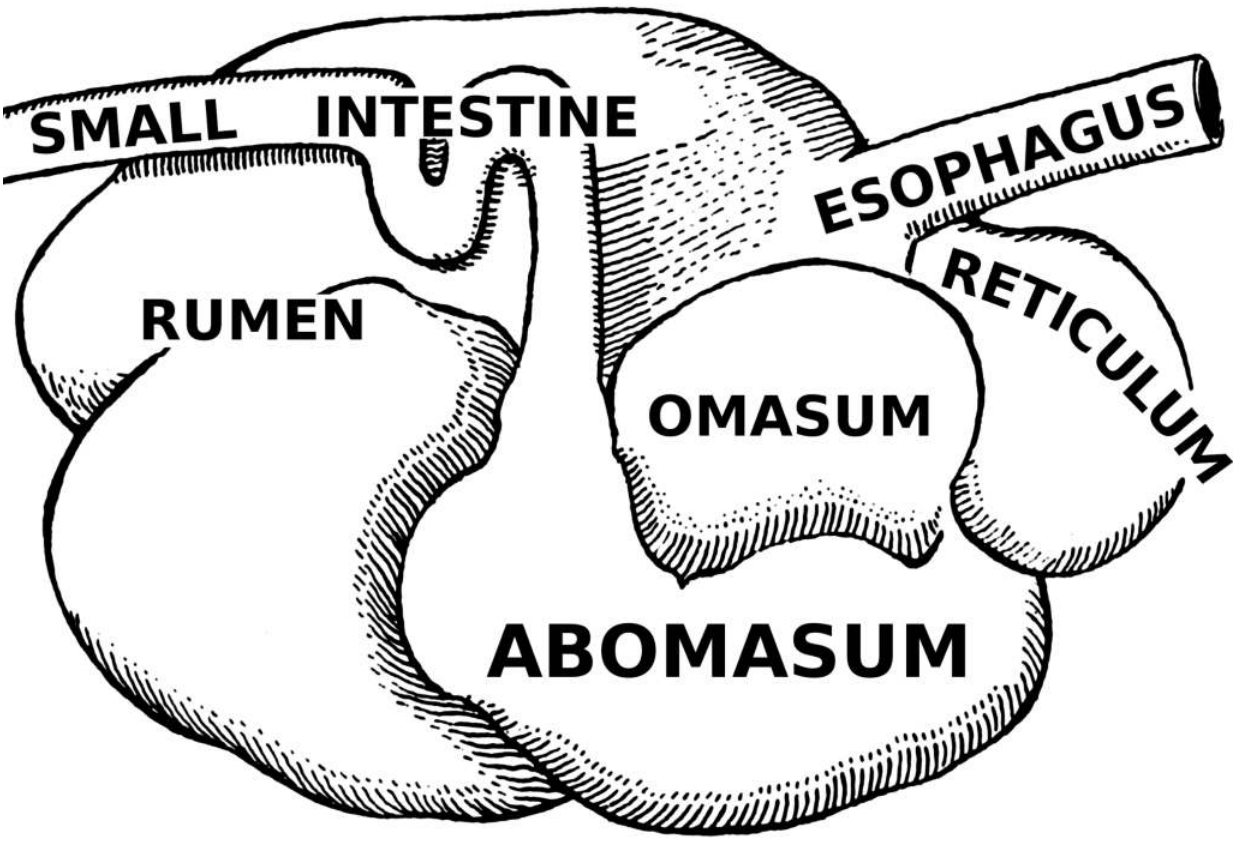


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6.8: The Fermentation Process--A Symbiotic Partnership

Rumen microorganisms and ruminant animals share a symbiotic relationship (specifically mutualism), where both partners benefit:

Benefits to the Animal:

- Microorganisms digest feeds (particularly cellulose and fiber) that the animal could not otherwise utilize
- Microbes generate essential nutrients, including amino acids, vitamins, and fatty acids, not present in the animal's diet

Benefits to the Microorganisms:

- The ruminal environment provides near-ideal living conditions:
  - Constant warmth
  - Adequate moisture
  - Continuous food supply
  - Removal of end products of digestion
  - Darkness
  - Anaerobic environment (lacking molecular oxygen)

The rumen houses many bacterial species, with specialized populations that digest specific carbohydrates (cellulose, hemicellulose, starch, sugars), proteins, and acids. Other bacteria produce ammonia, vitamins, and methane. Nearly 40 species of ciliate protozoa also inhabit the rumen, using the same substrates as bacteria and consuming them.

Virtually everything the ruminant eats is affected by fermentation. The major products include:

- **VFAs**: acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate
- **Bacterial protein**: microorganisms break down dietary protein to ammonia and organic acids, then use the ammonia to manufacture amino acids for their own growth. When bacteria pass out of the rumen, they are digested in the abomasum and small intestine, providing high-quality protein to the host animal.
- **Gas and heat**: by-products of fermentation. Heat can help warm the animal during winter.

High fat levels in ruminant diets are detrimental, as they reduce microbial function and overall fermentation efficiency.



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6.9: The Large Intestine Across Species

The large intestine consists of the cecum, colon, and rectum. Unlike the small intestine, it contains no villi, which restricts absorption. However, it plays important roles across different species:

In Monogastric Omnivores (e.g., pigs):

- Limited fermentation
- Absorption of water and electrolytes

In Monogastric Herbivores (e.g., horses, rabbits, guinea pigs, elephants):

- Extensive colon and functional cecum
- Microorganisms break down cellulose
- Produce B-complex vitamins
- Generate VFAs that are absorbed and used as energy sources
- Manufacture bacterial protein (though absorption is limited)

Some hindgut fermenters, such as rabbits, practice cecotrophy because bacterial protein and vitamins are produced in the hindgut but are not initially absorbed.



Image credit: Pixabay from Pexels: https://www.pexels.com/photo/brown-w...hamster-63853/

An important distinction exists between ruminants and hindgut fermenters regarding essential amino acid requirements:

Horses must receive essential amino acids in their diet because microbial protein synthesized in the hindgut passes beyond the small intestine (the primary site of protein absorption) and cannot be effectively utilized.

Cattle and other ruminants do not require dietary essential amino acids because microbial protein synthesized in the rumen travels to the abomasum and small intestine, where it is digested and absorbed, providing all necessary amino acids.

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6.10: Digestive Detective Activity

This activity is designed to apply your knowledge of animal digestive systems by having you act as a digestive detective. Divide into five groups, and assign one case file to each group below.

Your Task: As a group of digestive detectives, you must determine the animal species by piecing together the clues in the case file.

Instructions 6.10.1

1. **Check out your case file.** In your group, you'll get one of five case files and a bunch of clues — all pointing to a specific animal species.
2. **Determine the animal.** Go through the clues together as a group and see if you can figure out which animal your clues are describing.
3. **Answer the follow-up questions.** Once you've landed on an answer, complete the three worksheet questions about the digestive system details from your clues.
4. **Pass it on.** Done? Pass your case file to the next group and pick up theirs. Keep going until every group has looked at all five cases.
5. **Submit your worksheet.** Once you've been through all five, upload your findings to the assignment drop in BrightSpace.
6. **Class discussion.** Get ready to share! We'll talk through which animal you picked for each case and what clues tipped you off.

Case Files and Clues

1. **Field Report**: Researchers observed this animal grazing for hours and later re-chewing without any additional food intake. It produces large amounts of saliva and methane-rich belches. Dissection revealed four stomach compartments and VFAs in the bloodstream.

    - Rumen, reticulum, omasum, and abomasum are present.
    - Fermentation occurs before the small intestines.
    - VFAs are the main source of energy.
    - Regurgitates and re-chews food (cud).
    - Relies on microbes for cellulose digestion.

Suspect animal:

1. What digestive system type is this?
2. What is the function of each compartment?
3. Why can this animal survive on low-quality forage?

2. Field Report: This animal grazes small amounts all day. Its stomach is small and simple with no gallbladder. The cecum and large colon are massive and full of microbes. It produces bacterial protein but absorbs little.

- Monogastric stomach with reduced muscular activity.
- Hindgut fermentation in the large intestine and cecum.
- VFAs are produced in the hindgut, not the foregut.
- No gallbladder (continuous bile flow).
- Prone to colic and digestive disturbances.

Suspect animal:

1. Why is its hindgut so large?
2. How does its digestion differ from a cow's?
3. Why can’t it use microbial protein effectively?

3. Field Report: This animal roots with its snout and crushes food with its teeth. Its saliva has amylase, and digestion relies on its own enzymes. Protein and fat digestion occur mainly in the small intestine.

- One-chambered stomach.
- Autoenzymatic digestion predominates.
- Saliva contains amylase (minimally effective).

- The pancreas secretes enzymes and bicarbonate.
- An omnivorous diet of plants and meat.

Suspect animal:

1. What enzymes are key to digestion?
2. Why does salivary amylase play a small role?
3. What organ neutralizes stomach acid for intestinal enzymes?

4. Field Report: This creature lacks teeth but swallows pebbles for grinding. Food is stored in a crop, partially digested in a proventriculus, and ground in a muscular organ before passing through paired ceca.

- Crop → Proventriculus → Gizzard → Small intestine → Ceca → Cloaca.
- No mastication in the mouth.
- HCl and pepsin are secreted in the proventriculus.
- The gizzard handles mechanical digestion.
- Two ceca ferment fiber near the large intestine.

Suspect animal:

1. How does it compensate for no teeth?
2. What does the ceca contribute?
3. How is waste elimination unique?

5. **Field Report**: This high-altitude grazer eats coarse plants and stores food in three stomach chambers. It chews cud like a cow but has a smaller rumen. Microbial fermentation efficiently produces VFAs and vitamins.

- Three-chambered stomach (missing omasum).
- Adapted to sparse, high-altitude forage.
- Alloenzymatic digestion by microbes.
- Chews cud, produces VFAs.
- Foregut fermentation before the small intestine.

Suspect animal:

1. How is it both like and unlike true ruminants?
2. What are the fermentation benefits here?
3. Why is this ideal for its environment?

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6.11: Summary and Flashcards

Different species possess vastly different digestive systems—both anatomically and functionally—that dictate feeding strategies and nutritional requirements. Despite these differences, the fundamental goal remains the same: to break down complex feed materials and release nutrients for absorption and metabolism, enabling animals to maintain body functions and support production. Understanding these digestive differences is essential for proper animal nutrition and management.

The Gastrointestinal Tract and Digestion Flashcards

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6.12: Digestive Systems Study Guide

1. Define digestion and describe the three methods of food breakdown.
2. Classify digestive systems according to stomach type and dietary habits.
3. Outline the sequential steps of digestion from prehension to defecation.
4. Identify at least three differences and similarities in the digestive processes of different animals.
5. Explain the importance and benefits of the ruminant's complex stomach.
6. What is the major anatomical difference between ruminants and nonruminants?
7. What is the function of the rumen?
8. Define carnivore, omnivore, and herbivore.
9. What are the disadvantages of the ruminant digestive system?
10. What are VFAs, and what is their relative importance to ruminant energy requirements?
11. Why are VFAs important to ruminants, and how does the animal utilize them?
12. Describe the anatomy of the ruminant tract and identify the common names of the four digestive compartments between the esophagus and small intestine.

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CHAPTER OVERVIEW

7: Animal Breeding and Genetics

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Animal breeding has shaped human civilization for thousands of years, transforming wild species into the diverse array of domesticated animals we depend on today. From the cattle that provide milk and meat to the chickens that supply eggs for breakfast tables worldwide, selective breeding has fundamentally altered the genetic makeup of animals to better serve human needs and preferences.

At its core, animal breeding is both an art and a science. It combines careful observation, rigorous record-keeping, and increasingly sophisticated genetic tools to improve desirable traits in livestock, companion animals, and other species. Modern animal breeding enhances productivity, disease resistance, efficiency, and welfare while maintaining genetic diversity and adapting to changing environmental and market conditions.



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The fundamental principles that guide animal breeding programs include how traits are inherited from one generation to the next, how breeders identify superior animals for reproduction, and how today's breeding decisions shape the next generation. We'll explore traditional methods refined over centuries and cutting-edge genomic technologies revolutionizing the field.

The stakes of these breeding decisions extend far beyond individuals. Modern animal breeders must balance food security, economic sustainability, animal welfare, and environmental conservation as global population growth drives increased demand for animal products and climate change presents unprecedented challenges. Strategic, scientifically-informed breeding has never been more critical to meeting these complex, interconnected needs.

7.1: Fundamentals of Genetics

This page discusses the role of genetic principles in animal breeding to enhance production by altering traits of farm animals. It explains how an animal's genotype influences important characteristics like growth and disease resistance, thereby affecting market value. The genetic material, located in the nucleus and organized into chromosomes, is structured as DNA—composed of nucleotides.

7.2: DNA Replication and Gene Expression

This page covers the processes of DNA replication and gene expression. DNA replication ensures genetic continuity by unwinding the double helix and synthesizing complementary strands. Gene expression involves transcription, where mRNA is synthesized from DNA and processed, followed by translation, where ribosomes read mRNA to assemble amino acids into proteins based on the genetic code.

7.3: Principles of Inheritance

This page covers Gregor Mendel's foundational experiments with pea plants, establishing key genetic concepts such as genes, alleles, and homologous chromosomes. It explains the Principle of Segregation, which describes allele separation during gamete formation, and the Principle of Independent Assortment, indicating that allele segregation at one locus occurs independently of others. These principles are crucial for understanding genetic inheritance and animal breeding.

7.4: Cell Division and Sex Determination

This page discusses mitosis and meiosis, highlighting that mitosis produces two identical diploid cells for growth and maintenance, while meiosis yields four haploid gametes that enhance genetic diversity. It also explains sex determination in mammals, noting that females possess XX chromosomes and males have XY, with the male parent determining the offspring's sex through his contribution of either an X or a Y chromosome.

7.5: Gene Expression Patterns

This page covers inheritance patterns, highlighting dominant and recessive alleles, and explains expressions in homozygous recessive individuals. It distinguishes codominance and incomplete dominance, and discusses epistasis, multiple alleles, and testcross methods. Additionally, it explores sex-related inheritance, including sex-linked traits on X/Y chromosomes, sex-influenced traits influenced by hormones, and sex-limited traits specific to one sex.

7.6: Population Genetics and Genetic Variation

This page covers population genetics, emphasizing changes in gene and genotypic frequencies and their effect on genetic merit. It defines key concepts such as gene frequency and phenotypic frequency, while outlining four main forces driving

these changes: mutation (introducing new alleles), genetic drift (random changes in small populations), migration (new alleles through breeding), and selection (natural and artificial influencing reproductive success).

7.7: Quantitative Genetics and Heritability

This page covers livestock trait classification into qualitative and quantitative types, with quantitative traits emphasized for economic significance. It outlines how phenotypes arise from genetic and environmental factors, detailing additive, dominance, and epistatic effects. Heritability is defined as the genetic contribution to phenotypic variation, affecting trait selection.

7.8: Mating Systems

This page explains inbreeding, which involves mating closely related individuals, potentially leading to inbreeding depression due to harmful recessive genes. It contrasts this with linebreeding, a milder method that focuses on desirable traits from a single ancestor while reducing genetic risks.

7.9: Genetic Improvement Tools

This page explores genetic evaluation methods in livestock breeding, highlighting Expected Progeny Differences (EPDs) for beef cattle and Predicted Transmitting Ability (PTA) for dairy cows. It explains EPDs' role in predicting progeny performance and the importance of accuracy in assessments. The Dairy Herd Improvement system enhances genetic evaluation, while swine advancements take advantage of rapid reproductive rates.

7.10: Biotechnology and Genetic Engineering

This page discusses marker-assisted selection (MAS) in breeding, highlighting the use of genetic markers, particularly single nucleotide polymorphisms (SNPs), to identify traits like disease resistance. It emphasizes the benefits of transgenic animals and gene editing technologies such as CRISPR, which provide precise genetic modifications and address ethical considerations, ultimately enhancing livestock breeding outcomes.

7.11: CSI- Cow Scene Investigation — A Genetics Detective Game

This page describes an interactive genetics detective activity where students work in groups to solve farm cases by selecting suitable sire designations based on specific goals like milk production or mastitis reduction. They gather evidence, shortlist bull candidates, and justify their choices, utilizing designations such as RobotPRO and GrazingPRO. The activity concludes with the students presenting detective reports and facing potential cross-examinations from peers and instructors.

7.12: Summary and Flashcards

This page discusses the evolution of animal breeding, highlighting the shift from traditional genetic selection to advanced biotechnology and genetic engineering. It emphasizes the benefits of these innovations, including predictable breeding outcomes, faster genetic enhancements, and the creation of transgenic animals.

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7.1: Fundamentals of Genetics

Animal breeding, the application of genetic principles to improve the efficiency of farm animal production, is the science that has led to remarkable changes in animal species. Genetics, the very foundation of life, provides the mechanism to transfer traits from one generation to the next.

An animal's genotype, or genetic makeup, establishes the potential for numerous traits, including disposition, coat color and type, speed, body composition, growth, reproduction, milk production, and disease resistance. The observable expression of the genotype into traits of economic importance forms the basis for an animal's market value.

The genetic material of an organism is housed within the nucleus of each cell, organized into structures called chromosomes. These chromosomes are large molecules of deoxyribonucleic acid (DNA), and the smaller functional segments of DNA that provide the basis for inheritance are called genes. Collectively, the complete genetic material of an organism is termed its genome.

DNA's structure consists of two strands wound together to form a double helix. Each strand comprises alternating sugar deoxyribose and phosphate bonds, forming the backbone of the molecule. Attached to each sugar is one of four nitrogen bases—chemical compounds classified as either purines or pyrimidines. The purines are adenine (A) and guanine (G), while the pyrimidines are thymine (T) and cytosine (C). These bases pair in a highly specific manner to form the rungs connecting the two strands of the DNA ladder: adenine always pairs with thymine (A-T), and guanine always pairs with cytosine (G-C).

A gene, then, is a specific segment of this double helix composed of hundreds or thousands of nucleotides—the basic units consisting of a sugar, phosphate, and base. The precise sequence of these nucleotides encodes the information needed to build specific proteins, which ultimately determine an organism's traits.



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7.2: DNA Replication and Gene Expression

Genetic information flows through two fundamental processes: replication and expression.

DNA replication occurs when cells create exact copies of DNA molecules before cell division. The double helix unwinds, separating the two strands at their base pairs and exposing each base. The enzyme DNA polymerase then moves along each exposed strand, using it as a template to synthesize a new complementary strand. This ensures that each daughter cell receives a complete, identical copy of the genetic information.

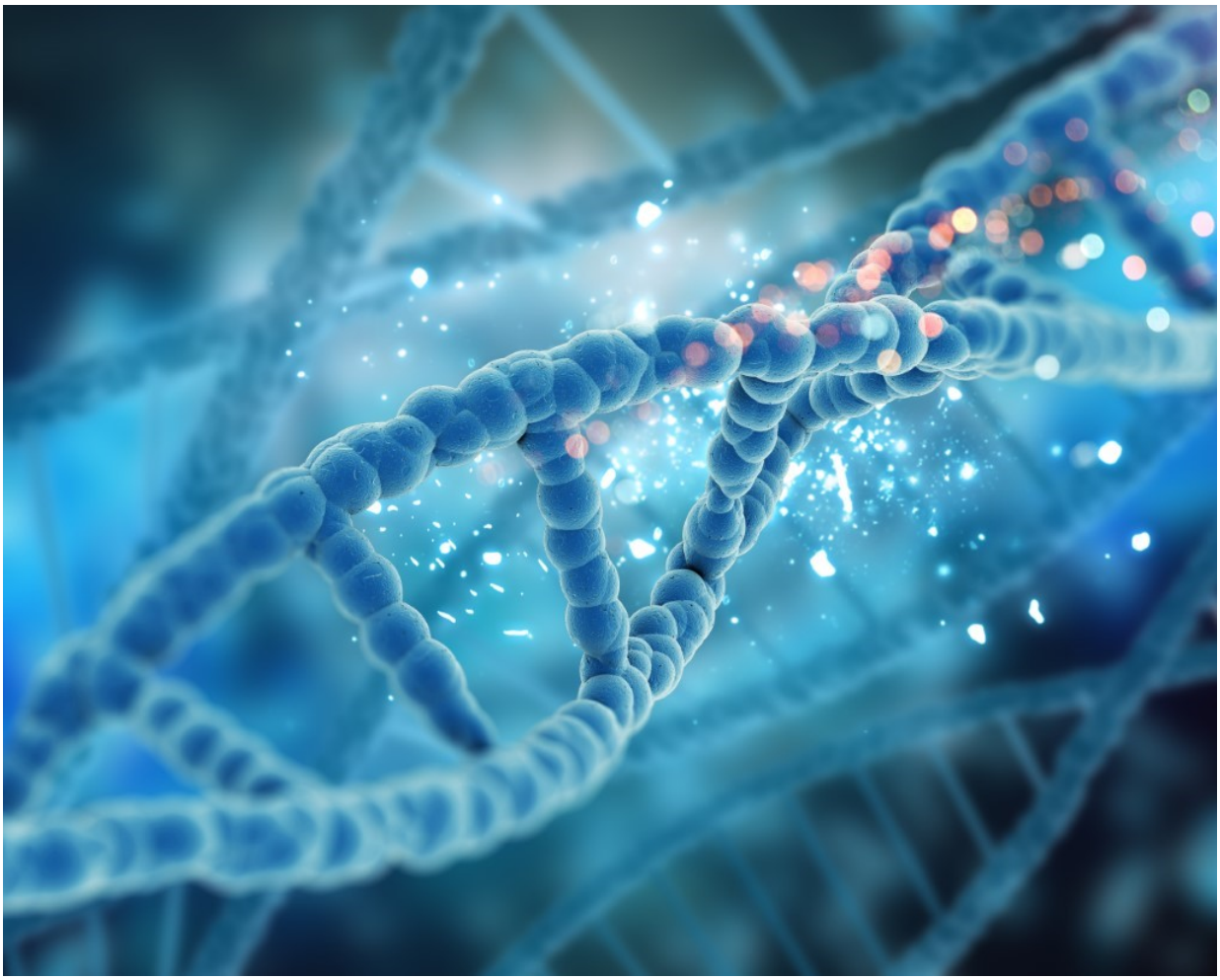


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Protein synthesis, or gene expression, is the process by which genetic information encoded in DNA is ultimately translated into functional proteins. This occurs in two main stages:

During transcription, a specific DNA segment serves as a template for the synthesis of a complementary strand of ribonucleic acid (RNA). The initial RNA transcript is then processed to remove non-coding regions, yielding messenger RNA (mRNA) that carries the instructions for protein synthesis. Simultaneously, DNA codes for transfer RNA (tRNA) molecules, each designed to transport specific amino acids.

During translation, the mRNA exits the nucleus and binds to a ribosome in the cytoplasm. As the ribosome moves along the mRNA sequence, it reads the genetic code in groups of three bases called codons. Each codon signals a specific tRNA molecule to deliver its corresponding amino acid. The ribosome links these amino acids together in the precise order dictated by the mRNA, assembling them into a functional protein chain.

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7.3: Principles of Inheritance

The fundamental laws governing the transfer of traits from parent to offspring were discovered by Gregor Mendel, an Austrian monk who conducted groundbreaking experiments with pea plants in the mid-1800s. His insights into inheritance remain central to our understanding of animal breeding today.

Genes exist at specific locations called loci (singular: locus) on chromosomes. Each gene can occur in different forms called alleles. For example, a gene for coat color might have one allele for black and another for brown. When an animal inherits two identical alleles at a particular locus (such as AA or aa), it is homozygous at that locus. When it inherits two different alleles (such as Aa), it is heterozygous.

Chromosomes occur in pairs called homologous chromosomes—matching partners that are similar in size and shape and carry genes affecting the same traits. Normal body cells, or somatic cells, contain the full diploid number of chromosomes (two complete sets). In contrast, sex cells or gametes (sperm and eggs) contain only the haploid number—half the diploid complement—ensuring that when fertilization occurs, the offspring receives one complete set from each parent.



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Mendel discovered two fundamental principles that explain how genetic information passes from parents to offspring:

The ***Principle of Segregation*** states that when gametes form during meiosis, paired alleles separate so that each gamete receives only one allele (randomly selected) for each locus. This means that if a parent is heterozygous (Aa), approximately half of its gametes will carry the A allele and half will carry the a allele.

The ***Principle of Independent Assortment*** states that the segregation of alleles at one locus occurs independently of the segregation of alleles at other loci. In other words, inheriting a particular allele for one trait does not influence which allele is inherited for an unrelated trait, assuming the genes are on different chromosomes or far apart on the same chromosome.

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7.4: Cell Division and Sex Determination

Cells in the body reproduce through two distinct processes. Mitosis is somatic cell division in which one diploid cell divides into two identical diploid cells, each containing a full complement of genetic information. This process supports growth and tissue maintenance.

Meiosis is the reductional process that produces gametes through gametogenesis. One diploid cell divides through two sequential divisions to produce four haploid cells, each containing only half of the genetic information. This process generates new allele combinations that contribute to genetic diversity in offspring.

In mammals, biological sex is determined by a specific pair of chromosomes. Females possess two X chromosomes (XX), while males have one X and one Y chromosome (XY). All other chromosomes, aside from these sex chromosomes, are called autosomes. Since females can only contribute an X chromosome to their offspring while males can contribute either an X or a Y, it is the male parent that determines the sex of the offspring.

The image below illustrates binary fission, mitosis, and meiosis.

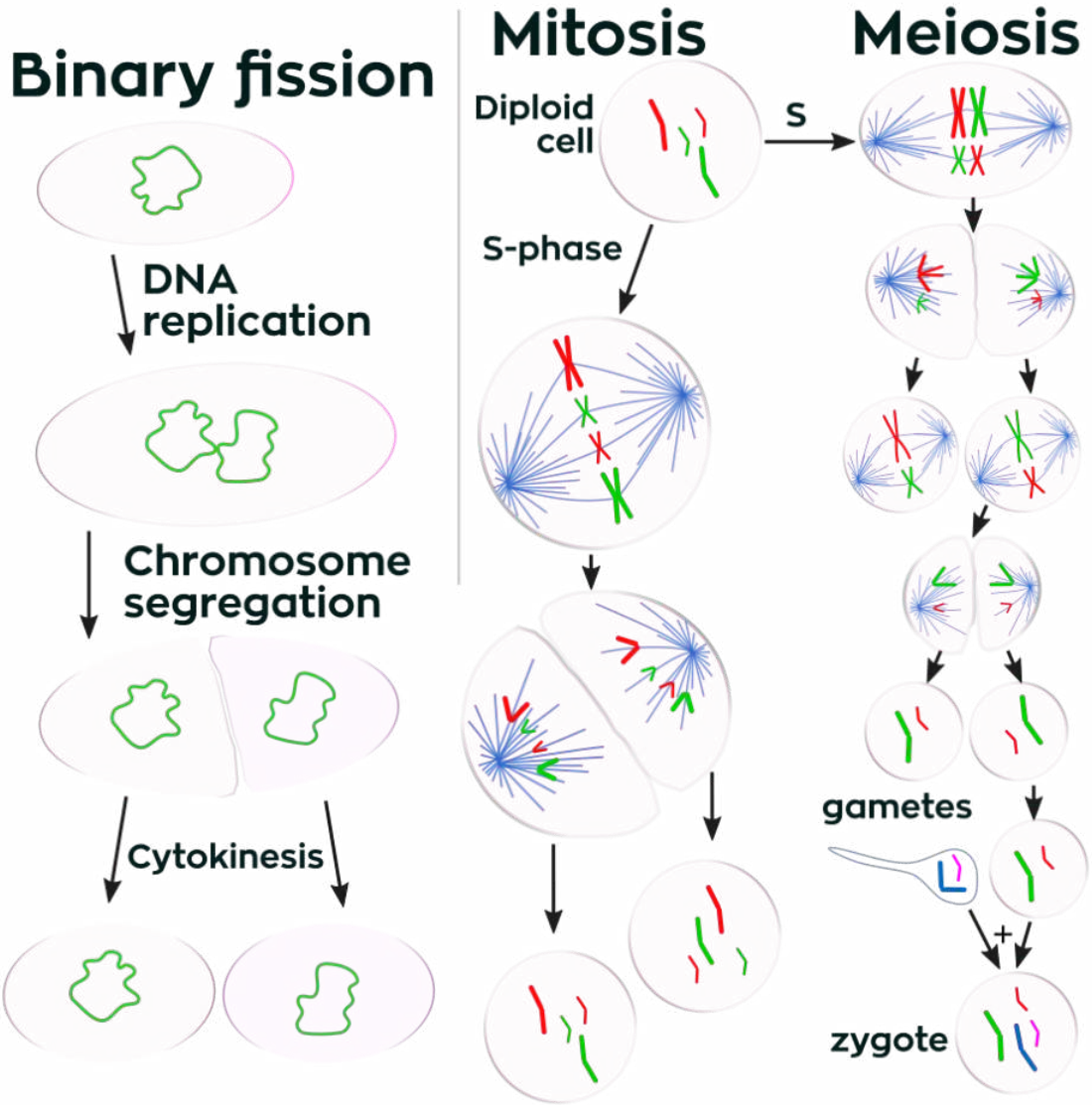


Image credit: Wikipedia Cell Divison, Link to binary fission, mitosis, and meiosis image

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7.5: Gene Expression Patterns

Dominant alleles are expressed to the exclusion of recessive alleles in heterozygous individuals. A recessive allele is only expressed when the dominant allele is absent from the animal's genome (i.e., in homozygous recessive individuals).

However, not all inheritance follows simple dominant-recessive patterns. In codominance, neither allele masks the other, and both are expressed simultaneously in the phenotype (e.g., roan coat color in cattle, where red and white hairs appear together). Incomplete dominance occurs when no dominance exists, and the heterozygous individual expresses an intermediate phenotype between the two homozygous forms.

Epistasis describes the interaction among genes at different loci, where the expression of genes at one locus depends on the presence of specific alleles at another locus. When a gene has more than two alleles present within a population—termed multiple alleles—an individual can still only possess two alleles at that locus, but population-wide variation increases.

A testcross is a practical breeding tool in which an animal expressing the dominant phenotype (homozygous dominant or heterozygous) is mated with a homozygous recessive individual to determine the unknown genotype based on the offspring phenotypes.

Sex-linked inheritance involves traits carried on the X or Y chromosomes. Genes on the X chromosome can be passed to either sex, but Y-linked genes are only inherited by males. Sex-influenced traits are carried on autosomes but expressed differently in males and females due to hormonal differences (e.g., horn development in sheep). Sex-limited traits are unique to only one sex, even though both sexes carry the genes (e.g., milk production, litter size).



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7.6: Population Genetics and Genetic Variation

Population genetics studies how gene and genotypic frequencies change within a population, thereby altering its overall genetic merit. Gene frequency refers to the proportion of loci in a population that contain a particular allele, while genotypic frequency indicates the frequency with which a specific genotype occurs. Phenotypic frequency represents the proportion of individuals expressing a particular observable trait.



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1. Mutation introduces new alleles by altering the chemical composition of genes. While most mutations are neutral or harmful, some provide the raw material for evolutionary change and selective improvement.
2. Genetic drift causes random changes in gene frequency, particularly in small breeding populations. These chance fluctuations can cause alleles to be lost or fixed regardless of their effects on fitness or production.
3. Migration occurs when new breeding stock is introduced into a population, bringing different alleles and altering existing gene frequencies.
4. Selection—both natural and artificial—allows some animals to contribute more offspring than others. Natural selection favors animals better adapted to their environment, while artificial selection reflects management decisions about which animals receive breeding opportunities. In livestock production, artificial selection is the primary tool for genetic improvement.

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7.7: Quantitative Genetics and Heritability



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Traits can be classified based on their mode of inheritance and expression. Qualitative traits are controlled by one or a few genes with large effects and fall into discrete categories that are easily classified (e.g., coat color, polled versus horned). Quantitative traits are controlled by many genes, each with small effects, and vary continuously across a range of values (e.g., milk yield, weaning weight, feed efficiency). Most economically important traits in livestock are quantitative.

The observable characteristics of an animal—its phenotype—result from both genetic and environmental influences. The genetic component itself can be partitioned into additive effects (transmitted reliably from parent to offspring), dominance effects (interactions between alleles at the same locus), and epistatic effects (interactions between alleles at different loci).

Heritability (h^2) measures the proportion of phenotypic variation in a trait that is due to additive genetic effects and can be passed from parent to offspring. It indicates how readily a trait responds to selection. Heritability values range from 0 to 1, with higher values indicating greater genetic influence:

- Low heritability (0–0.2)**:** Reproductive traits such as fertility, conception rate, and litter size. These traits are heavily influenced by environment and management, making genetic progress slower. However, they show high levels of heterosis in crossbreeding programs.
- Moderate heritability (0.2–0.4): Growth traits such as weaning weight, yearling weight, and rate of gain. These traits respond well to selection and show moderate heterosis.
- High heritability (0.4–0.6)**:** Carcass traits such as ribeye area, marbling, and backfat thickness, as well as fleece traits in sheep. These traits respond rapidly to selection but show little heterosis.

Genetic correlation occurs when the same genes or many of the same genes control two different traits. Positive correlations mean that breeding values for both traits tend to move in the same direction (e.g., improving rate of gain often improves feed efficiency). Negative correlations mean that increasing one trait tends to decrease the other (e.g., selecting for increased yearling weight may increase calving difficulty). Understanding these relationships is essential for balanced breeding programs that avoid unintended consequences.



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7.8: Mating Systems

Inbreeding is the mating of closely related individuals, such as parent-offspring or full siblings. This practice increases homozygosity, concentrating genes for desired traits and reducing genetic variation within a population. While inbreeding can fix favorable alleles, it may also cause expression of detrimental recessive genes, leading to inbreeding depression—reduced performance for fitness-related traits such as fertility, survival, and vigor.

Linebreeding is a mild form of inbreeding designed to concentrate the genes of a single outstanding ancestor while minimizing the accumulation of harmful recessives. When the common ancestor is three to four generations back in the pedigree, linebreeding results in only modest increases in homozygosity.

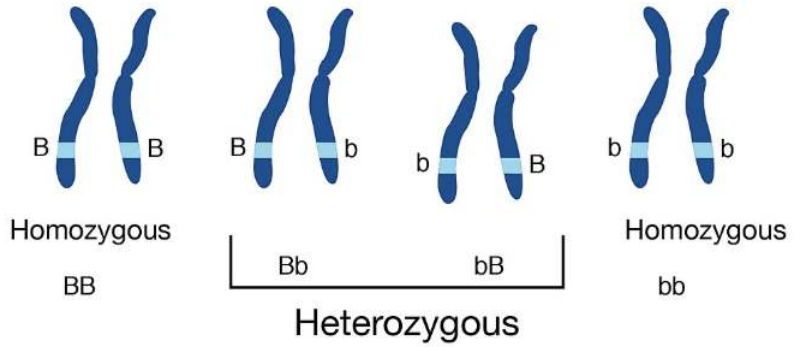


Image credit: Wikipedia, https://en.wikipedia.org/wiki/Zygosi...terozygous.jpg

Outbreeding is the mating of individuals that are less closely related than the population average. This practice increases heterozygosity and genetic diversity, leading to increased vigor called heterosis or hybrid vigor.

Crossbreeding—mating animals from different breeds—is a systematic form of outbreeding designed to capture heterosis. Crossbred individuals tend to be more vigorous, fertile, healthy, and faster-growing than the average of their parental breeds. The magnitude of heterosis is greatest for lowly heritable traits (reproduction) and smallest for highly heritable traits (carcass composition).

Many commercial livestock operations use structured crossbreeding systems that combine complementary breeds to optimize maternal ability, growth, and carcass quality while maintaining maximum heterosis in the market animals.

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7.9: Genetic Improvement Tools

An animal's breeding value represents its value as a parent—the genetic merit it transmits to offspring. The Expected Progeny Difference (EPD) equals half of the breeding value and predicts the future progeny performance of one individual compared to another individual within the same breed for a specific trait.

For example, if Bull A has a weaning weight EPD of +50 lb and Bull B has a weaning weight EPD of +20 lb, calves sired by Bull A are expected to be 30 lb heavier at weaning than calves sired by Bull B, assuming all other factors are equal.

Accuracy measures the reliability of an EPD, expressed as a value between 0 and 1. Higher accuracy indicates more information from the animal's own performance and that of its relatives. Young animals with few progeny have low accuracies, while proven sires with many offspring have high accuracies.

Sire summaries published by breed associations include EPDs, accuracies, breed averages, and other genetic information to help producers make informed selection decisions. Common beef EPDs include birth weight, weaning weight, yearling weight, milk (maternal ability), and carcass traits such as ribeye area, marbling, and fat thickness.

The DHI system is crucial for genetic improvement in the dairy industry, providing standardized testing and evaluation of milk production and composition. Dairy producers enroll their herds in DHI testing programs that regularly measure milk yield and quality, creating data for genetic evaluation.

Predicted Transmitting Ability (PTA) is the dairy equivalent of EPDs, representing half the breeding value. PTAs are calculated for milk yield, fat and protein production, productive life, somatic cell score (related to udder health), and numerous type traits.

Reliability (%R or REL) measures the accuracy of dairy evaluations, similar to accuracy in beef cattle. Economic indexes help dairy producers balance multiple traits simultaneously. The Total Performance Index (TPI), used by the Holstein Association, ranks bulls based on a balance of production and type traits weighted by their economic value. Net Merit Dollars (NM$), calculated by the USDA, measure the expected lifetime profit of a cow's daughters relative to the breed average.



Image credit: Mark Stebnicki from Pexels: https://www.pexels.com/photo/cows-in...farm-11679513/

Genetic progress is particularly rapid in swine due to high reproductive rates (large litters) and short generation intervals (animals can reproduce at 8–10 months of age). Selection focuses on reproductive efficiency (pigs per litter, farrowing rate), growth performance (days to market weight, feed efficiency), and carcass quality (loin eye area, backfat thickness).

STAGES (Swine Testing and Genetic Evaluation System) generates within-herd and across-herd EPDs using performance records on individuals and their relatives, allowing meaningful comparisons across farms. Selection indexes—equations that simultaneously evaluate multiple traits based on their economic value and genetic parameters—are commonly used in swine breeding to achieve balanced genetic progress.

Sheep producers select for lamb growth, maternal prolificacy (lambing rate, mothering ability), and fleece characteristics (weight, fiber diameter, staple length). The National Sheep Improvement Program (NSIP) provides EPDs for maternal, growth, and wool traits, enabling across-flock genetic comparisons.

Sheep breeds are often classified by their primary purpose: ewe breeds (e.g., Rambouillet) emphasize maternal ability and wool production; ram breeds (e.g., Suffolk, Hampshire) emphasize growth rate and carcass merit; and dual-purpose breeds (e.g., Dorset) balance both functions. Terminal crossbreeding systems use ewe breeds for maternal characteristics and ram breeds to sire market lambs with superior growth and carcass traits.



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7.10: Biotechnology and Genetic Engineering

Marker-assisted selection (MAS) enhances conventional selection by incorporating genetic markers obtained from DNA analysis to identify specific genes or chromosomal regions that affect traits of interest. This technology is particularly valuable for traits that are difficult or expensive to measure directly, such as carcass quality (which requires slaughtering the animal), disease resistance, or sex-limited traits like milk production in young bulls.

Single nucleotide polymorphisms (SNPs)—single base-pair differences among individuals—are now the primary type of genetic marker used in livestock breeding. High-density SNP chips allow genotyping of thousands of markers across the entire genome, enabling genomic selection that predicts breeding values with greater accuracy, especially in young animals without performance records.

Transgenic animals are created by inserting DNA from an external source—such as the same or a different species—into an organism's genetic code. More recent gene editing technologies, such as CRISPR, allow precise modification of existing genes without necessarily introducing foreign DNA.

These technologies offer several potential benefits: more predictable breeding outcomes compared to traditional selection, increased speed of genetic improvement, creation of animals that produce substances they otherwise could not (such as pharmaceutical proteins in milk), development of gene therapies for genetic diseases, production of organs for human transplant that minimize rejection, and selection for enhanced disease resistance.

While these technologies complement rather than replace conventional breeding, they continue to expand the toolkit available for livestock improvement and present both opportunities and ethical considerations for the future of animal agriculture.



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7.11: CSI- Cow Scene Investigation — A Genetics Detective Game

Instructions 7.11.1

You and your group are hired as genetics detectives. Your mission is to analyze a case file and recommend the sire designation(s) that best solve the farm's goals and constraints. You'll gather evidence from posted clue cards, compare bulls from a lineup, and defend your choice.

1. **Intake:**
   Each group is given a ***Case File*** to read. The case file lists the herd's goals, constraints, and "unknowns" (things that need investigation).
2. **Evidence Hunt:**
   Post the ***Clue Cards*** around the room (or scatter in slides/handouts). Teams circulate and collect "evidence" by taking notes. They're allowed to revisit clues as needed.
3. **Suspect Lineup:**
   Give teams the ***Bull Lineup Cards*** (fictional sires with different designation combos). Teams shortlist 2–3 "suspects" (sires/designations) that best solve their case, writing 2–3 evidence-based reasons for each. They must explicitly reference the designations and what they signal.
4. **Report and Cross-Examination:**
   Groups discuss their ***Detective Report and*** peers, and the instructor asks "cross-examination" questions about the group's choices.
5. **Optional Speed Round:**
   Lightning quiz: instructor reads a mini-clue; first team to hold up the correct designation card gets a point.

Case Files

- Two box robots; struggling with unit attachment on some cows; nervous heifers cause re-attachments and slow milkings.
- Management wants higher component counts and longer longevity; no appetite for a major parlor retrofit.
  Your task: Recommend designations and justify. Consider temperament and udder conformation for robot success.
  Strong leads: RobotPRO (opens in new window) (robot-fit traits; added *Udder Floor* and *Milking Temperament* in Aug 2024) and possibly Mastitis ResistantPRO for udder health.

Case B — 'Green Hills Grazing' (350 cows, seasonal grass-based)

- Tight spring calving block; pasture lanes are hilly; manager wants compact, mobile cows with fertility and components.
  Your task: Prioritize designations for a grazing profit model; defend stature/fitness choices.
  Strong leads: GrazingPRO (opens in new window), fertility, longevity, mobility, moderate stature, components.

Case C — 'TMR Tight Margins' (800 cows, freestall, feed costs up)

- Corn silage prices spiked; the owner wants higher *income from feed costs* without sacrificing health or reproduction; dislikes oversized cows.
  Your task: Choose designations that lift IOFC while keeping cows durable and fertile.
  Strong leads: FeedPRO (opens in new window) (IOFC, moderate size, maintain BCS, mastitis resistance, daughter fertility).

Case D — 'Fresh Pen Blues' (600 cows)

- Elevated mastitis treatment bills and high bulk tank SCC; clinical cases spiking in first and second lactations.
  Your task: Create a genetics-plus management plan specifically targeting mastitis risk reduction.
  Strong leads: Mastitis ResistantPRO (opens in new window) (combines CDCB Mastitis Resistance, CDCB SCS, Zoetis Mastitis Resistance). Consider FertilityPRO if conception is also lagging.

Case E — 'Heifer Rocket' (450 cows, rapid expansion)

- New heifer barn; plan to double replacements over the next 2 years; wants sex-sorted semen that **actually settles**.
  Your task: Recommend designations and dose types; explain 2M vs 4M and conception expectations.
  Strong leads: gender SELECTED (opens in new window) (sex-sorted availability and ongoing performance monitoring) + **Elite Sexed Fertility** (above-average conception with sex-sorted semen; comes in **2M and 4M**); 4M = twice the cells of Ultraplus.

Case F — 'Show String Dreams' (120 cows, type-focused)

- Targeting state fair and national shows; also wants to lift udder and frame traits across the herd.
  Your task: Identify the designation that best signals show-winning or herd type improvement, and justify trade-offs.
  Strong lead: Showcase (opens in new window) (breed-leading Type/show pedigrees).

Clue Cards

All "Clue Cards" are derived from the Select Sires designations pages (opens in new window)

- **FeedPRO®** (opens in new window): improves *income over feed costs* while maintaining health and reproduction; optimizes for increased production and *moderate body size* with attention to body condition, mastitis resistance, and daughter fertility.
- **FertilityPRO®** (opens in new window): identifies sires with semen likely to improve pregnancy rates by examining industry **Sire Conception Rate (SCR)** and intensive in-house semen quality evaluations.
- **GrazingPRO®** (opens in new window): for grass-based systems—transmits outstanding daughter fertility, greater longevity, mobility, *moderate stature*, and improved component yields.
- **Mastitis ResistantPRO®** (opens in new window): selects sires that excel across multiple indicators of mastitis resistance, using **CDCB Mastitis Resistance, CDCB Somatic Cell Score (SCS), and Zoetis Mastitis Resistance**.
- **RobotPRO®** (opens in new window): targets traits that fit robotic milking—components & milk yield, udder health, longevity/durability, and functional udder traits. In **Aug 2024** the formula added Canadian **Udder Floor** and **Milking Temperament** to help robots attach more reliably, especially on reverse-tilt udders and with nervous cows.
- **Showcase™**: (opens in new window) emphasizes breed-leading **Type** or show-winning pedigrees for herds chasing the next show winner or overall Type improvement.
- **gender SELECTED™** (opens in new window): sex-sorted semen available; Select Sires tracks conception data and **removes bulls that perform unacceptably** with sexed semen. 4M icon = **4 million sex-sorted sperm**, **twice** the cells of gender SELECTED Ultraplus per unit.
- **Elite Sexed Fertility™** (opens in new window): flags **gender SELECTED** sires whose **sex-sorted semen** shows above-average conception performance (available in both **2M and 4M** products).

- **"Atlas"** — FeedPRO, FertilityPRO
- **"Maple"** — GrazingPRO, FertilityPRO
- **"Titan"** — RobotPRO, Mastitis ResistantPRO
- **"Halo"** — gender SELECTED, Elite Sexed Fertility
- **"Velvet"** — Showcase (Type specialist)
- **"Shield"** — Mastitis ResistantPRO, FeedPRO
- **"Sprint"** — FertilityPRO (fertility specialist)
- **"Pivot"** — RobotPRO, gender SELECTED

Detective Report Form

Case: _____ **Team:** _____

What are the herd goals/constraints (bullets):

Bull Shortlist (2–3 bulls/designations):

____ because _____ (cite clues)

____ because _____ (cite clues)

____ because _____ (optional)

Main recommendation (circle one): Bull/Designation ____

Risks/trade-offs: _____

One practical next step for the farm: _____

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7.12: Summary and Flashcards

Animal breeding has long relied on traditional genetic selection to improve traits such as productivity, health, and adaptability. However, recent advances in biotechnology and genetic engineering are revolutionizing this field, offering unprecedented precision and possibilities.

Biotechnology in Animal Breeding: Modern biotechnological tools allow for:

- **More predictable breeding outcomes**, reducing reliance on chance and improving consistency.
- **Accelerated genetic improvement**, enabling faster progress in desirable traits.
- **Creation of transgenic animals** capable of producing substances they naturally wouldn't—such as pharmaceuticals or specialized proteins.
- **Development of gene therapies that offer** potential cures or treatments for inherited diseases.
- **Production of transplantable organs** that are less likely to trigger immune rejection in humans.
- **Selection for disease resistance**, enhancing animal welfare, and reducing reliance on antibiotics.

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CHAPTER OVERVIEW

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8.2: The Biotechnology Industry in the United States
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8.1: Introduction to Biotechnology and Genetic Engineering

Biotechnology is the use of biological systems, organisms, or their components to develop products and technologies that benefit society. In agriculture and animal science, biotechnology ranges from traditional methods such as fermentation and selective breeding to modern applications like genetic engineering, gene editing, and cloning. The modern era of biotechnology began in 1953 with the discovery of DNA's double-helical structure, laying the foundation for recombinant DNA (rDNA) technologies and molecular genetics.

Today, biotechnology supports food production, animal health, environmental management, and human medicine. Genetic engineering—one of the most transformative tools in biotechnology—allows scientists to directly modify an organism's DNA to introduce beneficial traits, improve productivity, produce pharmaceuticals, and study disease. Its development has transformed fields such as livestock management, disease prevention, drug production, and transplantation medicine.

Let's explore the foundational principles underlying these biotechnological approaches, examine the techniques that enable genetic modification, and consider both the remarkable opportunities and the essential ethical responsibilities that accompany our growing ability to reshape animal biology.



Image credit: Erwin Bosman from Pexels: https://www.pexels.com/photo/muscula...ture-32782007/

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8.2: The Biotechnology Industry in the United States

The United States biotechnology sector represents a multibillion-dollar industry encompassing agriculture, pharmaceuticals, environmental applications, and industrial manufacturing. In agriculture, genetically modified crops such as corn, soybeans, and cotton dominate U.S. farmland. Animal agriculture benefits from improved feed efficiency, disease resistance, reproductive technologies, and production of high-value biopharmaceuticals.



Image credit: Tom Fisk from Pexels: https://www.pexels.com/photo/combine...ening-9940117/

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8.3: Foundations of Recombinant DNA Technology

Recombinant DNA (rDNA) combines DNA molecules from different biological sources. Recombinant DNA technology encompasses techniques for introducing, removing, or modifying genes in an organism's genome. Organisms modified this way are known as genetically modified organisms (GMOs), and when genes come from different species, they're called transgenic organisms.

Modern biotechnology relies on several essential molecular tools that allow scientists to isolate, manipulate, copy, and transfer DNA. These tools enable the study of genes in detail, the creation of recombinant DNA, and the production of useful biological products. Among the most important tools used in molecular biology are restriction enzymes, plasmids and vectors, DNA ligase, and the polymerase chain reaction (PCR). Each of these components plays a specific role in genetic analysis and genetic engineering.

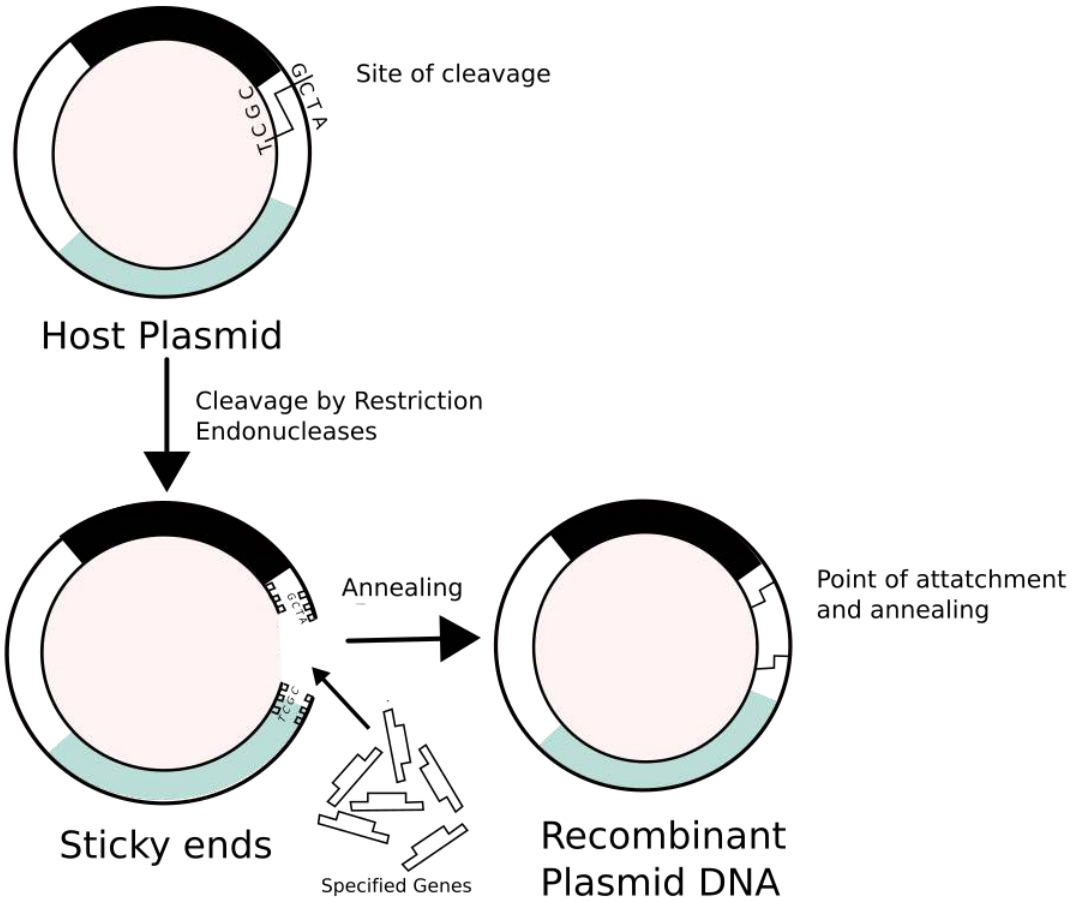


Image credit: Wikipedia - Recombinant formation of plasmids, https://en.wikipedia.org/wiki/Recombinant_DNA

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8.4: Restriction Enzymes

Restriction enzymes are specialized proteins that cut DNA at specific nucleotide sequences called restriction sites. These enzymes are naturally found in bacteria, where they serve as part of the bacterial defense system against invading viruses known as bacteriophages. When viral DNA enters a bacterial cell, restriction enzymes recognize specific DNA sequences within the viral genome and cut it into fragments, preventing viral replication.

In biotechnology laboratories, scientists exploit this natural DNA-cutting ability. By selecting restriction enzymes that recognize particular DNA sequences, researchers can cut DNA molecules at precise locations. This allows them to isolate specific genes or DNA fragments from larger chromosomes. The cuts made by restriction enzymes can produce two types of ends. Some enzymes create "sticky ends," short single-stranded overhangs that readily pair with complementary DNA fragments. Other enzymes create "blunt ends," in which the DNA strands are cut straight across, without overhangs. Both types of cuts are useful for constructing recombinant DNA molecules.

These DNA-cutting enzymes are found primarily in bacteria, where they defend against invading viruses by cutting viral DNA. Restriction enzymes cut DNA only at specific sites called restriction sites, allowing scientists to excise desired genes from chromosomes. The cuts may produce "sticky ends" or "blunt ends" that facilitate DNA manipulation.

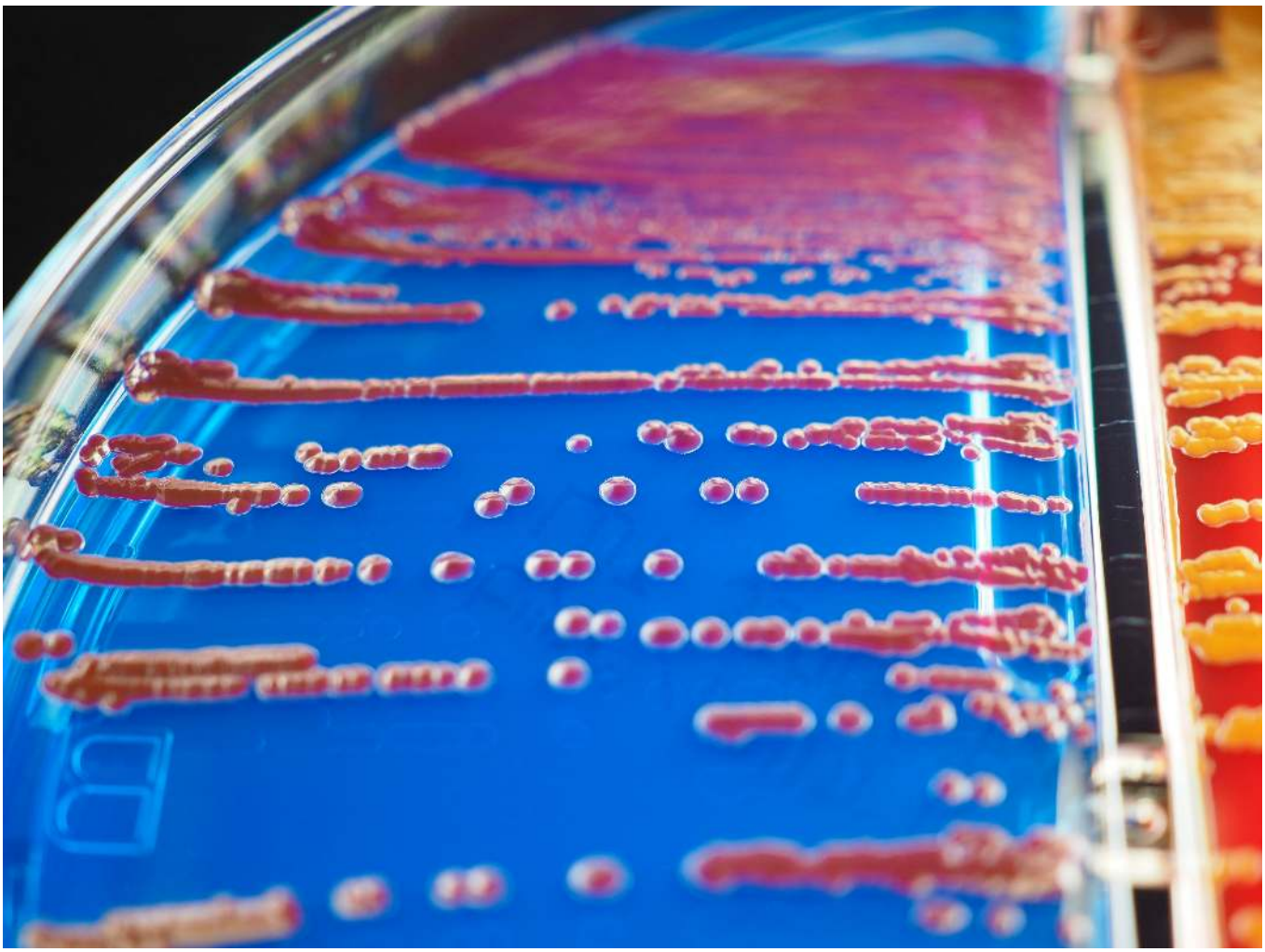


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8.5: Plasmids and Vectors

Plasmids are small, circular, self-replicating DNA molecules that scientists manipulate to carry and clone other DNA pieces. They function as vectors—DNA molecules that carry foreign DNA into host cells, replicate there, and produce many copies. Because of their small size and ability to replicate independently, plasmids are extremely useful tools in genetic engineering.

Scientists can modify plasmids to carry additional DNA fragments, such as genes from other organisms. When plasmids are used to transfer foreign DNA into host cells, they are called vectors. A vector is any DNA molecule that acts as a carrier to introduce foreign genetic material into another cell. Once the plasmid vector enters the host cell, it replicates along with the cell's own DNA, producing many copies of the inserted gene. This process allows researchers to clone genes, study gene function, or produce large amounts of specific proteins. Plasmid vectors often contain special features, such as selectable marker genes, that help scientists identify cells that have successfully taken up the recombinant DNA.

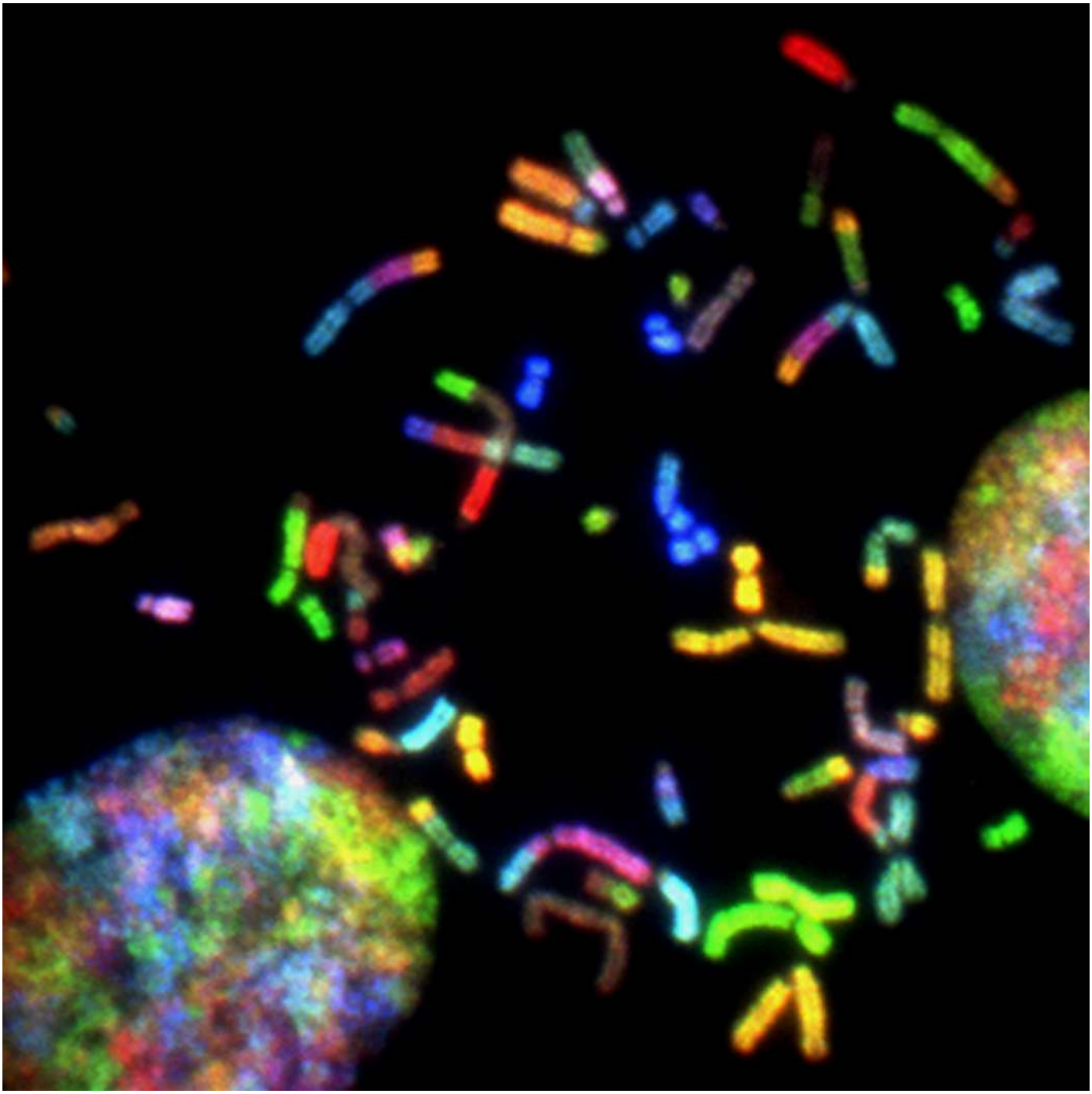


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8.6: DNA Ligase

DNA ligase is an enzyme that plays a crucial role in joining DNA fragments. After restriction enzymes cut DNA into fragments, those fragments must be reconnected in a controlled way to form new combinations of DNA. DNA ligase performs this task by "gluing together" DNA fragments, joining them to vectors.

This "gluing" process is known as ligation. During ligation, DNA ligase connects the fragment of foreign DNA with the plasmid vector that has been cut with the same restriction enzyme. Because sticky ends from different DNA fragments can base-pair with each other, DNA ligase can then seal the strands together, creating a stable recombinant DNA molecule. Without DNA ligase, the inserted DNA fragment would not remain permanently attached to the vector.



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8.7: Polymerase Chain Reaction (PCR)

The polymerase chain reaction (PCR) is a powerful and widely used laboratory technique that allows scientists to amplify millions of copies of a specific DNA sequence in a relatively short time. Developed in the 1980s, PCR revolutionized molecular biology by enabling researchers to amplify tiny amounts of DNA for analysis, cloning, or sequencing.

PCR works through a series of temperature-controlled steps. The first step, denaturation, involves heating the DNA sample to a high temperature, which separates the double-stranded DNA molecule into two single strands. In the second step, known as annealing, the temperature is lowered so that short DNA sequences, called primers, can bind to complementary regions of the single-stranded DNA templates. These primers mark the starting points for DNA synthesis.

The third step, elongation, occurs when a heat-stable DNA polymerase enzyme extends the primers by adding nucleotides to form new complementary DNA strands. This results in the duplication of the target DNA region. Each PCR cycle doubles the amount of DNA, and after many cycles, a very large number of copies of the original DNA sequence are produced. Because of its efficiency and sensitivity, PCR is widely used in research, medical diagnostics, forensic science, and biotechnology.



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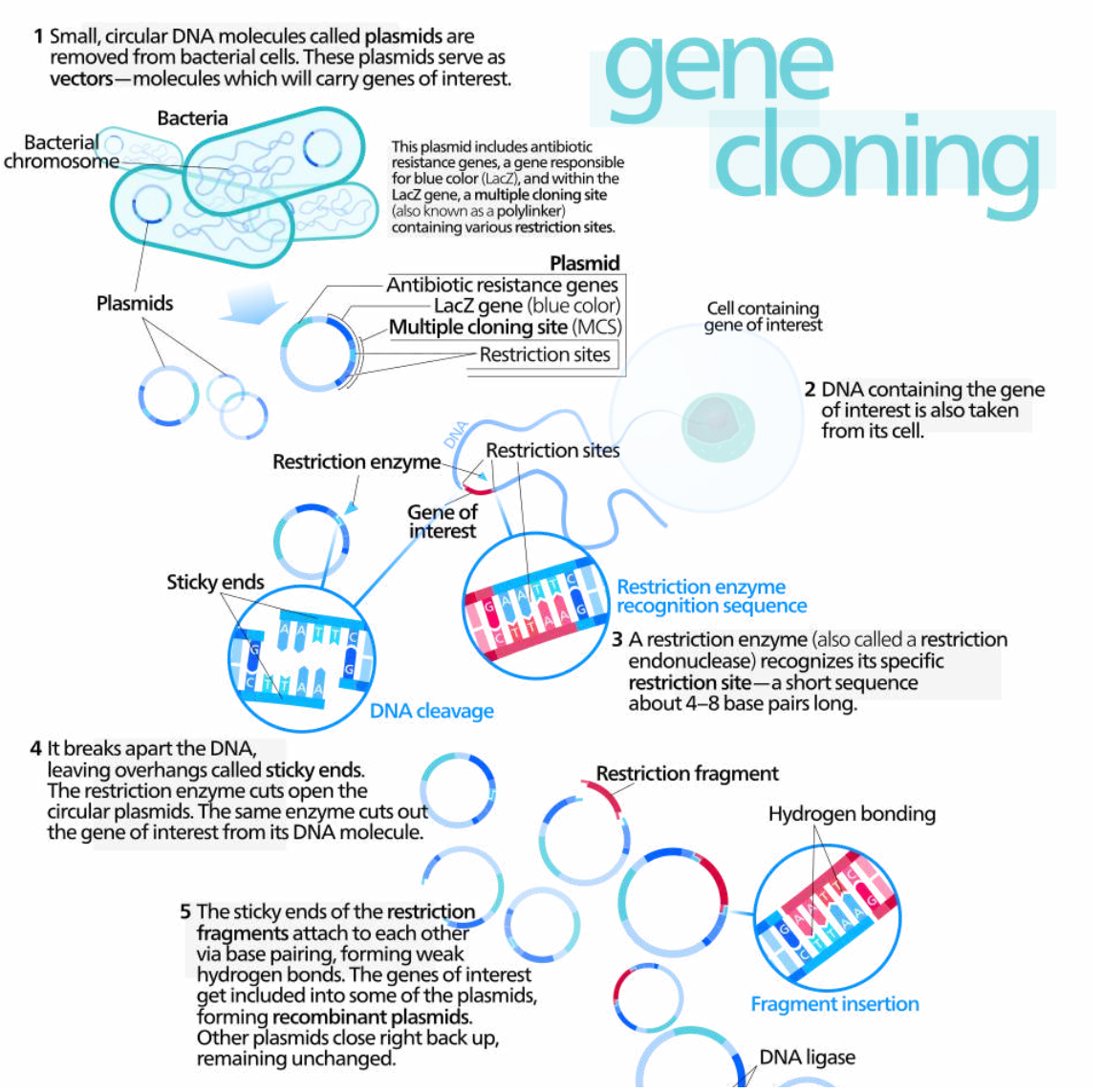
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8.8: Gene Cloning and DNA Manipulation

In biotechnology, cloning refers to the process of producing genetically identical copies of biological material. A clone may be an organism, a cell, or a DNA molecule that is genetically identical to the source. Cloning is widely used in research and biotechnology because it allows scientists to reproduce specific genetic material in large quantities and maintain desirable genetic traits. Applications of cloning include producing multiple copies of valuable genes for research or protein production, preserving genetic material from superior animals, creating genetically identical organisms for controlled experiments, and propagating transgenic organisms that possess beneficial traits.

At the molecular level, cloning involves producing multiple copies of a DNA fragment through a series of coordinated laboratory steps. The process typically begins with fragmentation, in which DNA is cut into smaller pieces using restriction enzymes that recognize specific nucleotide sequences. Next, during ligation, the desired DNA fragment is joined to a carrier DNA molecule, usually a plasmid vector, using the enzyme DNA ligase. The recombinant DNA molecule is then introduced into a host cell via a process called transformation. Once inside the cell, the recombinant DNA replicates along with the host's genetic material. Finally, researchers perform screening or selection to identify the cells that have successfully taken up the recombinant DNA and contain the desired gene.

Microorganisms, particularly *Escherichia coli* (E. coli), are commonly used as host organisms for molecular cloning. These bacteria grow rapidly, are easy to culture in laboratory conditions, and have well-understood genetics, making them ideal for producing large quantities of cloned DNA.



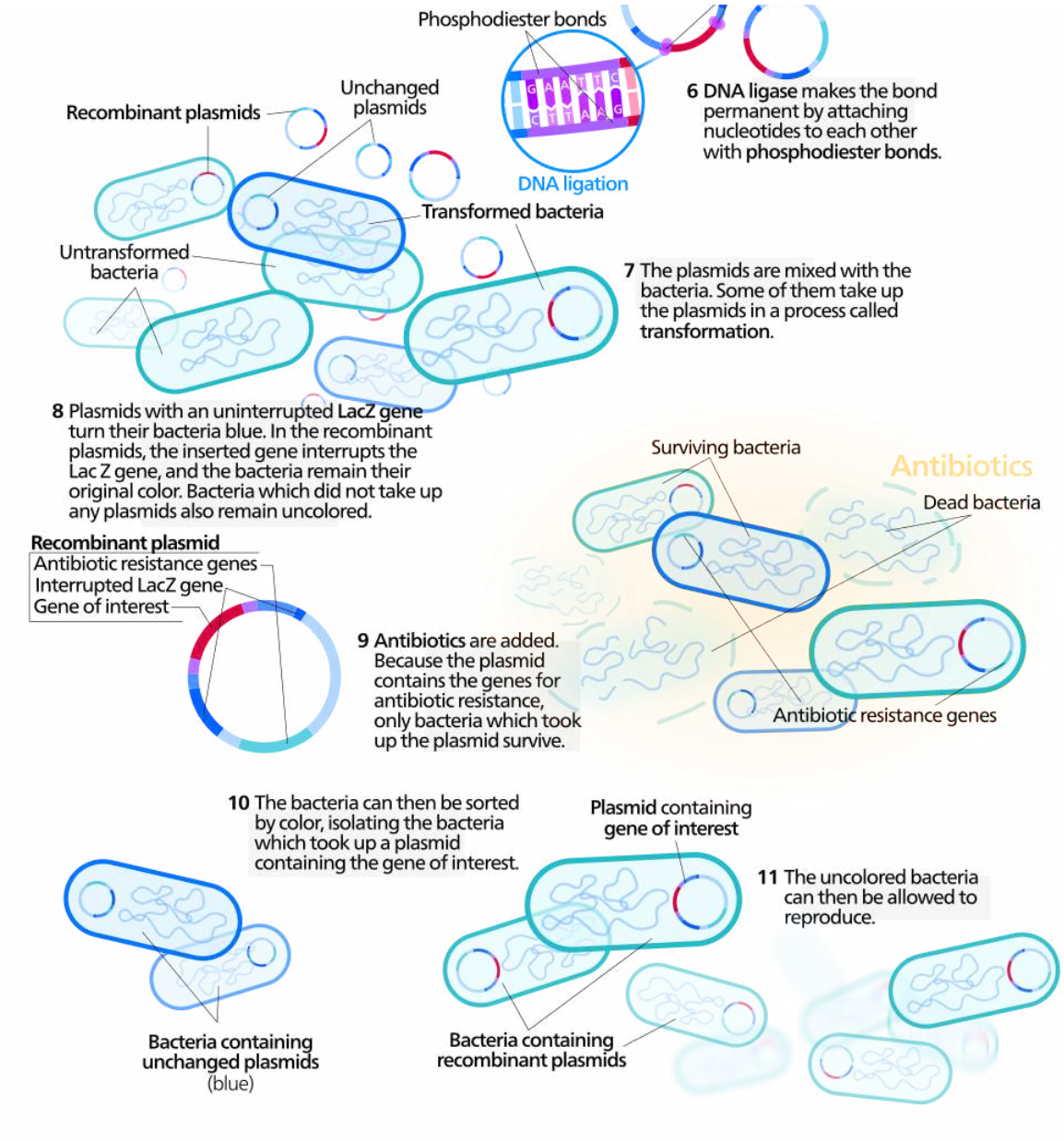


Image credit: Wikimedia Commons contributors, Link to image of gene cloning [commons.wikimedia.org]

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8.9: Gene Mapping – Understanding Genome Organization

Gene mapping is the process of determining the location of genes on chromosomes and establishing their relative positions within a genome. By identifying the locations of specific genes, gene mapping provides essential information for understanding how genetic traits are inherited and expressed. Genetic maps are fundamental tools in modern biology because they help researchers connect specific genes to observable characteristics and biological functions.

Gene mapping has many important applications in biology, medicine, and agriculture. It allows scientists to identify genes responsible for inherited diseases and contributes to the diagnosis and study of genetic disorders. In agriculture and animal science, gene maps support selective breeding programs by helping breeders locate genes associated with desirable traits such as productivity, disease resistance, or growth. Gene mapping also helps understand evolutionary relationships among species by comparing gene organization across different organisms. In addition, accurate gene maps enable targeted genetic modifications by identifying the precise regions of DNA that can be altered through modern gene-editing technologies.

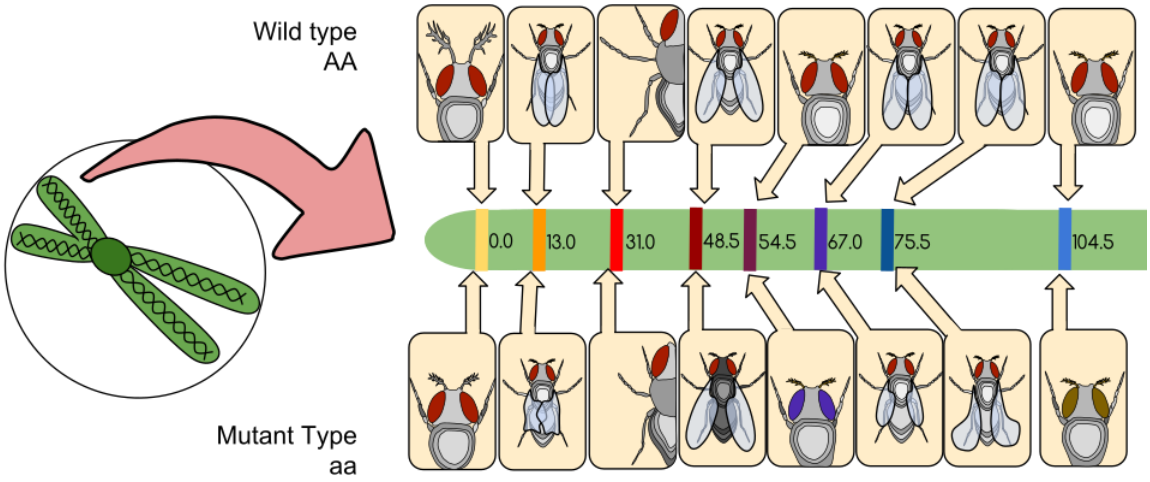


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Two complementary approaches are commonly used to create gene maps: genetic mapping and physical mapping. Genetic mapping determines the relative positions of genes or genetic markers by analyzing how frequently they are inherited together during crossbreeding experiments. Genes that are located close together on a chromosome tend to be inherited together, while those farther apart are more likely to be separated during recombination. By measuring these recombination frequencies, scientists can estimate the distance between genes and construct a map showing their relative order.

In contrast, physical mapping identifies the exact location of genes or markers on a chromosome using molecular techniques. Instead of relying on recombination frequencies, physical mapping measures the actual distance between DNA sequences in base pairs. This approach provides precise genomic coordinates, essential for detailed genome analysis and advanced applications such as gene editing, genome sequencing, and gene therapy. Together, genetic and physical mapping provide complementary information that helps scientists understand genome structure and function.

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8.10: Creating Transgenic Organisms

A transgenic organism has been genetically modified to contain and express a gene from another organism. The creation of genetically modified organisms (GMOs) is a central technique in modern biotechnology and is used in research, agriculture, and medicine to introduce desirable traits or study gene function.

The process of producing a transgenic organism typically begins with identifying and isolating a gene associated with a desired trait, such as disease resistance, improved growth, or the production of a useful protein. Once the gene of interest has been identified, it is often amplified using the polymerase chain reaction (PCR) to produce many copies of the DNA sequence. The amplified gene is then inserted into a plasmid vector, creating a recombinant DNA molecule that can carry the gene into a host cell.

After the recombinant plasmid has been constructed, it must be introduced into the target organism's cells. Several methods can be used to accomplish this step, including transfection techniques, direct microinjection, or modern gene-editing methods such as CRISPR-based systems. Once the foreign DNA is successfully introduced, the modified cells are allowed to grow and develop under controlled laboratory conditions. Researchers then perform screening and selection procedures to identify individuals who have successfully incorporated the foreign gene and express the desired trait.

In mammals, foreign DNA can be introduced in several ways. One common approach involves inserting the gene into embryonic stem (ES) cells, which can then be incorporated into developing embryos. Another method is direct microinjection of DNA into fertilized eggs, allowing the introduced gene to become part of the organism's genome as development proceeds. More recently, CRISPR-mediated gene editing has enabled scientists to introduce or modify genes directly in zygotes with greater precision.

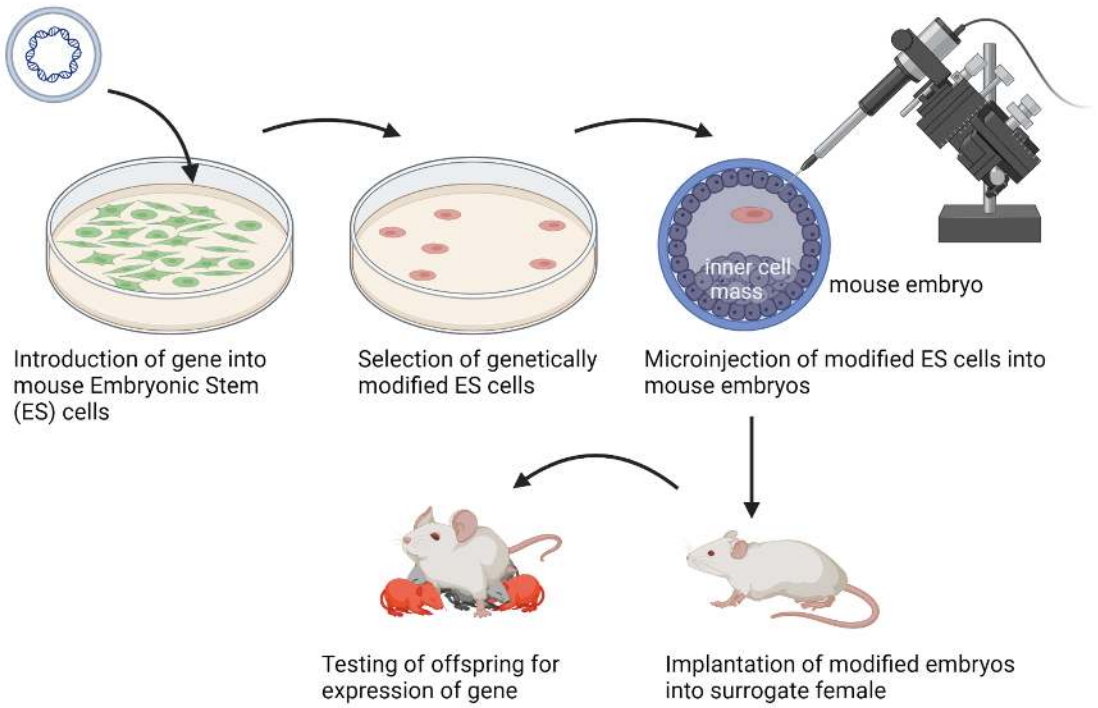


Image credit: Zuk, P. (2025). GMO Plant Production. Created in BioRender. Link to cloning image [BioRender.com]

Although genetic engineering is widely used in microorganisms and plants, relatively few transgenic animals have been developed. This difference is largely due to several practical, biological, and ethical challenges associated with animal genetic engineering.

One major limitation is technical complexity. Manipulating animal genomes, particularly those of mammals, is more difficult than manipulating those of microorganisms or plant cells. The procedures often require sophisticated laboratory techniques and precise control over early developmental stages. In addition, producing transgenic animals is costly because it requires specialized facilities, skilled personnel, and long experimental timelines.

Another challenge is low efficiency. Many attempts to introduce foreign DNA into animal embryos fail to achieve successful integration or expression of the gene, resulting in a high rate of failed experiments. Furthermore, animal welfare concerns and questions about the ethical treatment of genetically modified animals can limit research and public acceptance. Regulatory oversight is also stricter for animals, especially those intended for agricultural use or entry into the human food supply.

Finally, biological complexity contributes to the difficulty of producing transgenic animals. Mammalian genomes and developmental processes are more complex than those of microorganisms or plants, making genetic modifications harder to control and predict. As a result, although transgenic animals are extremely valuable for biomedical research and certain agricultural applications, they remain less common than genetically engineered microbes or plants.

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8.11: Gene Modification Approaches

Inserts functional genes to add or improve traits, including disease-resistant pigs, cattle with reduced BSE susceptibility, and AquAdvantage® salmon that grow nearly twice as fast.

Turns off defective or harmful genes using RNA interference (RNAi). Small interfering RNA (siRNA) and microRNA (miRNA) target and degrade specific mRNA molecules, reducing gene expression. RNAi therapeutics are being explored for Huntington's disease, cancer, and viral infections.

CRISPR-Cas9 allows precise, targeted DNA modification. A single-guide RNA (sgRNA) directs Cas enzymes to specific genomic sites where they can knock out genes by creating double-stranded breaks, replace mutated sequences with correct copies, or insert new DNA during repair. While powerful, CRISPR requires careful validation to avoid unintended edits.

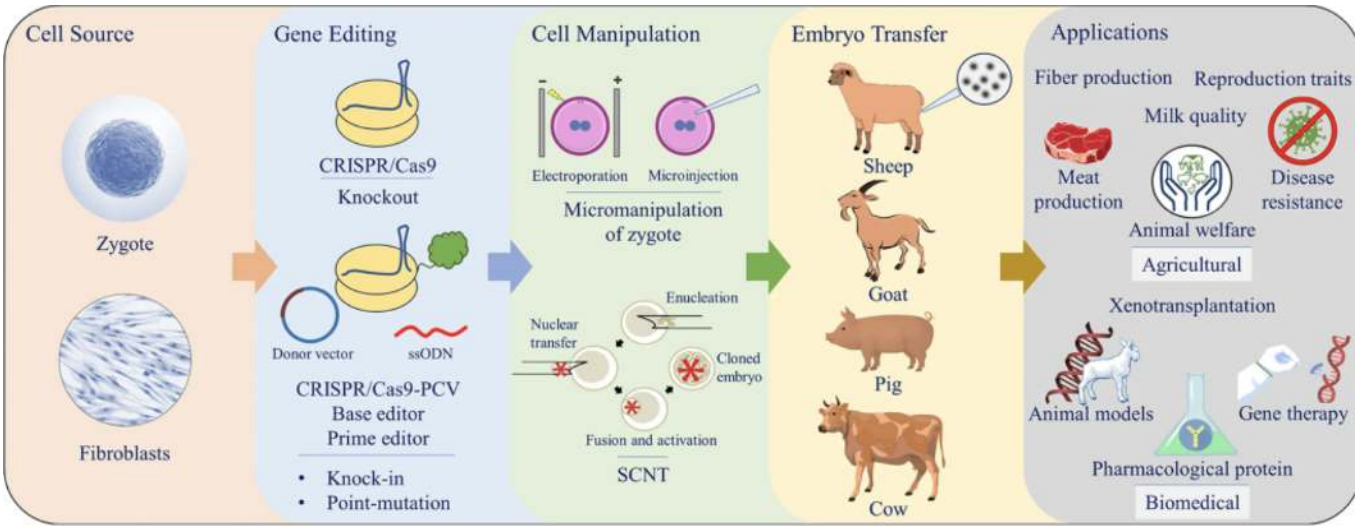


Image credit: To CRISPR article for more in depth information(opens in new window) [Perisse I.V., Fan Z., Singina, G.N., White, K.L. and Polejaeva, I.A. (2021) Improvements in gene editing technology boost its applications in livestock. Figure 2. Frontier. Genetics. 11:614688. doi: 10.3389]

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8.12: Animal Pharm – Food for Thought

As global populations grow and climate pressures intensify, the way we raise animals and produce food is changing faster than ever before. This video is a thought-provoking look at the rapidly evolving world of modern food production

Animal Pharm explores the intersection of science, ethics, and sustainability. It examines how biotechnology, genetic research, and innovative farming practices are reshaping the livestock industry—and what those changes mean for our health, our environment, and our future food systems.

As you watch, pay attention to:

- **The complex questions raised by the technological breakthroughs:**
  - How do we balance efficiency with animal welfare?
  - How can innovation support both farmers and consumers?
  - What responsibilities do we share as part of a global food ecosystem?



Critical Viewing Questions 8.12.1

After watching the documentary, answer the following questions and upload them to the assignment drop in Brightspace.

- How is biotechnology being used to create the Belgian Blue?
- What characteristics are being developed in Belgian Blues?
- What are the advantages and disadvantages of developing this technology in Belgian Blues?
- How is biotechnology being used to develop a featherless chicken?
- What are the advantages and disadvantages of featherless chickens to farmers?
- How is biotechnology being used to develop transgenic rabbits?
- Transgenic rabbits contain a gene from what organism. What does this gene do?
- Why is this technology being developed in transgenic rabbits?
- What are the advantages and disadvantages of developing transgenic rabbits?
- How is biotechnology being used to develop transgenic salmon?
- Is there a risk that transgenic salmon will reproduce in the wild? Why or why not?
- Why are transgenic salmon being developed?
- What are the advantages and disadvantages of transgenic salmon?
- How is biotechnology being used to address the environmental impact of pig manure?
- What are the advantages and disadvantages of developing this type of biotechnology in pigs?

- How is biotechnology being used to create Golden Rice?
- Where did the genes for the genetically modified rice come from?
- What are the advantages and disadvantages of growing Golden Rice?
- How is a clone created?
- What are the advantages and disadvantages of cloning animals?
- Do you think we should clone animals? Explain why or why not.
- What biotechnology is being used to create non-animal meat?
- Why is this technology being developed?
- What are the advantages and disadvantages of creating non-animal meat?
- Would you eat any of the foods seen in the Animal Pharm video? Explain why or why not.
- Choose one of the following and investigate where the technology or product is being used today.
  - Belgium Blue
  - AquAdvantage Salmon
  - Enviro Pig
  - Golden Rice
  - Scamper's clone - Clayton

Video Resource: Eric Ochieng. May 11, 2017, *Animal Pharm Food For Thought Top Documentary Films*, [Video], YouTube, https://www.youtube.com/watch?v=g89xj3oDvgI&t=510s

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8.13: Crop Production Applications

Genetically modified crops outnumber all other genetically manipulated organisms. They aim to increase global food production by reducing crop losses and increasing yields.

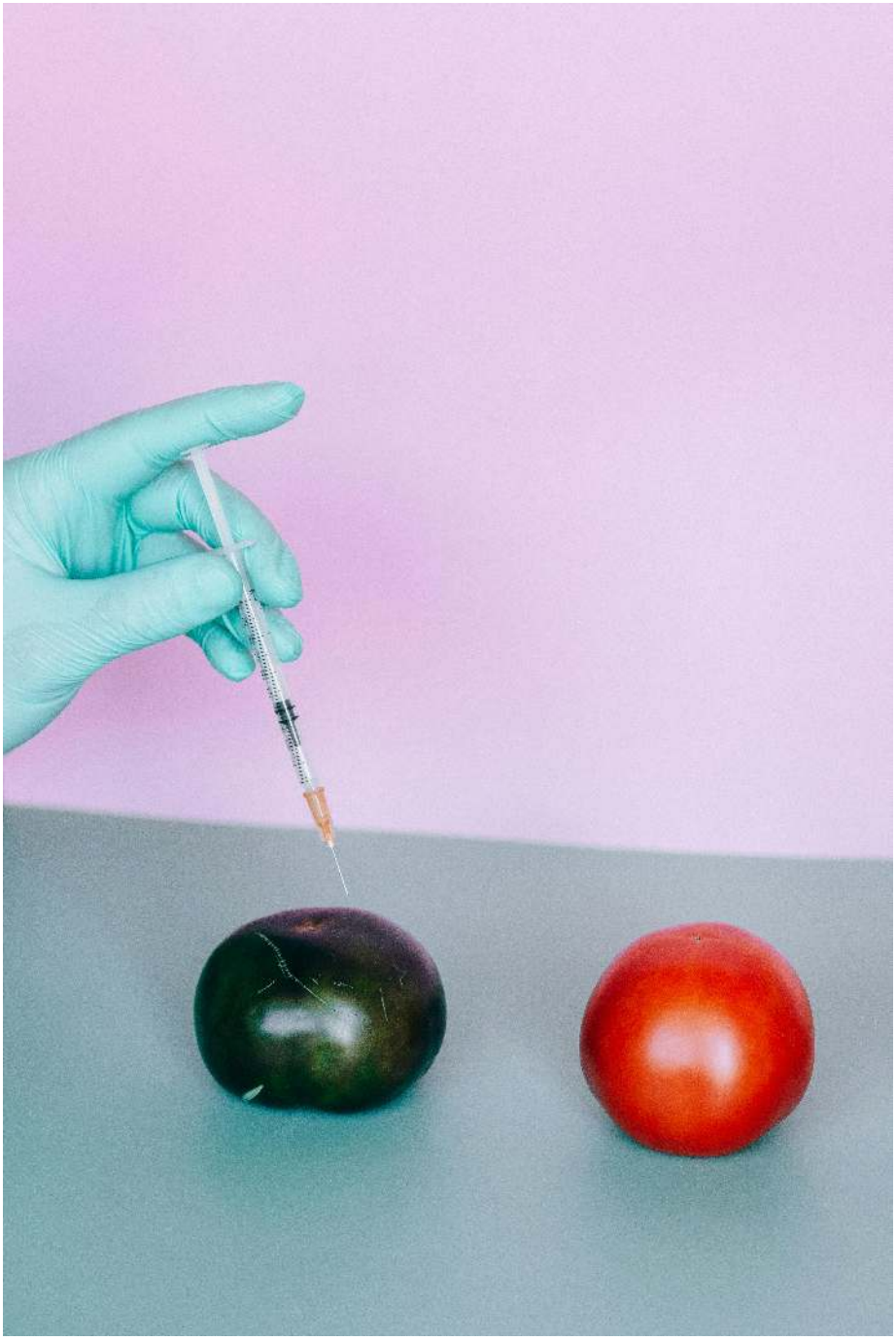
Transgenic plants are created for:

- **Enhanced nutritive value**: Golden rice with beta-carotene, high-lysine corn
- **Pest resistance**: Bt corn and cotton that produce insecticidal proteins
- **Disease resistance**: Virus-resistant papayas and squash
- **Herbicide tolerance**: Roundup Ready® soybeans, corn, and cotton
- **Environmental stress tolerance**: Drought-resistant varieties
- **Extended shelf life**: Flavr Savr® tomatoes with delayed ripening
- **Unique ornamental value**: Blue carnations and roses
- **Production of edible vaccines**: Plant-based vaccine delivery systems

Research continues on crops that:

- Fix their own nitrogen, reducing fertilizer needs
- Tolerate saline soils for expanded growing areas
- Produce industrial compounds and biofuels
- Deliver pharmaceuticals and nutraceuticals

Safety assessments using internationally accepted procedures indicate that risks from GM crops are not greater than those from plants produced by traditional breeding methods. Regulatory agencies worldwide have approved numerous GM crops after rigorous testing. However, ongoing monitoring continues to evaluate long-term environmental and health impacts.



A hand holding a syringe over a green tomato

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8.14: Livestock Production Applications

Transgenic livestock production is rapidly developing, with both current applications and promising future uses.

- Enhanced growth rates and improved feed efficiency
- Improved carcasses with better meat quality
- Modified milk production and composition
- Resistance to diseases such as mastitis in dairy cows
- Production of environmentally friendly animals (e.g., enviropigs that produce less phosphorus waste)
- Animals producing omega-3 fatty acids in meat and milk
- Livestock with enhanced heat tolerance for climate adaptation
- Cattle resistant to trypanosomiasis for African agriculture
- Pigs producing organs suitable for human transplantation
- Chickens resistant to avian influenza

Recombinant bovine somatotropin (rBST) provides an important example of biotechnology in livestock. BST is produced commercially by:

1. Isolating the bovine growth hormone gene
2. Inserting it into *E. coli* bacteria using plasmid vectors
3. Growing bacteria in large fermentation tanks
4. Extracting and purifying the BST protein
5. Formulating it for injection into dairy cows

The value of rBST includes:

- Increased milk production (10-15% more milk per cow)
- Improved feed efficiency
- Reduced environmental impact per unit of milk produced
- Lower production costs for dairy farmers
- Reduce the need for additional cows to meet milk demand

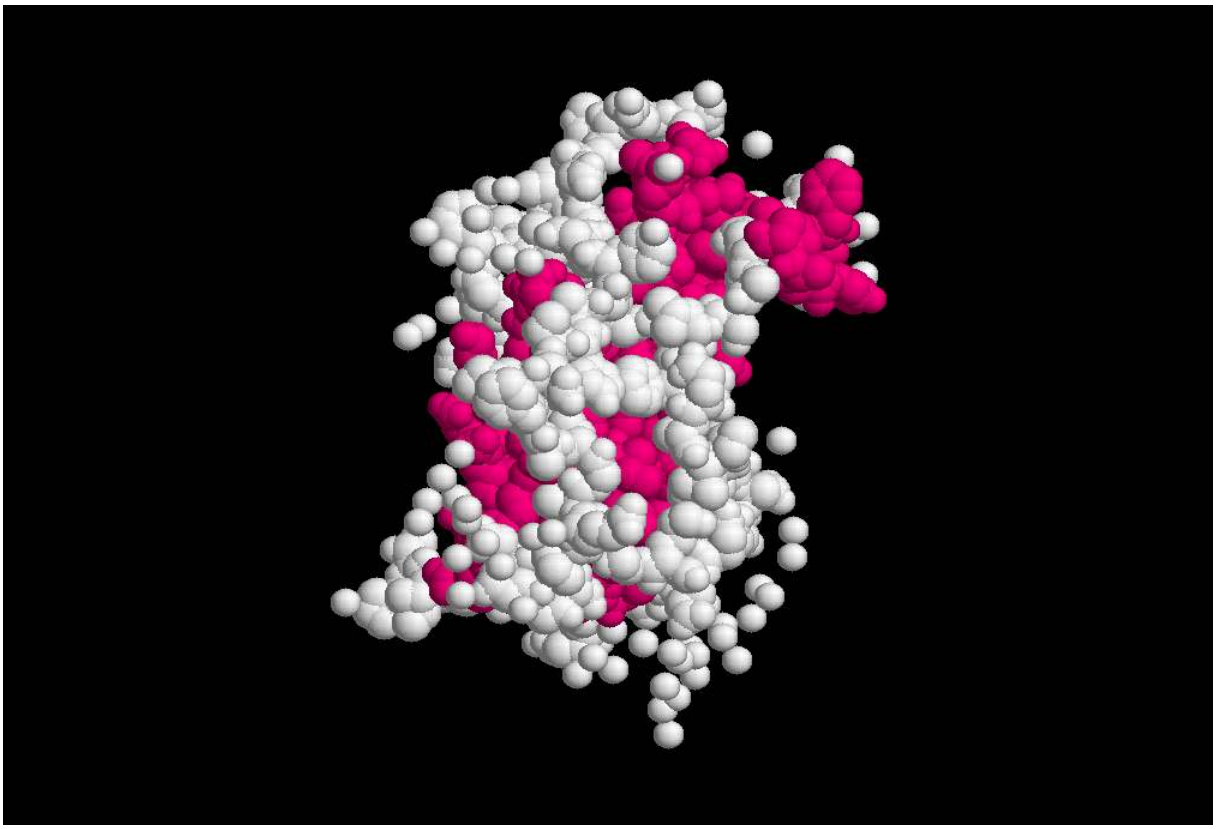


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8.15: Biotechnology and Genetic Engineering in Food Animals Activity

Genetic engineering (also called genetic modification) is a process that uses laboratory-based technologies to alter an organism's DNA makeup. Biotechnology is the application of advances made in the techniques and instruments from the biological sciences (e.g., Animal Pharm).

Your group will investigate the role of biotechnology and genetic engineering in food animal production, focusing on the ethical, environmental, and economic impacts. Critically analyze the benefits, risks, and ethical considerations of using these technologies. Your group will present your findings on the future of these technologies in animal agriculture to the rest of the class.

? Instructions 8.15.1

1. Your group will be assigned one of the following topics to research, finding a current event that illustrates these discussions:
    - Animal Health and Disease Resistance: Research how genetic engineering is used to improve disease resistance in livestock (e.g., PRRS-resistant pigs, foot-and-mouth disease-resistant cattle).
    - Enhanced Production Traits: Investigate how biotechnology is used to improve traits like growth rate, feed efficiency, and reproductive performance (e.g., AquaAdvantage salmon, increased milk yield in cows).
    - Environmental Impact: Explore how genetic engineering could reduce the environmental footprint of animal agriculture (e.g., low-emission cattle, less resource-intensive animals).
    - Ethics and Consumer Perceptions: Examine the ethical concerns and public perceptions of genetically engineered food animals (e.g., animal welfare, labeling and transparency, food safety, and consumer choice).
    - Economic Impact: Analyze the potential economic benefits and challenges of genetic engineering for farmers, the food industry, and consumers.
2. Conduct research using reliable sources (that pass the CRAAP Test).
3. Prepare a 10-minute presentation on your topic. Include the following points:
    - An overview of the specific application of genetic engineering in food animals.
    - Pros and cons, including scientific, ethical, and economic perspectives.
    - Relevant examples of genetically engineered animals and their uses.
4. Each group will present its findings to the class and answer any questions about its topic.
5. Class Debate: Should genetic engineering be widely adopted in food animal production?

Get into two teams—those in favor of widespread adoption and those against it. Each team will develop arguments based on the presentations and their perspectives. Each team will then present its stance, followed by a rebuttal session where each team responds to the other's points.

Deliverables

Reflection and Summary to turn in at the end of class:

- What were three ***new*** things you learned today about the current state of genetic engineering in animal agriculture?
- What are two questions you have about the current trends or policies discussed regarding genetic engineering?
- What is one concern ***you*** have about the future of our food supply?

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8.16: Cloning Whole Organisms

Whole organism cloning uses somatic cell nuclear transfer (SCNT), which involves:

1. Removing the nucleus from an egg cell
2. Transplanting a nucleus from a somatic cell (any cell other than a gamete) into the enucleated egg
3. Inducing embryonic development
4. Implanting the embryo into a surrogate mother

Dolly the sheep was the first mammal cloned using this method in 1996. Potential advantages include:

- Propagating transgenic animals with valuable traits
- Cloning outstanding animals for production purposes
- Preserving the genetics of elite breeding stock
- Combining cloning with rDNA technology for precise genetic modifications
- Conserving endangered species

However, the technique remains extremely inefficient, with low success rates and potential health issues in cloned animals.

SCNT also supports therapeutic cloning—generating embryonic stem cells for regenerative medicine without creating a full organism.



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8.17: Biomedical Applications

The term bioreactor refers to animals genetically engineered to produce large quantities of specific proteins or compounds in their tissues or secretions. Gene pharming or biopharming describes using these animals to manufacture pharmaceuticals—a revolutionary approach to drug production.

1. Inserting human genes for desired proteins
2. Attaching these genes to mammary-specific promoters
3. Creating transgenic founder animals
4. Breeding populations that consistently express the protein
5. Harvesting and purifying proteins from milk or other secretions

- **Complex protein processing**: Animals perform post-translational modifications that bacteria cannot
- **Human-like proteins**: Mammalian systems produce proteins similar to natural human proteins
- **Scalability**: Large animals produce substantial quantities in milk (liters per day)
- **Cost-effectiveness**: Lower production costs than cell culture systems for some proteins
- **Stability**: Proteins in milk can be more stable than those from cell cultures

- Anti-thrombin (ATryn®) from goat milk for blood clotting disorders
- Alpha-1 antitrypsin from sheep for cystic fibrosis and emphysema
- Human serum albumin from cattle
- Erythropoietin (EPO) from rabbits
- Spider silk proteins from goats for biomaterials
- Monoclonal antibodies from various species

Most transgenic animals developed to date have been created for pharmaceutical production, making this the primary use of animal biotechnology. This focus exists because:

- High value justifies development costs
- Medical applications face less public resistance than food animals
- Regulatory pathways are better established
- Market demand for biologics continues to grow rapidly

Microorganisms have been genetically harnessed to produce numerous pharmaceuticals:

- Human insulin for diabetes treatment
- Human growth hormone for growth disorders
- Interferon for viral infections and cancer
- Blood clotting factors (Factor VIII, Factor IX) for hemophilia
- Tissue plasminogen activator (tPA) for heart attacks and strokes
- Erythropoietin for anemia

- Hepatitis B vaccine produced in yeast
- HPV vaccine components
- COVID-19 mRNA vaccine lipid components
- Experimental vaccines for influenza and other diseases

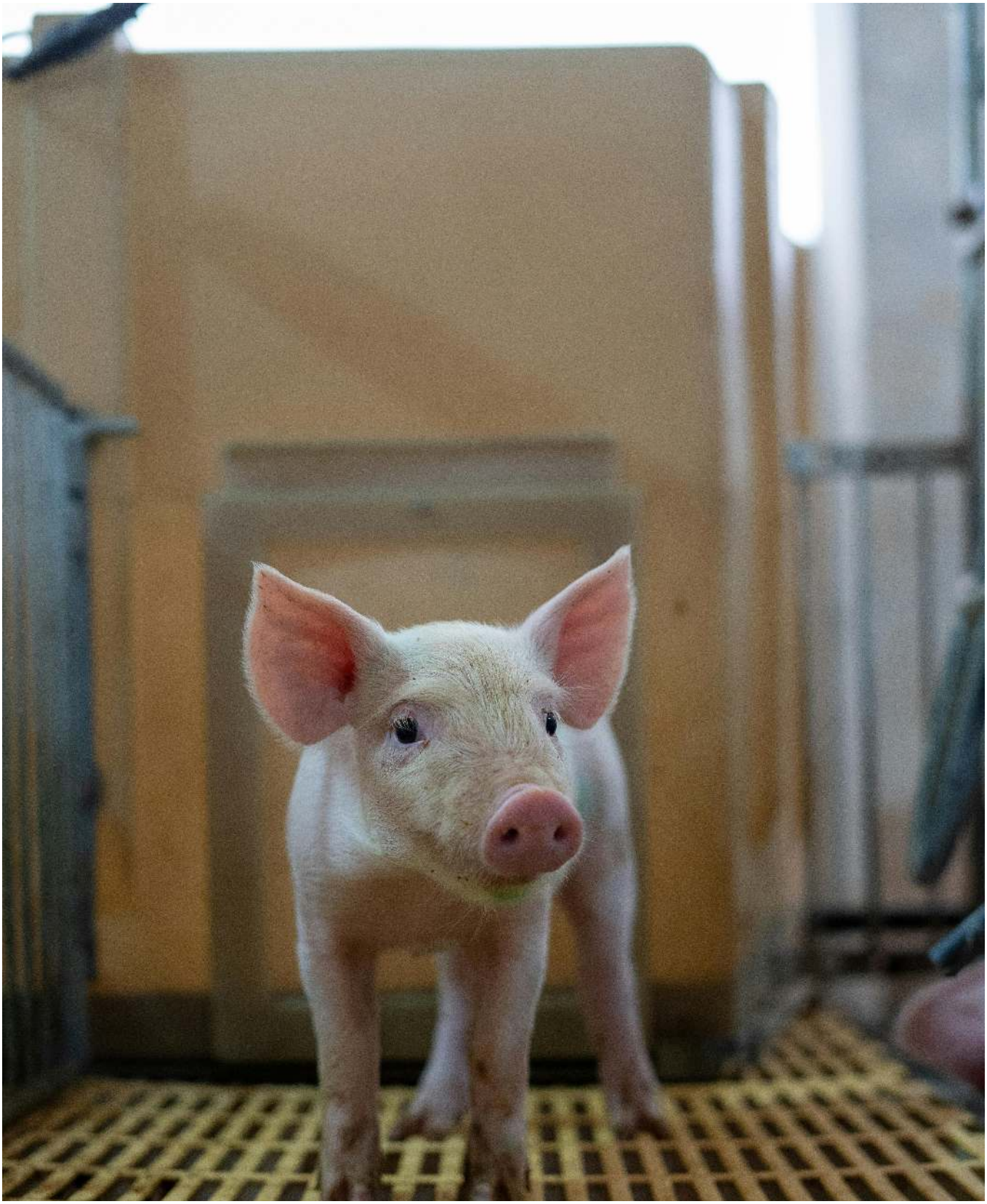
- Monoclonal antibodies for cancer therapy
- Therapeutic antibodies for autoimmune diseases
- Diagnostic antibodies for disease detection

Using organs from genetically engineered animals (primarily pigs) addresses human organ donor shortages. Pigs are modified to:

- Knock out immunoreactive genes (alpha-gal enzyme)
- Knock out porcine endogenous retroviruses (PERVs)
- Express human immune-regulatory proteins (CD46, CD55, CD59)
- Add human coagulation factors to prevent clotting issues

Recent milestones include successful pig heart and kidney transplants into human patients, with increasing survival times. However, challenges remain regarding:

- Immune rejection despite modifications
- Risk of cross-species infections
- Physiological compatibility differences
- Ethical concerns about animal use and genetic modification



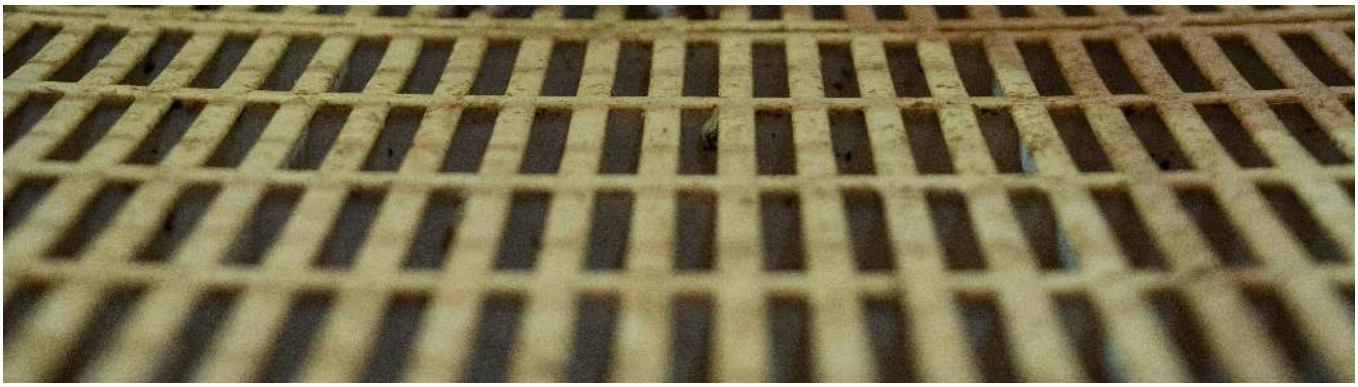


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Animals are engineered to help researchers study and treat human diseases. Genetically modified animals serve as models for:

- Cancer research (oncogene expression, tumor formation)
- Alzheimer's disease (amyloid protein accumulation)
- Cardiovascular diseases (cholesterol metabolism disorders)
- Diabetes (insulin production and signaling defects)
- Cystic fibrosis (CFTR gene mutations)
- Muscular dystrophy (dystrophin gene defects)

These models allow researchers to:

- Understand disease mechanisms
- Test potential treatments
- Develop new therapeutic strategies
- Screen drug candidates before human trials

Transgenic organisms produce **nutraceuticals**—foods with health benefits beyond basic nutrition:

- Omega-3-enriched eggs from hens fed modified grains
- High-antioxidant tomatoes and berries
- Probiotic-producing dairy animals
- Vitamin-enriched crops (Golden Rice with vitamin A)

Genetically modified organisms help manage environmental waste:

- Bacteria engineered to break down oil spills
- Plants that absorb heavy metals from contaminated soil (phytoremediation)
- Microbes that degrade plastics and industrial pollutants
- Enviropigs are producing less phosphorus waste, reducing water pollution

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8.18: Summary and Flashcards

Biotechnology and genetic engineering have revolutionized agriculture, medicine, and research. From creating disease-resistant livestock and producing pharmaceuticals in milk to engineering pig organs for transplant, biotechnology offers transformative possibilities. At the same time, ethical considerations, regulatory oversight, and public dialogue remain essential to guide the responsible use of these technologies.

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CHAPTER OVERVIEW

9: Animal Welfare and Rights

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9.10: Animal Welfare and Rights Study Guide
9.11: Summary and Flashcards

Since the 1980s, few social issues have generated as much emotion and debate as animal welfare and animal rights. This topic affects every sentient animal used by humans — for food, research, companionship, labor, and entertainment. This chapter explores the philosophical, legal, and practical dimensions of how these animals are treated in modern society.

The issue has evolved alongside changes in agriculture, science, and society. Traditional family farming has shifted toward large-scale production systems, often labeled "factory farms," raising public discomfort over animal treatment. Additionally, popular culture and limited contact with livestock have fostered a highly anthropomorphic view of animals — attributing human-like emotions and reasoning to them.



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9.1: Animal Well-Being Frameworks

Animal welfare refers to the physical and psychological well-being of animals as they serve human needs, encompassing proper nutrition, housing, medical care, and freedom from unnecessary suffering. Two primary models are used to define and measure animal welfare.

Developed by the UK's Farm Animal Welfare Council (1965), the Five Freedoms outline the minimum requirements for animal care and serve as the foundation of modern welfare science. This classic framework outlines the minimum standards for animal care:

- **Freedom from hunger and thirst:** Access to fresh water and a diet that maintains health and vigor.
- **Freedom from discomfort:** An appropriate environment, including shelter and a resting area.
- **Freedom from pain, injury, or disease:** Prevention or rapid diagnosis and treatment.
- **Freedom to express normal behavior:** Sufficient space, proper facilities, and the company of the animal's own kind.
- **Freedom from fear and distress:** Conditions that avoid mental suffering.

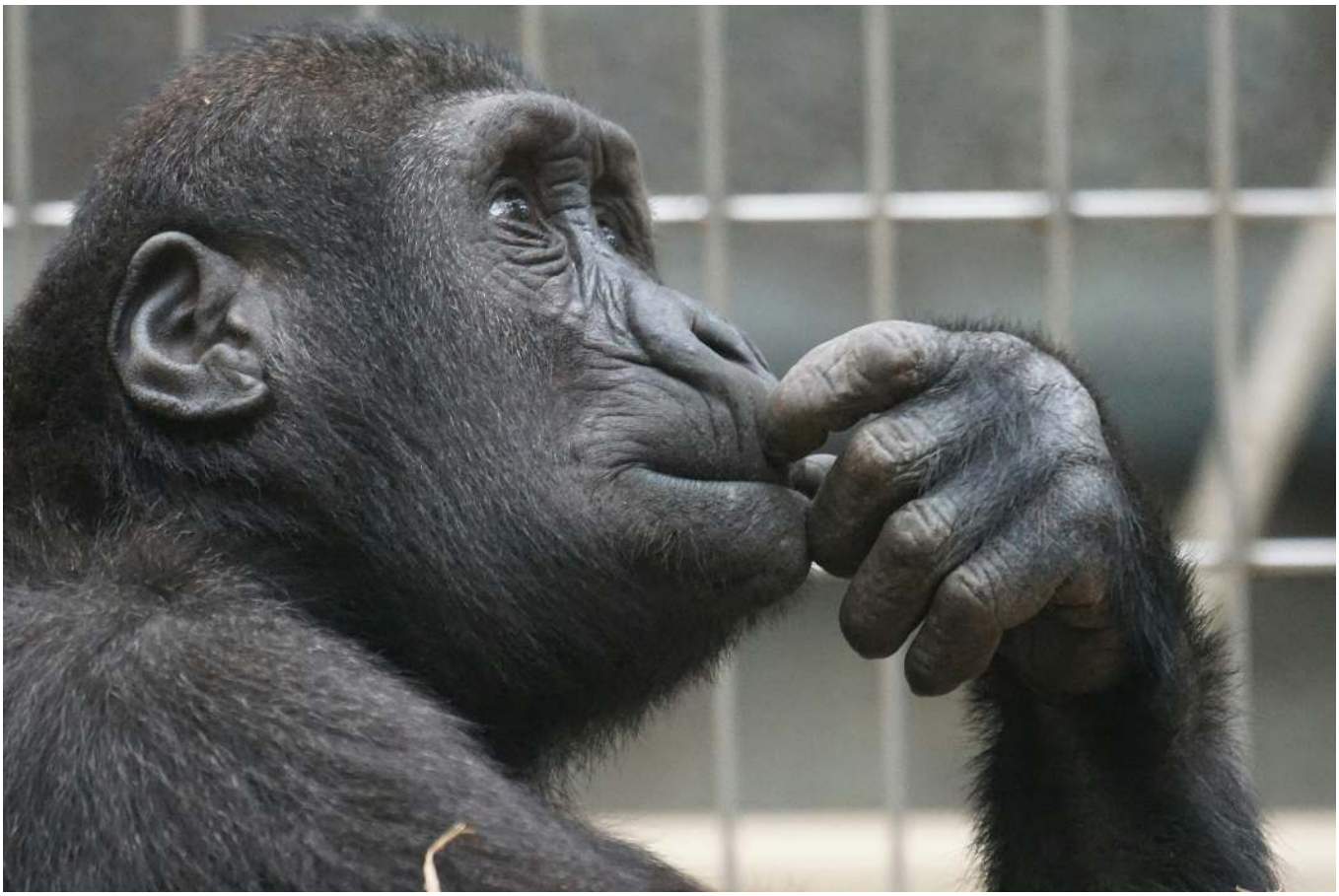


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These principles were later refined by the Five Domains Model, first proposed by Mellor and Reid (1994) and expanded through 2020. This model, developed as a more comprehensive assessment tool, links physical states to mental experiences.

- **Domain 1: Nutrition**: Focuses on water/food intake and quality.
- **Domain 2: Environment**: Considers thermal, physical, and atmospheric challenges.
- **Domain 3: Health**: Accounts for the presence or absence of disease and injury.
- **Domain 4: Behavior**: Ability to interact with the environment, other animals, and humans.
- **Domain 5: Mental State**: The overall welfare state resulting from the first four domains (e.g., thirst, hunger, anxiety, or comfort)

The Five Domains framework emphasizes both reducing suffering and promoting positive experiences, incorporating positive welfare states and human-animal interactions into its assessment.

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9.2: Let's Compare Welfare Activity

Compare Welfare 9.2.1

In this activity, your group will examine two real-world animal care scenarios side by side. The goal is to observe, question, and reflect — thinking critically about the conditions and practices in each setting. As you work through the scenarios, connect your observations to the two foundational frameworks used in animal welfare science: the Five Freedoms and the Five Domains. These frameworks will help you move beyond surface-level observations toward a deeper understanding of what good animal care truly requires.

Your group will be assigned a scenario by your professor from the scenarios used in past Animal Welfare Assessment Contests.

As your group examines each scenario, use the guiding questions below to structure your thinking. For each question, record your observations for both scenarios, noting similarities and differences.

1. How were the animals obtained?
2. Did they receive care there, or were they healthy before they were obtained?
3. Who owns or pays for the animals and their care?
4. Could funding impact animal care and welfare?

1. How is the animal fed?
2. What is the animal fed?
3. How is water provided?
4. How much is the animal fed?
5. How is feeding calculated?

1. How does the climate of where the animal is kept affect the animal's care?
2. Is all the equipment working correctly?
3. Where does the animal originate? Does the provided environment support its natural habitat?
4. Is the animal housed with other species that would have the same environmental requirements?
5. Does the facility have certifications, inspections, or licenses? Are they required?
6. Ideally, how should the animals be housed? What is the ideal enclosure (substrate, ambient temperature, enrichment, ventilation, sleeping areas, eating areas, access to water, etc)
7. Is appropriate housing provided for the animal? How do you know? Could the animals be exposed to parasites or other things that could impact their health?
8. How often is everything cleaned? What is it cleaned with? Is the cleaning sufficient?
9. Do the animals act differently after their enclosure is cleaned?

1. Who is guiding health care decisions? (Should be a DVM).
2. What does pain look like in this species?
3. If an animal is injured, how are they treated? Is there a protocol?
4. Is there a euthanasia plan?
5. If an animal can't perform its duties, what happens?
6. Is the animal given time to heal after an injury?
7. Who or how decides that an animal is healthy again after an illness or injury?
8. Is there a quarantine plan?
9. What happens when an animal is sick?
10. What regular vet care does the animal receive? (deworming, bloodwork, etc.)
11. What is the quarantine period for this species?
12. What should a quarantine space look like?
13. How are the animal's health parameters tracked?
14. Is preventative healthcare provided?
15. Is there a DVM available? On premises? As needed? Only occasionally?
16. What common diseases may this species get?

1. What is normal behavior for the species?

2. Can the animal express normal behavior?
3. What are the animals doing in the scenario? How are they spending their time?
4. What are the adverse behaviors for this species? What do they look like?
5. What is agonistic behavior for this species?
6. What is affiliate behavior for this species?
7. What does stress in this species look like?
8. Compare the ideal behavioral outcomes with what is being described or observed.
9. Is the animal being trained? (Schedule, appropriate behaviors, etc.)

1. Is enrichment provided?
2. How does the animal react when interacting with caretakers?
3. How does the animal react to handling?
4. What causes stress in this animal?
5. Are there other species of animals around that can cause stress in the target animal?

1. Who is taking care of the animals?
2. Do they have training?
3. What is their experience with that type of animal?
4. Is training ongoing?
5. What are the safety protocols for dangerous animals?
6. Are only trained people handling the animals?
7. How are the animals handled? Should they be handled?
8. Is any equipment shared between animals or species?

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9.3: Philosophical Perspectives on Animal Use

Views on the ethical use of animals by humans lie along a broad continuum. At one end are those who reject all forms of animal use, while at the other are those who support traditional and instrumental uses of animals for food, research, labor, clothing, and entertainment. Most individuals and societies fall somewhere between these poles, holding nuanced and sometimes inconsistent positions depending on context, culture, necessity, and evolving moral standards.

Animal rights concern the moral and legal status of animals in relation to human society. Rights-based advocates believe animals have intrinsic value and moral consideration independent of their utility to humans.

Abolitionists argue for the complete elimination of all forms of animal use by humans. This includes the use of animals for food, clothing (e.g., leather, fur, wool), biomedical research, entertainment (e.g., zoos, circuses, racing), and labor.

Core Beliefs:

- Animals possess intrinsic moral value, independent of their usefulness to humans.
- Using animals as a means to human ends is inherently unjust and exploitative.
- Animals should be regarded as rights-bearing individuals, with moral status similar to that of humans (though not necessarily in the same capacities).

Ethical Foundations:
Abolitionism is often grounded in:

- Rights-based ethics (e.g., Tom Regan)
- Deontological principles that reject harm and exploitation as morally impermissible, regardless of benefits

Practical Implications:

- Promotion of veganism and cruelty-free living
- Opposition to animal agriculture, hunting, animal testing, and pet ownership (in some abolitionist views)
- Advocacy for legal personhood or strong legal protections for animals

Reformists accept that humans will continue to use animals but seek to improve the conditions under which animals are bred, housed, transported, and killed, to minimize suffering.

Core Beliefs:

- Animal use is not inherently wrong, but unnecessary suffering is.
- Humans have moral obligations to treat animals humanely.
- Incremental reforms can significantly reduce animal suffering.

Ethical Foundations:

- Utilitarianism (minimizing suffering and maximizing welfare)
- Pragmatism (working within existing social and economic systems)

Examples of Reformist Measures:

- Bans on battery cages and gestation crates
- Humane slaughter regulations
- Enrichment standards for laboratory and zoo animals
- Development and adoption of the “3Rs” in research: Replace, Reduce, Refine

Critiques:

- Abolitionists argue that reform legitimizes exploitation and slows actual moral progress.
- Some reformists counter that abolition is unrealistic and neglects immediate suffering.

For much of Western history, attitudes toward animals have been shaped by Judeo-Christian theology, particularly the concept of human dominion over animals as articulated in the Book of Genesis.

Key Tenets:

- Humans are granted authority or stewardship over animals.
- Animals exist primarily for human use and benefit.

- Humans may use animals for food, labor, clothing, and sacrifice.

Interpretations:

- **Dominion Model:** Humans have a God-given right to use animals as they see fit.
- **Stewardship Model:** Humans have a moral responsibility to care for animals and avoid cruelty.

Historical Impact:

- Justified widespread animal agriculture, hunting, and animal experimentation.
- Influenced legal systems that classify animals as property.





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The anti-use philosophy holds that animals should never be used by humans for any purpose, regardless of potential benefits to humans.

Core Beliefs:

- All animal use is morally wrong.
- There can be no ethical compromise in exploiting sentient beings.
- Moral consistency requires total rejection of animal use.

Relationship to Abolitionism:

- Often overlaps with abolitionism.
- Tends to emphasize moral purity and strict ethical boundaries.

Critiques:

- Considered impractical or extreme by critics.
- Raises difficult questions about pest control, medical emergencies, and ecological management.

Pro-use philosophy accepts animal use as morally permissible and often necessary, but recognizes that standards and practices should evolve as society and science advance.

Core Beliefs:

- Humans are justified in using animals for food, research, and other purposes.
- Ethical obligations increase as animal sentience and cognitive complexity are better understood.
- Social values and scientific evidence should shape animal welfare standards.

Characteristics:

- Flexible and adaptive
- Supports humane treatment but rejects total bans
- Often aligned with reformist approaches.

Examples:

- Ethical meat production
- Regulated animal research
- Sustainable hunting and fishing

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9.4: Comparing Perspectives

The following table summarizes the key differences between Animal Welfare and Animal Rights positions across several contentious areas of animal use.

Issue	Animal Welfare Position (Pro-Use/Reformist)	Animal Rights Position (Anti-Use/Abolitionist)
General Philosophy	Animals can be used by humans if they are treated humanely and provided "good husbandry".	Animals have an inherent right to live free from human interference and should not be used for any human purpose.
Livestock & "Factory Farming"	Focuses on improving confinement conditions, nutrition, and health to maximize well-being and productivity.	Advocates for the total abandonment of animal agriculture and the adoption of veganism.
Biomedical Research	Supports research if it benefits humans/animals and follows the 3 Rs: Replacement, Reduction, and Refinement.	Generally opposes all medical research on animals, viewing it as a violation of their autonomy and right to life.
Hunting & Trapping	Accepts regulated hunting as a tool for wildlife management and food, provided it minimizes pain and suffering.	Opposes hunting and trapping as "entertainment" or exploitation, often calling for it to be banned on public lands.
Cloning	Investigate how to improve the health outcomes for clones and surrogate mothers to ensure survival.	Views cloning as an unethical extension of human desire that causes inherent suffering and "birth failures."
Entertainment (Rodeo, Circus)	Promotes high standards of care and safety for performing animals to prevent injury.	Views these activities as "exploitation" and believes animals should not be forced to perform for others.

- **Welfare** is often scientific and pragmatic, seeking to measure and improve the quality of an animal's life while it is under human control.
- **Rights** are philosophical and absolute, arguing that the use of animals is inherently wrong regardless of how "humanely" they are treated.



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9.5: Influential Figures in Animal Ethics

Key Contribution (1789): In An Introduction to the Principles of Morals and Legislation, Bentham famously argued:

"The question is not, Can they reason? Nor can they talk? But can they suffer?"

Significance:

- Shifted moral consideration from intelligence or language to the capacity for suffering.
- Laid the foundation for modern animal welfare ethics.
- Supported legal protections for animals based on sentience.

Key Contribution (1983): In *The Case for Animal Rights*, Regan developed a rights-based framework for animal ethics.

Core Ideas:

- Animals are "subjects of a life" with inherent value.
- Animals possess moral rights not to be harmed or used merely as means.

Impact:

- Provided a philosophical foundation for abolitionism.
- Strongly influenced legal and ethical debates on animal rights.

Peter Singer (b. 1946)

Key Contribution (1975): In Animal Liberation, Singer extended utilitarian ethics to animals.

Core Ideas:

- The principle of equal consideration of interests
- Speciesism as a form of unjust discrimination
- Moral obligation to minimize suffering regardless of species

Impact:

- Sparked the modern animal rights movement.
- Popularized veganism and animal advocacy.

The ethics of animal use spans a broad spectrum, from absolute rejection of all animal use to conditional acceptance grounded in tradition, utility, and evolving welfare standards. Influential philosophers such as Bentham, Singer, and Regan have profoundly shaped modern debates by reframing how humans morally perceive animals, shifting the conversation from dominion and utility toward suffering, interests, and rights.



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9.6: The Three Rs and Animal Research

Modern ethical frameworks for animal research are built around three foundational principles known as the **"**3 Rs**"**: Replacement, Reduction, and Refinement. First proposed by William Russell and Rex Burch in *The Principles of Humane Experimental Technique* (1959), these principles aim to balance scientific progress with moral responsibility toward animals. They are now embedded in research regulations, institutional review processes, and international guidelines governing the use of animals in science.

Replacement refers to methods that avoid or substitute the use of live animals in research. When animal use cannot be eliminated, it also includes replacing higher-order, more sentient animals (e.g., primates, dogs) with lower-order species (e.g., fish, insects) or non-sentient biological systems.

Types of Replacement:

- *Absolute Replacement: No animals are used at all.*
  Examples:
  - Computer modeling and simulations
  - Artificial intelligence–based drug screening
  - Organ-on-a-chip technologies
  - Human cell and tissue cultures
- *Relative Replacement: Animals are still used, but species thought to have lower sentience or capacity for suffering are substituted.*
  Examples:
  - Using fruit flies (Drosophila) instead of mammals
  - Using zebrafish embryos in early-stage toxicity testing

Rationale:

- Avoids ethical concerns associated with animal suffering
- Often reduces cost and time
- Can provide more human-relevant biological data

Limitations:

- Many biological systems (e.g., immune response, whole-organism behavior) cannot yet be fully replicated
- Regulatory agencies still require animal data for safety and efficacy in many cases
- Technological and regulatory barriers slow the adoption of replacement alternatives

Reduction means using the fewest animals necessary to obtain scientifically valid and reproducible results, without compromising the integrity or reliability of the research.

Key Strategies:

- Improved experimental design and statistical planning
- Power analysis to determine the appropriate sample size
- Sharing data and biological samples across studies
- Longitudinal studies using the same animals over time
- Advanced imaging techniques that allow repeated measurements in the same subject

Rationale:

- Minimizes the total number of animals used
- Increases research efficiency
- Reduces financial and logistical burdens

Ethical Tension:

- Using too few animals can invalidate results, potentially leading to repeated experiments and *more* animal use overall
- Reduction must be balanced with scientific rigor

Refinement involves modifying experimental procedures and animal care practices to minimize pain, suffering, distress, and lasting harm, and to improve overall animal welfare.

Examples of Refinement:

- Use of anesthesia, analgesia, and sedation
- Non-invasive or minimally invasive techniques
- Improved housing and environmental enrichment
- Training animals to cooperate with procedures (e.g., voluntary blood draws)
- Early humane endpoints to prevent unnecessary suffering

Rationale:

- Recognizes animals as sentient beings capable of suffering
- Improves both ethical standards and data quality (since stress can confound results)

Ethical Tension:

- Critics claim that refinement may legitimize harmful practices by making them appear humane
- Abolitionists argue that the 3 Rs merely regulate exploitation rather than ending it



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Institutional Oversight:

- Institutional Animal Care and Use Committees (IACUCs)
- Ethical review boards and regulatory agencies

Legal and Policy Frameworks:

- U.S. Animal Welfare Act
- EU Directive 2010/63/EU
- International Council for Laboratory Animal Science (ICLAS) guidelines

Researcher Responsibilities:

- Justify animal use
- Demonstrate that alternatives have been considered
- Apply the 3 Rs at every stage of study design and execution

Replacement, Reduction, and Refinement form the ethical backbone of modern animal research. Together, they promote the development of alternatives, minimize the number of animals used, and reduce suffering when animal use is unavoidable. While they do not resolve all ethical concerns about animal experimentation, they represent a widely accepted compromise between scientific necessity and moral responsibility.

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9.7: IACUC in Practice – The 3 Rs Challenge

The 3 Rs Challenge 9.7.1

This activity is designed to apply your knowledge of animal ethics by acting as members of an Institutional Animal Care and Use Committee (IACUC). Divide into two groups, and assign each group a scenario below.

Your Task: As members of the IACUC, your group must determine if this research should be approved, modified, or rejected based on the 3 Rs of animal research.

Scenarios

1. Project Neon-Heart

A team of researchers has submitted a proposal to test a new synthetic heart valve. They plan to use 60 adult sheep over two years. The sheep will undergo invasive surgery to implant the valve, followed by monthly blood draws and a final procedure where the animals are euthanized to examine the heart tissue.

Part 1: Analyze and Identify Concerns

- ***Identify:*** the Interests in this scenario.
- ***Determine Welfare Risks:*** Using the Five Domains Model, identify which domains are most at risk during the "Project Neon-Heart."
- ***Check Legislation***: Identify which US law would most likely apply to the oversight of these sheep in a research facility.

Part 2: Evaluate the Protocol

- ***Justify the Means****:* Animal research has added 25–30 years to the American lifespan. Does the potential for a life-saving heart valve justify the use of 60 sheep?
- ***Critique the "3 Rs" Implementation****:*
  - ***Replacement****:* Could the researchers use something instead of live animals?
  - ***Reduction****:* Is 60 sheep a statistically necessary number, or could they achieve results with 30?
  - ***Refinement****:* What can be done to minimize the sheep's pain?

Part 3: Create a Modified Protocol

Draft a Conditional Approval: Write a 3-paragraph response to the researchers. You must propose at least two specific refinements to the surgical recovery process to ensure the sheep's psychological and physical well-being.

- ***Develop a Welfare Plan****:* Create a monitoring checklist for the lab technicians that incorporates the Five Freedoms, specifically detailing how they will ensure the sheep can express normal behavior while in a research environment.
- ***Alternative Methods****:* Propose one "Replacement" technology that the researchers must investigate before they are allowed to move to a second year of animal testing.
- ***Justify the Means****:* Animal research has added 25–30 years to the American lifespan. Does the potential for a life-saving heart valve justify the use of 60 sheep?

2. Project Dolly's Legacy

A commercial livestock company wants to produce ten clones of a champion dairy cow known for record-breaking milk production. They claim this will improve agricultural efficiency and food security.

Part 1: Analyze and Identify Concerns

- ***Identify*** the interests in this scenario.
- ***Determine Welfare Risks:*** Using the Five Domains Model, identify which domains are most at risk during "Project Dolly's Legacy."
- ***Check Legislation***: Identify which US law would most likely apply to the oversight of these cows in a research facility.

Part 2: Evaluate the Protocol

- ***Justify the Means**:* The demand for milk, cheese, butter, and yogurt continues to increase. Does the pursuit of efficiency and productivity justify the high rate of birth failures and the shortened lifespans often observed in cloned animals?
- ***Critique the "3 Rs" Implementation***:
  - ***Replacement**:* Could the researchers use something other than cloned animals to improve agricultural efficiency and food security
  - ***Reduction**:* How could researchers limit abnormal growth in the womb and high mortality rates seen in cloned animals?
  - ***Refinement**:* What can be done to improve cloning outcomes?

Part 3: Create a Modified Protocol

Draft an Informed Consent document: Write a 3-paragraph response to the farm's investors that details the welfare costs and proposes a limit on the number of attempts allowed per surrogate mother to prevent any negative impacts.

- ***Develop a Welfare Plan**:* Create a monitoring checklist for the researchers that incorporates the Five Freedoms, specifically detailing how they will ensure the cows can "express normal behavior" while in a research environment.
- ***Alternative Methods:*** Propose one "Replacement" technology that the researchers must investigate before cloning can move forward.

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9.8: Significant U.S. Legislation on Animal Welfare and Rights

In the United States, animal welfare is governed by a patchwork of federal laws that regulate how animals may be used, treated, transported, and protected. Rather than recognizing animals as rights-bearing persons, these statutes generally treat animals as property while imposing minimum standards of humane treatment. Together, these laws reflect a reformist, welfare-based approach to animal ethics.

The Federal Humane Slaughter Act requires that livestock be rendered insensible to pain before being slaughtered for food, to minimize suffering during the killing process.

- Animals must be stunned (e.g., captive bolt, gunshot, electrical stunning) before being shackled, hoisted, or cut.
- Slaughter methods must result in rapid unconsciousness.
- Religious slaughter (e.g., kosher and halal) is exempted.

- Applies to livestock slaughtered in federally inspected facilities.
- Covers cattle, pigs, sheep, goats, horses, and mules.
- **Does not cover:** poultry (chickens, turkeys), fish, or animals killed outside federally inspected plants.

- First major U.S. law to mandate humane treatment at the point of slaughter.
- Reinforced the idea that unnecessary suffering, even in food production, is morally unacceptable.

The Animal Welfare Act is the primary federal law regulating the treatment of animals used in research, exhibition, commercial breeding, transport, and by animal dealers.

- Establishes minimum standards for housing, feeding, sanitation, ventilation, veterinary care, and handling.
- Requires licensing and registration of animal dealers, breeders, exhibitors, and research facilities.
- Mandates recordkeeping and USDA inspections.

- Requires institutions to establish Institutional Animal Care and Use Committees (IACUCs).
- Requires review and approval of research protocols.
- Encourages the use of alternatives to animal use.

- Covers warm-blooded animals used in research, exhibition, and commerce.

- Rats, mice, and birds bred for research (which make up over 90% of research animals)
- Farm animals used for food and fiber

- Cornerstone of U.S. animal welfare law.
- Criticized for narrow scope and weak enforcement.



"Court Gavel - Judge's Gavel - Courtroom" by weiss_paarz_photos is licensed under CC BY-SA 2.0, https://www.weisspaarz.com/

The Horse Protection Act was enacted to end the abusive practice of "soring," in which chemicals, pressure devices, or physical abuse are used to cause pain in horses' legs and hooves to exaggerate their gait in show competitions.

- Prohibits the showing, exhibition, sale, or transport of sored horses.
- Authorizes inspections at horse shows, auctions, and exhibitions.
- Establishes penalties for trainers, owners, and exhibitors who violate the law.
- Recognized intentional infliction of pain for entertainment as unacceptable.
- Highlighted federal concern for cruelty beyond agricultural and research settings.

The Marine Mammal Protection Act provides comprehensive federal protection for marine mammals, including whales, dolphins, porpoises, seals, sea lions, walruses, and manatees.

- Prohibits the "take" (harassment, hunting, capture, or killing) of marine mammals in U.S. waters.
- Bans the import and export of marine mammals and their products.
- Establishes a permit system for scientific research, public display, and incidental take.
- Requires conservation and recovery plans for depleted species.
- One of the strongest wildlife protection laws in the world.
- Reflected growing public concern for intelligent, socially complex species.

Originally passed as the **Animal Facilities Protection Act (AFPA)** in 1992, this law was later expanded and renamed the **Animal Enterprise Terrorism Act (AETA)** in 2006.

The Act protects animal production, research, and testing facilities from vandalism, theft, and harassment by extremist animal rights activists.

- Criminalizes damage to or interference with animal enterprises.
- Enhances penalties for threats, harassment, or intimidation of employees.
- Allows federal prosecution of offenders.
- Reflected political backlash against radical animal rights activism.

- Criticized for chilling free speech and protest.
- Illustrates legal prioritization of animal industries over animal rights.

U.S. animal welfare laws reflect a compromise between ethical concern for animals and economic, scientific, and cultural interests in using them. The Humane Slaughter Act and Animal Welfare Act seek to reduce suffering without banning animal use. The Horse Protection Act and Marine Mammal Protection Act address particularly egregious or high-profile abuses. The Animal Facilities Protection Act (now AETA) underscores how strongly U.S. law protects animal industries from disruption, even as debates about animal rights continue to evolve.

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9.9: Current Challenges and Controversies

Several modern issues continue to shift public perception and generate significant conflict around the treatment of animals. One of the most prominent is the rise of factory farming, in which animals are raised in large-scale confinement systems designed to maximize efficiency and output. Practices such as housing hens in battery cages or confining cattle in feedlots have drawn sharp criticism from those who view these methods as a stark and troubling departure from the more humane standards of traditional farming. For many, these systems represent not just a practical concern, but a moral one — raising fundamental questions about what society owes to the animals it raises for food.

Advances in biotechnology have introduced additional ethical dilemmas, particularly in the area of animal cloning. While cloning has potential scientific and agricultural applications, it raises serious welfare concerns. Cloned animals frequently suffer from significant health complications, and the process itself carries alarmingly high mortality rates among the surrogate mothers used to carry cloned embryos to term. These outcomes have prompted many scientists, ethicists, and advocacy groups to call for greater scrutiny of cloning practices and their regulation.



Image credit: Brett Sayles from Pexels: https://www.pexels.com/photo/close-up-shot-of-a-black-piglet-4751420/

Underlying much of this debate is a broader shift in how the general public perceives and relates to animals. As urbanization has accelerated, fewer people have direct experience with farming or rural life, making it increasingly difficult for many to understand or contextualize modern agricultural practices. At the same time, popular culture — particularly the anthropomorphic portrayal of animals in films and media produced by companies like Disney — has shaped the way generations of people emotionally connect with animals, often attributing human feelings, personalities, and moral status to them. These cultural influences have played a meaningful role in driving changing attitudes and heightening sensitivity to animal welfare issues.

In response to the growing need for credible information on these complex topics, resource centers like the Animal Welfare Information Center (AWIC) have become increasingly valuable. Operating as part of the National Agricultural Library, AWIC serves as a key hub for research, education, and policy guidance on animal welfare, helping stakeholders across government, academia, and the public navigate an ever-evolving, often contentious landscape.

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9.10: Animal Welfare and Rights Study Guide

1. Why should we be concerned about animal welfare and animal rights?

2. Compare and contrast animal welfare issues and animal rights issues. In your opinion, are animal rights and animal welfare different issues or the same issues?

3. What are the major pieces of legislation that have been passed in the US regarding animal welfare and animal rights?

4. Describe the major philosophical differences in animal welfare and animal rights.

5. Detail the “Five Freedoms” of animal well-being.

6. What is the difference between a reformist and an abolitionist?

7. In the Western world pro-animal use is based on _____ _____ philosophy.

8. What are the three R’s of animal research?

9. What is anthropomorphism? How does anthropomorphism relate to animal welfare and animal rights?

10. What is the AWIC? What types of information does it provide?

11. Do you think attitudes about animal use have changed in the past few years? Why or why not?

12. What are some problems determining practices that promote livestock welfare?

13. Why is philosopher Jeremy Bentham (1789) credited with originating the animal rights movement? (Use your researching skills to tackle this question.)

15. What US law applies to animal fighting?

16. How does cloning relate to animal welfare and animal rights?

17. Do you think a predatory animal species should have rights?

19. It’s estimated that animal research has added 25 to 30 years to the average American lifespan since 1900. Do you think the end has justified the means?

20. What is speciesism and how does it relate to animal welfare and/or animal rights?

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9.11: Summary and Flashcards

The debate surrounding animal welfare and animal rights is one of the most emotionally charged social issues in modern history, affecting sentient animals used for purposes ranging from food production to biomedical research. While often used interchangeably, these two concepts represent distinct philosophical foundations: animal welfare focuses on the humane treatment and well-being of animals while they provide for human needs, whereas animal rights focuses on the legal and philosophical standing of animals in relation to human society.

Flashcards for Animal Welfare and Rights (opens in a new window)

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CHAPTER OVERVIEW

10: Animal Behavior, Handling, and Health

10.1: Introduction
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10.4: Dr. Temple Grandin
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10.1: Introduction

The fields of animal behavior and health are deeply interconnected, forming the foundation of modern animal science. Understanding an animal's instincts and physiological responses is essential for both humane treatment and productive management. Since the mid-20th century, the shift toward intensive production systems and a heightened focus on animal welfare have transformed ethology—the study of animal behavior—into a critical tool. Aligning handling practices and health protocols with the biological realities of livestock can reduce stress, enhance immunity, and ensure the safety of animals and humans alike.



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10.2: Foundations of Animal Behavior

A working understanding of behavior is valuable across multiple dimensions of animal science—it improves animal welfare by ensuring conditions that meet natural needs, enhances handler safety by reducing unpredictable responses, and increases productivity and efficiency by aligning management practices with how animals naturally function. Because behavior is shaped by both genetics and lived experience, it is simultaneously predictable enough to plan around and adaptable enough to be influenced by thoughtful management. Behavioral study, or ethology, provides the tools to manage these stressors by exploring how animals communicate and learn within their environments.

Ethograms, which are inventories of all behaviors a species exhibits naturally, help identify "clinical signs"—observable differences in function, such as abnormal sleep or activity levels —that indicate a disease state.

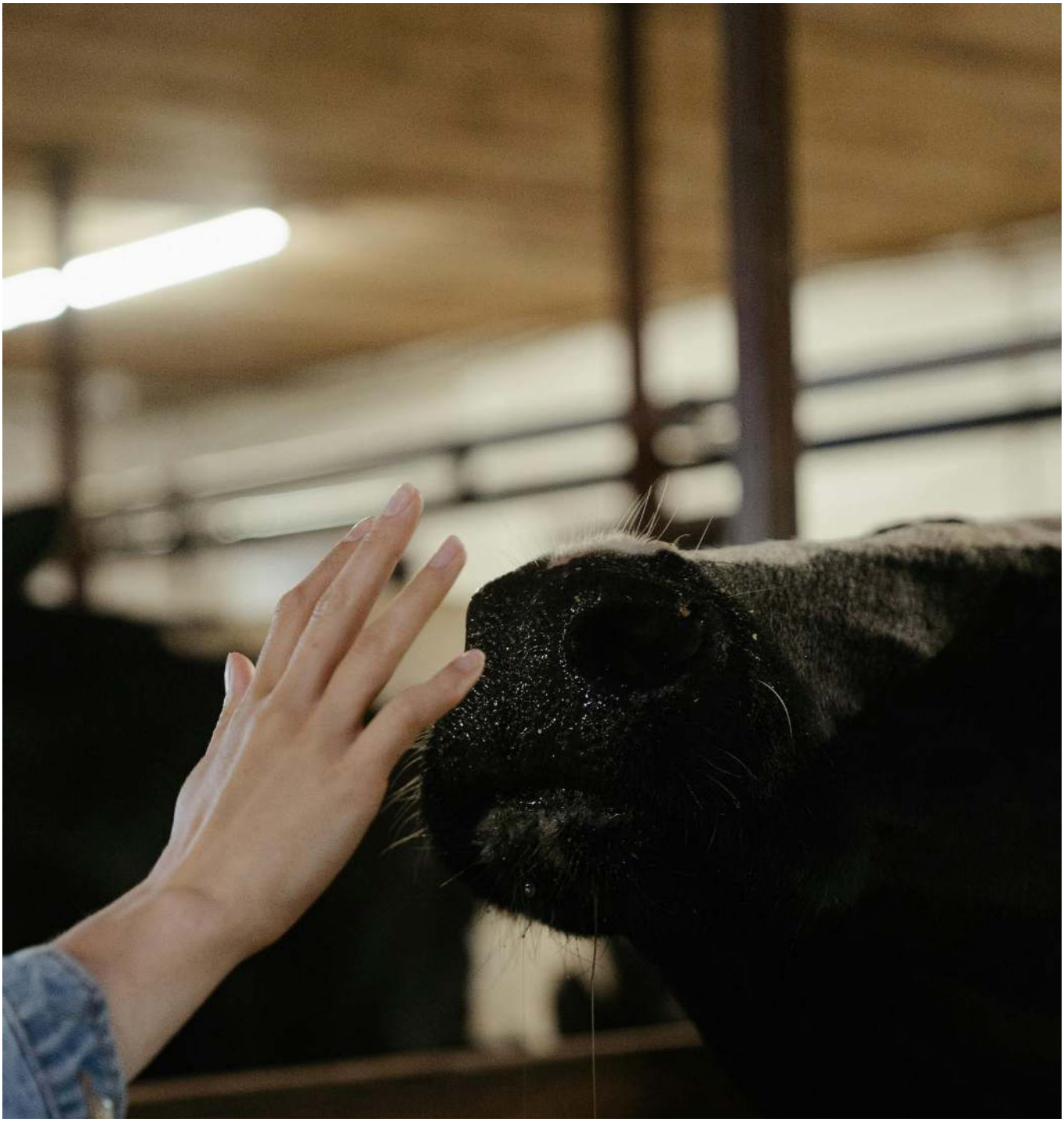




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Areas of Behavioral Study

Animal behavior encompasses several interconnected domains, each with practical implications for livestock producers.

1. ***Communication:*** Animals exchange visual, auditory, and olfactory signals; understanding these is vital for effective management and underlies all social interactions within a herd or flock.
2. ***Social structure and aggression:*** Dominance hierarchies dictate how animals interact and how animals are grouped and introduced to one another; problems often arise when humans or other animals vie for status.
3. ***Biological rhythms:*** Circadian (24-hour) cycles influence activity and physiological responses and are governed by factors like light and the endocrine system. Both daily and seasonal cycles affect feeding, reproduction, and activity patterns that producers must account for in scheduling and husbandry.
4. ***Maternal behavior:*** Includes bonding and offspring care, both of which are critical to neonatal survival and overall herd productivity.
5. ***Learning:*** Animals are most receptive to training during "sensitive periods." Through habituation, animals can be trained to ignore neutral stimuli, whereas operant conditioning uses rewards to encourage cooperative behaviors such as accepting restraint. Learning shapes how animals respond to handling and new environments.
6. ***Ingestive behavior:*** Governs feeding and drinking patterns, informing decisions about feed delivery and water access.
7. ***Behavioral disorders:*** Abnormal or harmful behaviors that often arise from stress or poor conditions and serve as important indicators that something in the management system needs correction.

Together, these domains give producers the knowledge needed to design more effective and humane livestock management systems.

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10.3: Behavior and Livestock Handling

Effective handling relies on understanding an animal's temperament—a trait determined by a combination of genetics and previous experiences. Fearfulness is a major component of temperament; once an animal experiences a frightening stimulus, "fear memories" form a subcortical circuit in the brain, allowing it to react instantly to similar threats in the future. To mitigate this, handlers utilize the "flight zone," or the animal's personal safety zone. Entering the flight zone prompts the animal to move away, while standing at the "point of balance"—usually the shoulder—can direct it forward or backward.

Facility design should complement these instincts. For example, curved chutes are highly effective because they prevent animals from seeing what lies ahead and capitalize on their natural tendency to circle a handler. Additionally, because livestock have wide-angle vision (exceeding 300°), solid fences are recommended to eliminate visual distractions that might cause them to balk. Managing noise and illumination is equally vital, as unexpected sounds or harsh shadows act as significant stressors.

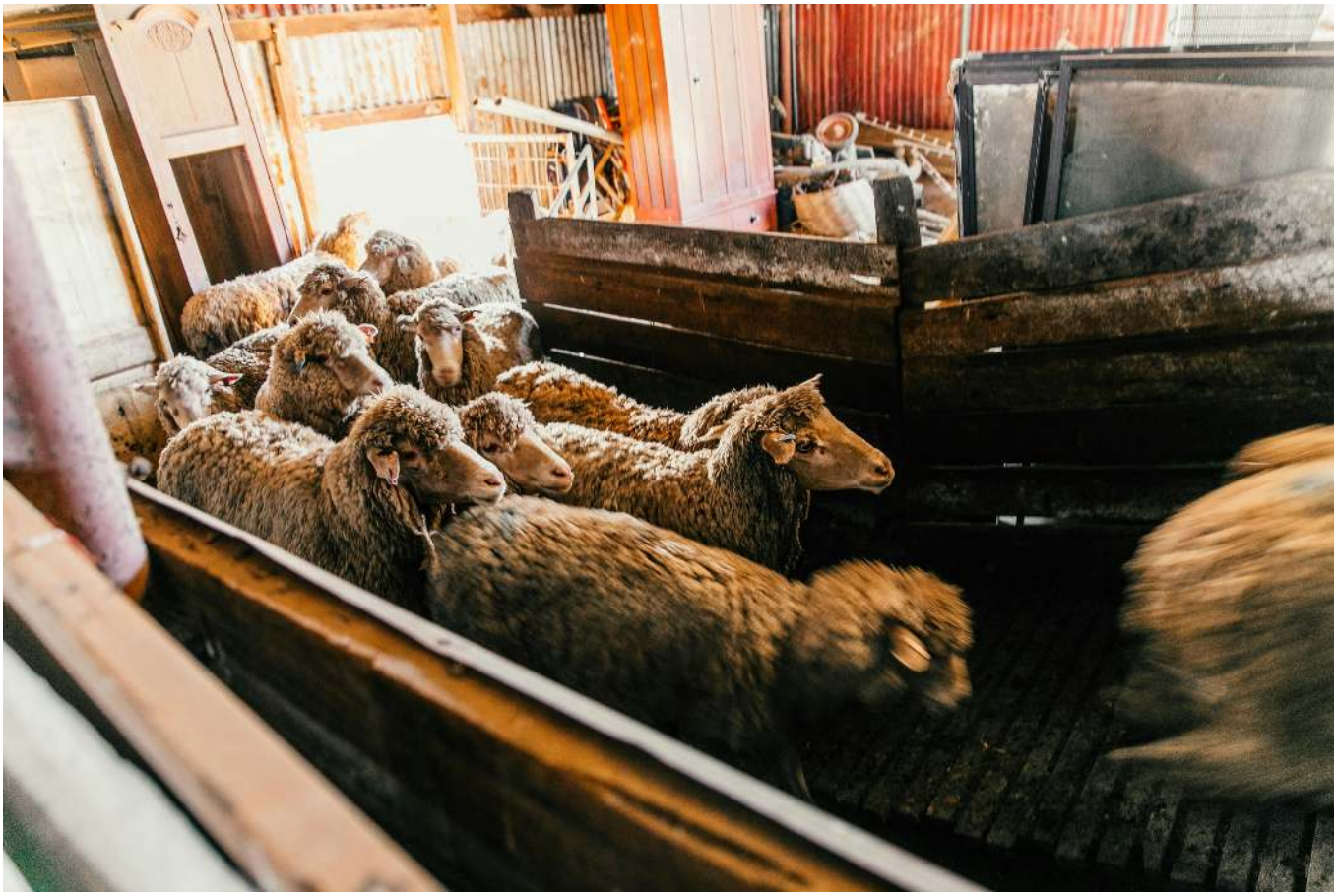


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Designing for Behavior

Facilities designed with behavioral principles reduce stress and injury:

- ***Curved Chutes:*** These take advantage of an animal's natural tendency to circle and prevent them from seeing the squeeze chute or truck until they are nearly there.
- ***Solid Fences:*** Recommended for chutes and crowd pens to block out visual distractions and "novelty," which is a strong stressor for flighty animals.
- ***Flooring:*** Ramps should not exceed 20° (15° for pigs) and should include stair steps to provide secure footing.

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10.4: Dr. Temple Grandin

Dr. Temple Grandin is a renowned animal scientist, educator, and advocate whose work has profoundly shaped modern approaches to animal welfare in livestock production. A professor of animal science at Colorado State University, she is internationally recognized for bridging scientific research with practical, humane solutions for managing farm animals. Drawing on her deep understanding of animal behavior—shaped in part by her lived experience as a person on the autism spectrum—Dr. Grandin has helped producers better understand how livestock perceive and respond to their environments.

Her pioneering research and designs in livestock handling systems have transformed how animals are moved, restrained, and processed in facilities worldwide. By emphasizing low-stress handling, clear lines of sight, and facility layouts that align with animals' instincts, Dr. Grandin's curved chutes, solid-sided alleys, and calm-handling principles have been widely adopted across the cattle, pork, and poultry industries. Her work has improved both animal welfare and worker safety while enhancing operational efficiency, making her a central figure in advancing humane, science-based livestock facility design.

> As you watch, pay attention to how scientific understanding, empathy, and innovative thinking intersect to improve animal welfare while balancing human needs in agriculture.



? Critical Viewing Questions 10.4.1

After watching the video, answer the following questions and upload them to the assignment drop in Brightspace.

1. What is Dr. Grandin's way of thinking? How has this helped her understand livestock?
2. What is Dr. Grandin's concerned with when it comes to breeding livestock?
3. Why don't verbal or word commands work for most livestock?

Video Resource: American Humane Society. December 15, 2025, *Revolutionizing Animal Welfare with Temple Grandin*, [Video], YouTube, https://www.youtube.com/watch?v=yeAOP91DmNI

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10.5: Behavior, Stress, and Animal Health

Behavior and health are closely linked through the body's stress response. When animals experience stress, susceptibility to disease increases as the immune system is compromised. Elevated cortisol levels—the primary hormonal marker of stress—signal that the body is diverting resources away from growth, reproduction, and immune function. Poor handling practices in particular can have measurable consequences, suppressing productivity and leaving animals more vulnerable to illness.

Sources of Stress

Stress in livestock can arise from a variety of environmental and management-related factors. Novel environments trigger fear responses that can be difficult to manage if animals have not been gradually acclimated. Loud or sudden noises heighten arousal and anxiety. At the same time, poor facility design—such as inadequate space, poor ventilation, or confusing handling layouts—creates chronic low-level stress that compounds over time. Rough or aggressive handling undermines trust between animals and handlers, making future interactions more dangerous and stressful for both. Social isolation is equally disruptive, as most livestock species are highly social and experience significant distress when separated from their group.

Given the breadth of consequences that stress carries for health, welfare, and productivity, reducing it has become a central goal of modern animal production.



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10.6: Understanding Animal Disease

Maintaining animal health is a fundamental responsibility in animal science, as it directly affects productivity, welfare, and human well-being. Disease is broadly defined as any condition in which normal body function is disrupted. It is typically caused by a combination of predisposing "stress" factors—such as poor nutrition or extreme weather—and direct causes, such as bacteria, viruses, or fungi. Diseases may be clinical, with observable signs such as fever or weight loss, or subclinical, with no outward symptoms. Acute conditions have a sudden onset and short duration, while chronic diseases persist for weeks or months.

Disease typically results from a combination of predisposing factors and direct causes. Predisposing factors—often referred to as stressors—weaken an animal's defenses and include nutritional deficiencies, genetic weaknesses, environmental stress such as extreme weather, poor housing, or overcrowding, and inadequate management practices. Direct causes fall into two categories: infectious agents, such as bacteria, viruses, fungi, protozoa, parasites, and prions, and noninfectious causes, such as toxins, injuries, genetic disorders, and nutrient imbalances. This interaction explains why animals already under stress are far more susceptible to disease outbreaks.

For an infectious disease to take hold, a pathogen must successfully enter a host, survive and multiply within it, exit the host, and transmit to a new one. Contagious diseases spread readily from animal to animal through direct contact, while vector-borne diseases rely on intermediate organisms—such as ticks or mosquitoes—to carry the pathogen between hosts.

Disease is also classified by its progression and visibility. Acute diseases develop rapidly and resolve quickly, whereas chronic diseases emerge slowly and persist over time. Clinical disease presents with visible, observable symptoms, while subclinical disease causes harm without producing obvious outward signs—making it particularly difficult to detect and manage.

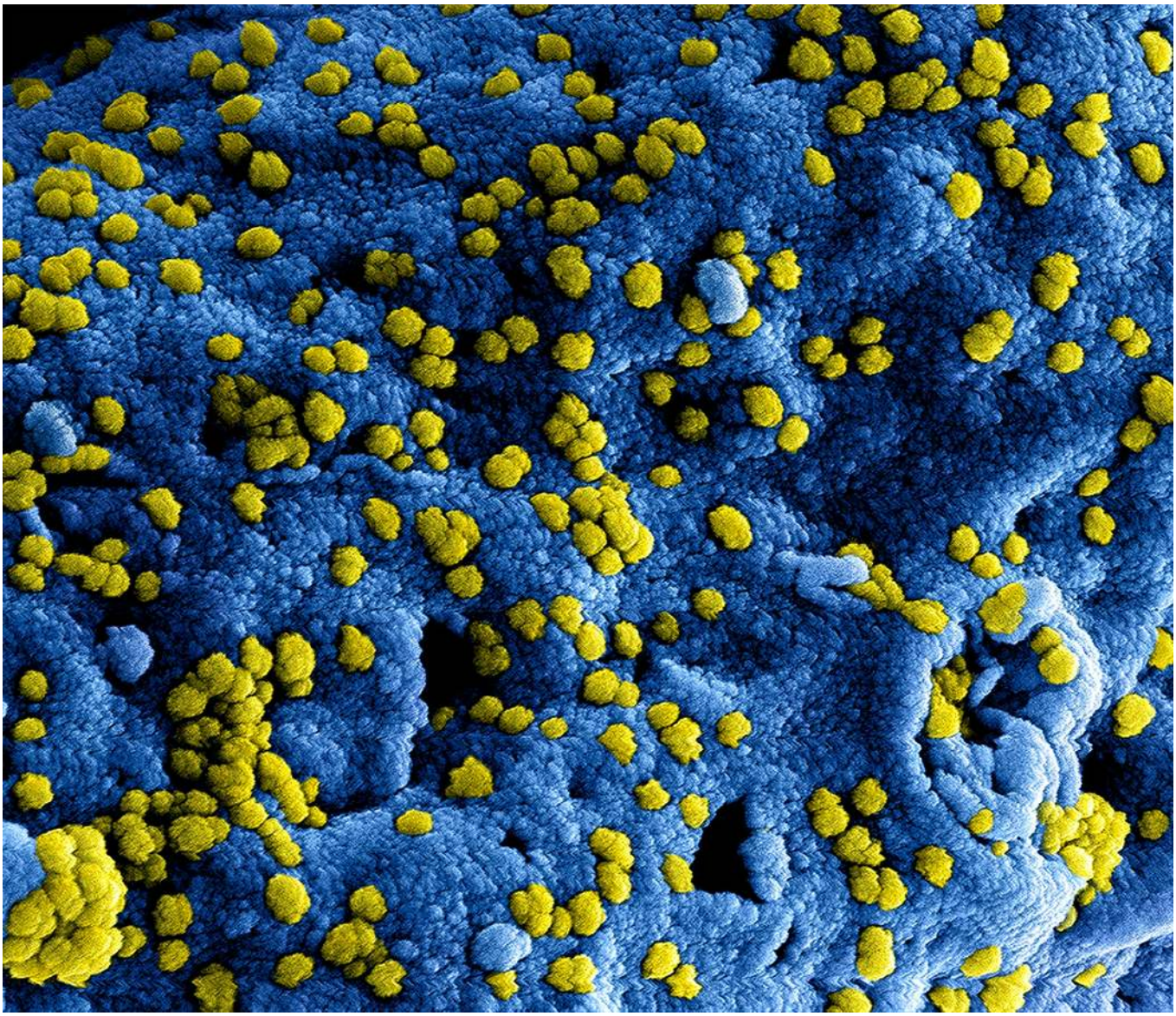


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10.7: Disease Diagnosis and Prevention

Diagnosis is the process of identifying a disease and its underlying cause. It typically begins with a review of the animal's history and herd records, followed by a physical examination that assesses temperature, respiration, and visible signs of illness. When necessary, veterinarians may also perform palpation and internal examination, collect laboratory samples such as blood, feces, urine, or tissue, and, in the case of death, conduct a necropsy to determine cause. Early and accurate diagnosis is especially critical in herd settings, where a single case can quickly escalate into a widespread outbreak if left unaddressed.

An animal’s resistance to disease is maintained by its immune system. The innate immune system provides the first line of defense through surface barriers such as the skin and mucous membranes. The adaptive immune system provides long-term, specific protection by producing antibodies. Immunity can be active, developed by the animal's own system (often via vaccination), or passive, such as when a mother transfers antibodies to her offspring through colostrum.

Animals rely on two major defense systems to combat disease. Innate immunity, the body's nonspecific first line of defense, includes physical barriers such as skin and mucous membranes, as well as the inflammatory response that acts rapidly to contain threats. When innate defenses are insufficient, the adaptive immune system responds by producing targeted antibodies and establishing long-term protection against specific pathogens.

Immunity itself can be acquired in two ways. Passive immunity is transferred from mother to offspring—most notably through colostrum, the antibody-rich first milk—providing immediate but temporary protection. Active immunity, by contrast, develops when an animal is exposed to a pathogen or receives a vaccination, prompting the immune system to build its own lasting defenses.



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10.8: Herd Health Management

Effective herd health programs integrate multiple factors to maintain productivity and prevent disease. Management serves as the foundation, coordinating all health-related practices across the operation. Nutrition plays an equally important role, as balanced diets help prevent deficiencies that can compromise immune function and overall health. Genetic selection helps eliminate hereditary disorders from the herd over time, while prevention strategies—including vaccinations, parasite control, and biosecurity protocols—form the final critical layer of protection.

Sound day-to-day management practices are essential to keeping a herd healthy. Detailed health records should be maintained to track individual and herd-level trends, and new or sick animals should be isolated promptly to prevent disease spread. Where feasible, all-in, all-out systems—in which groups of animals move through a facility together rather than in a continuous flow—help reduce pathogen buildup between groups. Clean feed and water must be consistently provided, and exposure to outside contamination should be limited through controlled access and strict biosecurity measures. Regular observation of animals allows for early intervention before minor issues develop into costly problems.

Ultimately, preventive care is far more cost-effective than treating disease after it occurs, making proactive herd health management both an ethical and economic priority.



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10.9: Comprehensive Health Management

Modern animal stewardship requires a coordinated herd health management program focused on prevention rather than on treatment alone. Key elements include maintaining balanced nutrition, eliminating genetic faults, and following "all-in, all-out" management to prevent the spread of pathogens. Regular observations and detailed record-keeping enable early diagnosis, which is essential for identifying the disease's etiology and limiting its transmission.

Animal health also has profound implications for human well-being through "One Health," a concept that recognizes the link among animal, human, and environmental health. Zoonotic diseases—those that can be transmitted from animals to humans—require vigilant monitoring and, in some cases, mandatory reporting to government agencies such as the USDA's Animal and Plant Health Inspection Service (APHIS). Through regulatory oversight, vaccination, and proper handling, the livestock industry protects the food supply, national economies, and animal welfare.

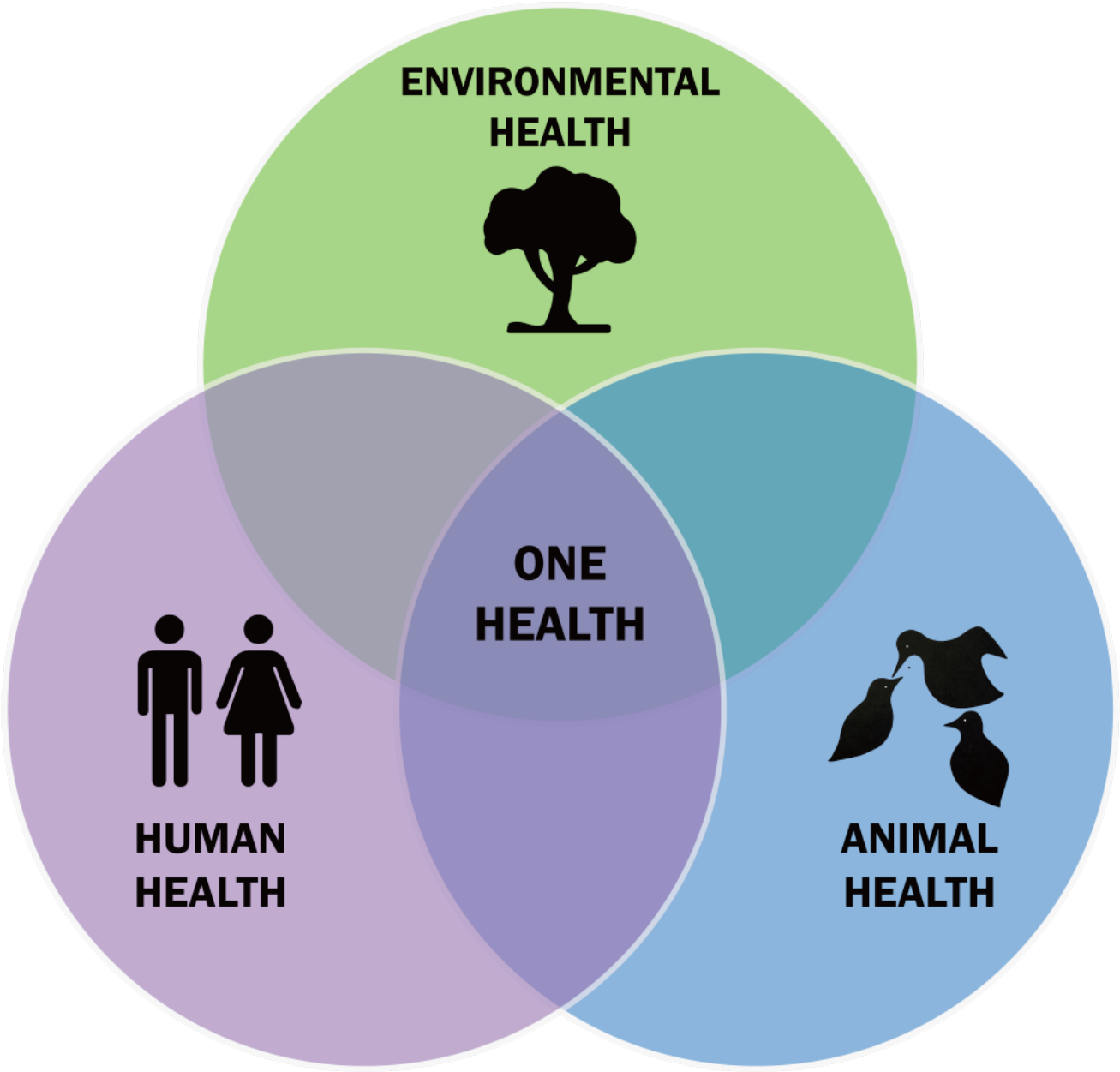


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10.10: Summary and Flashcards

Animal health and behavior are inseparable components of successful animal production systems. Disease prevention, proper diagnosis, and strong herd health programs must be combined with an understanding of animal behavior and stress responses. By integrating these areas, producers can improve animal welfare, enhance productivity, and protect public health.

Animal health and behavior are deeply interconnected:

- Poor handling → stress → weakened immunity → disease
- Good management → reduced stress → improved health and productivity

Thus, effective animal management requires both medical knowledge and behavioral understanding.

Flashcards for Animal Behavior and Handling

Flashcards for Animal Health

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10.11: Virtual Field Trip

Immersive Farming 360°

Welcome to your virtual farm tour! Today, you'll be stepping directly into the daily operations of modern agriculture. Using 360° video technology, you aren't just watching a screen; you are standing in the middle of the action.

Graphic Content Warning

This virtual field trip may include an immersive 360-degree investigation of industrial farming. **The footage contains graphic scenes of animal confinement, physical procedures performed without anesthesia, and the slaughter process.** If you feel overwhelmed or distressed, please look away or pause the video. The purpose is to witness the inherent realities and costs of our current agricultural systems.

The following are only some of the video choices to use for this activity:

1. A dairy farm (Visual, Nov. 6, 2019, *SMSU 360°: Huntjens Dairy Farm*, [Video], YouTube, https://youtu.be/sM_9geODWr4?si=lxqO0alm84ZgSFxy)
2. An automated dairy farm (Visual, July 1, 2019, *SMSU 360: Lingen Farm preview, [Video]*, *YouTube*, *https://youtu.be/LjoIF86Fjd0?si=FOVPewwS7DRc8O63*)
3. The dairy industry (content warning) (Animal Equality, *iAnimal - The dairy industry in 360 degrees, narrated by Evanna Lynch*, [Video], YouTube, https://youtu.be/YZADGGwVKj8?si=LRngahWIOQBWCMT9)
4. 42 Days in the Life of Chickens (content warning) (Animal Equality, *Kat Von D introduces iAnimal - 42 days in the life of chickens*, [Video], YouTube, https://youtu.be/tX7FHeLaLqg?si=4WWT_zSaC9qRpJia)
5. Industrial pig farming (content warning) (Animal Equality, March 1, 2016, *iAnimal Pigs - Narrated by Tony Kanal*, [Video], YouTube, https://youtu.be/A-VMMotnujM?si=vt39hH3lca8yD3fp)





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Instructions

1. Ensure you are in a space where you can safely pivot or turn. If using a tablet or phone, you will move the device to look around. If using a computer, use your mouse to click and drag the video to see behind, above, and below you.
2. **The First Pass (Observation):** Watch the assigned video all the way through once, without taking notes. Focus on the sounds, spacing, and movements of both humans and animals.

3. **The Second Pass (Investigation):** Watch the video again. This time, pause at key moments. Look at the "periphery"—what is happening in the corners of the scene?
4. **Pause and Pivot:** When you see a specific interaction (like feeding or moving animals), pause the video and rotate the view 360 degrees to see how the environment affects that interaction.

Observation Notes Activity

- As you watch the video, describe in writing what you observe, considering all of your senses (even the ones you can't experience by watching the video).
- Before watching the 360° video, what was your 'mental map' of how farming looked? How did being able to look around the entire environment confirm or disrupt that original mental image?
- What was your takeaway from the video?
- During the video, what specifically triggered you to pivot or turn your device in a different direction? Was your attention drawn by a sound, a movement, or a curiosity, and what might you have missed if you had only looked straight ahead?
- What would you like to share with others after watching the video?
- Of the themes we have studied (animal welfare, rights, health, handling, and behavior), which one did you find easiest to identify in the video, and which was the most difficult? Why do you think your brain prioritized one over the other?
- What did you learn, and what questions came up during this activity?

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CHAPTER OVERVIEW

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11.2: The Role of Animals in Sustainable Systems
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11.11: Part 4 -- The Pitch Presentation
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Modern agriculture in industrialized countries is currently seeing an active movement toward more sustainable practices. This shift is driven by a core belief that technologically driven, petrochemical-dependent specialization—while successful at maximizing production—carries high environmental and social costs that may eventually outweigh its benefits.

At its simplest, sustainable agriculture is defined as farming that meets the needs of the present generation without jeopardizing the ability of future generations to meet their own needs or limiting their choices. While many people mistakenly equate it solely with organic farming, it is a complex field that addresses philosophical, economic, and sociological issues alongside scientific and environmental questions.

To be considered truly sustainable, agricultural practices must satisfy the triple bottom line: they must be ecologically sound, economically viable, and socially responsible. The 1990 Farm Bill further expands this by recommending systems that enhance environmental quality, make efficient use of nonrenewable resources, and improve the quality of life for both farmers and society as a whole.



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11.1: The Sytems Philosophy

A central tenet of this movement is the systems philosophy, which views an individual farm as part of a larger, interconnected ecosystem. This broad perspective allows researchers and farmers to see the long-term consequences of farming practices on local and global communities. In these systems, animal and plant interactions combine to cycle carbon, nitrogen, minerals, and energy. Furthermore, sustainable agriculture is highly site-specific, meaning that its unique local environment and resources determine the best practices for one farm.



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11.2: The Role of Animals in Sustainable Systems

Animals are considered indispensable for maintaining highly functioning sustainable systems, particularly in areas with dense human populations. Unlike specialized modern operations, a sustainable unit does not always prioritize maximum production for each animal. Instead, the goal is for the livestock to produce as much as possible while contributing to the health of the entire system.

Diversified operations that include both plant and animal enterprises have distinct advantages in managing natural resources. For example, ruminants can be used to manage small-grain crops through the winter or to eat food-processing wastes. Poultry can provide weed and pest control in market gardening operations, while swine might be used to scavenge behind ruminants in intensive dairy or beef operations.

Another innovative approach is agroforestry, which involves planting woody perennials (trees) alongside livestock or crops. This can include producing livestock forage in timber forests or planting "fodder trees" for animal feed to help slow deforestation.

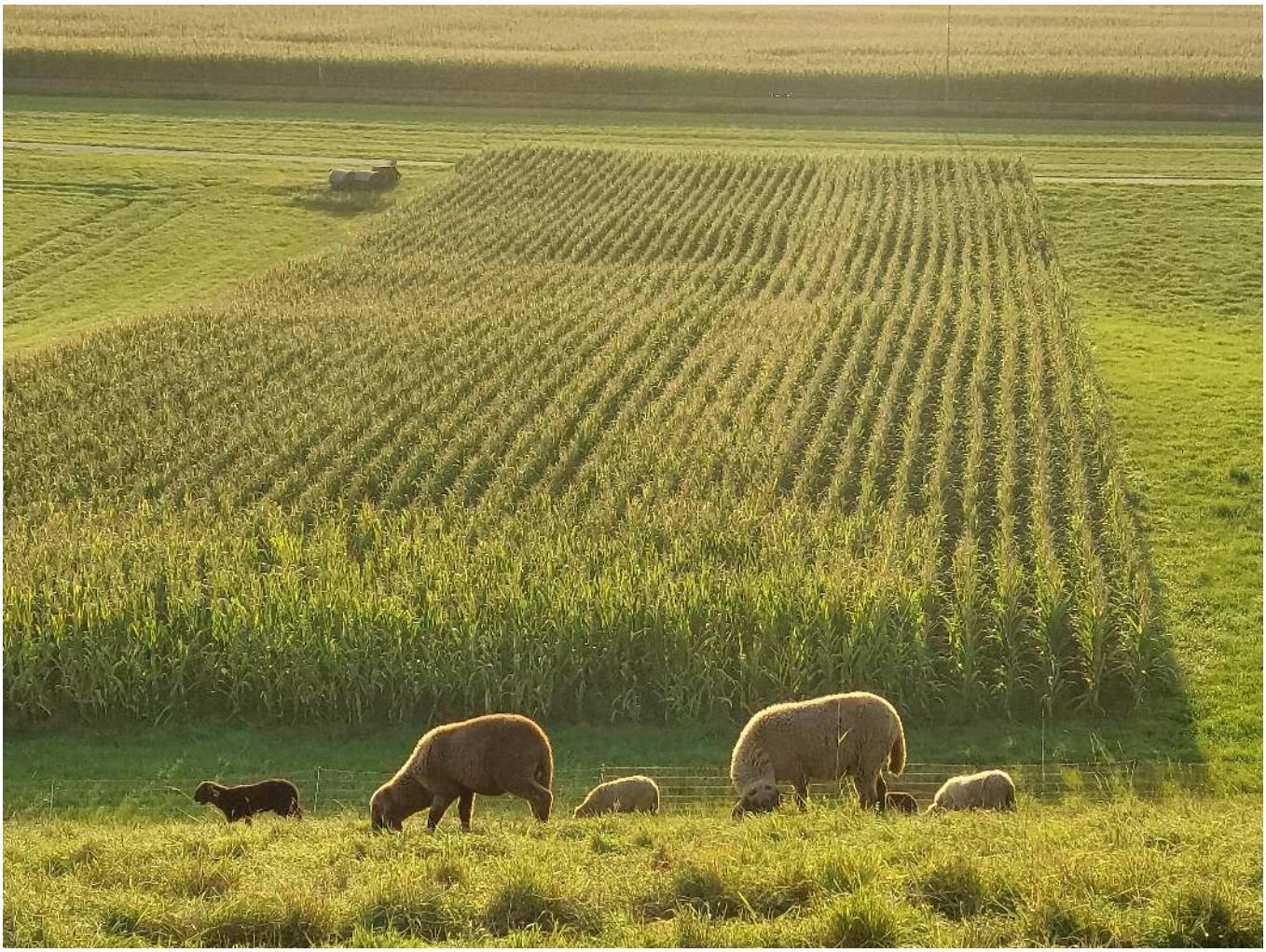


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11.3: Comparing Farming Systems

Sustainable agriculture is often contrasted with the monoculture systems prevalent today, where a farm produces only one crop or livestock species.

A table comparing features of monoculture and diversified farming systems

Feature	Monoculture Systems	Diversified/Sustainable Systems
Diversity	Low; often only one species.	High; multiple plant and animal species.
Stability	Susceptible to price fluctuations.	More stable due to multiple income sources.
Inputs	Heavily dependent on petrochemicals.	Relies on biological cycles and manures.
Environment	It can lead to soil damage and habitat loss.	Enhances soil health and provides habitat.

Many sustainable agriculturists argue that large-scale factory farms exploit animals and communities while contributing to the loss of livestock biodiversity. As standardized production conditions become the norm, unique livestock breeds adapted to harsh conditions are being lost at an alarming rate.

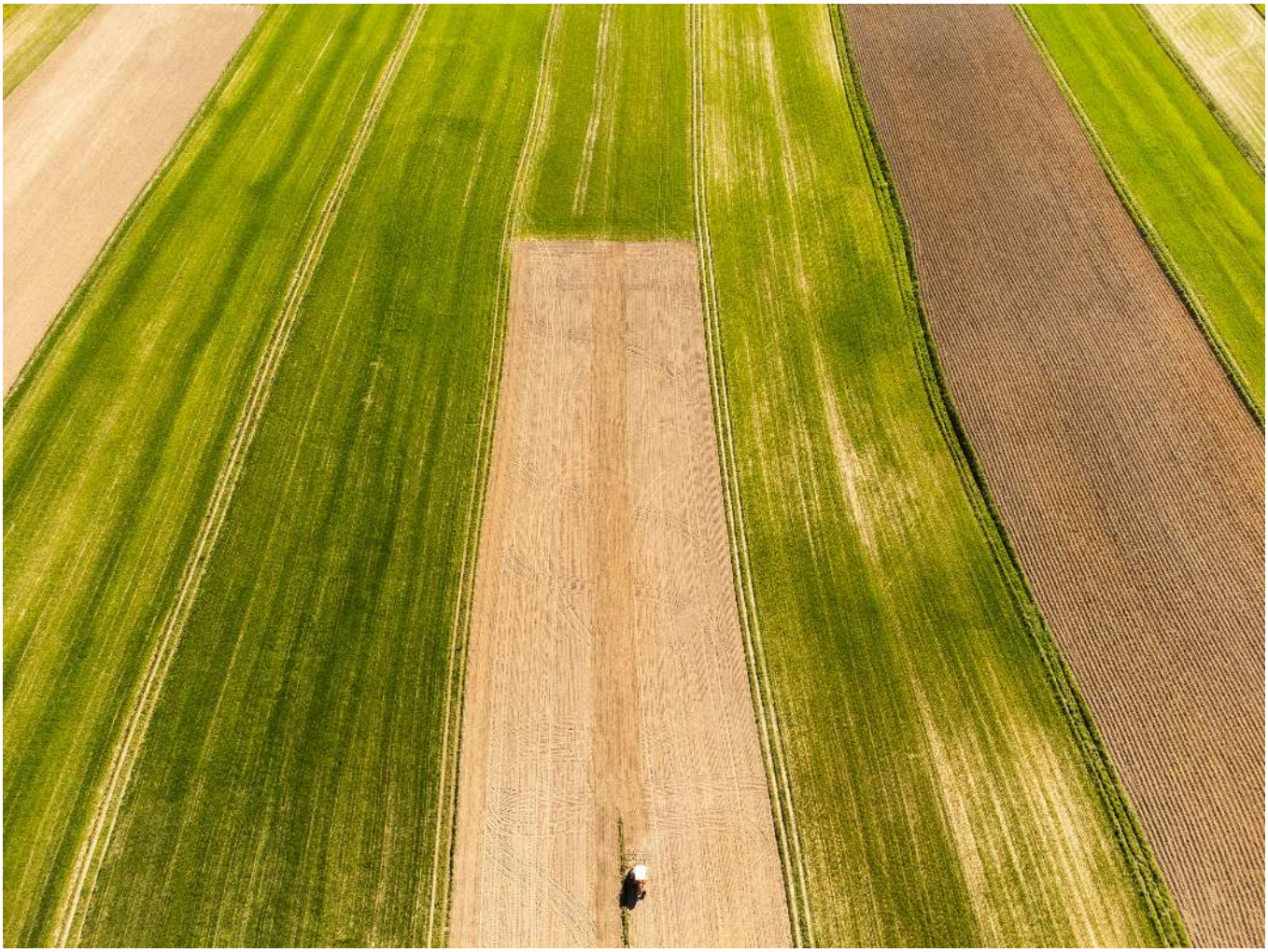


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11.4: Challenges and the Path Forward

While diversified systems offer many benefits, it is unrealistic to expect U.S. agriculture to abandon current methods immediately. Small profit margins, a growing world population, and existing social structures currently favor large-scale monoculture. A more realistic strategy involves viewing sustainability at a regional or national level, where even monoculture producers can adopt specific sustainable practices.

Key practices that can be integrated into modern systems include crop rotation—the practice of planting different crops each year to reduce pests and erosion—and integrated pest management, which uses biological controls to reduce chemical pesticide use. Additionally, the proper use of grazing animals, characterized by intensive grazing followed by substantial rest cycles, has been shown to increase long-term soil productivity and reduce water runoff.

Ultimately, the transition to sustainable agriculture is a process of small, realistic steps that requires rethinking government policy, economic goals, and personal values regarding how we interact with the environment.



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11.5: Kiss the Ground

The documentary *Kiss the Ground* serves as a powerful visual testament to the "systems philosophy" of sustainable agriculture. While modern, technology-driven agriculture often focuses on maximizing production through petrochemical-dependent specialization, this film echoes the movement's belief that such practices exact hidden costs, including soil damage, topsoil depletion, and loss of soil health. By highlighting the regenerative potential of our soil, the film aligns with the core definition of sustainability: meeting the needs of the present without jeopardizing the ability of future generations to meet theirs.

The film advocates for several key practices outlined in sustainable agricultural strategies, such as:

- **Regenerative Grazing**: Utilizing animals to increase soil quality and reduce erosion through properly managed grazing cycles.
- **Biodiversity and Integration**: Moving away from the monoculture of a single species and toward diversified systems where plant and animal interactions cycle carbon and nitrogen naturally.
- **The Triple Bottom Line**: Demonstrating that agriculture can be ecologically sound, economically viable, and socially responsible all at once.

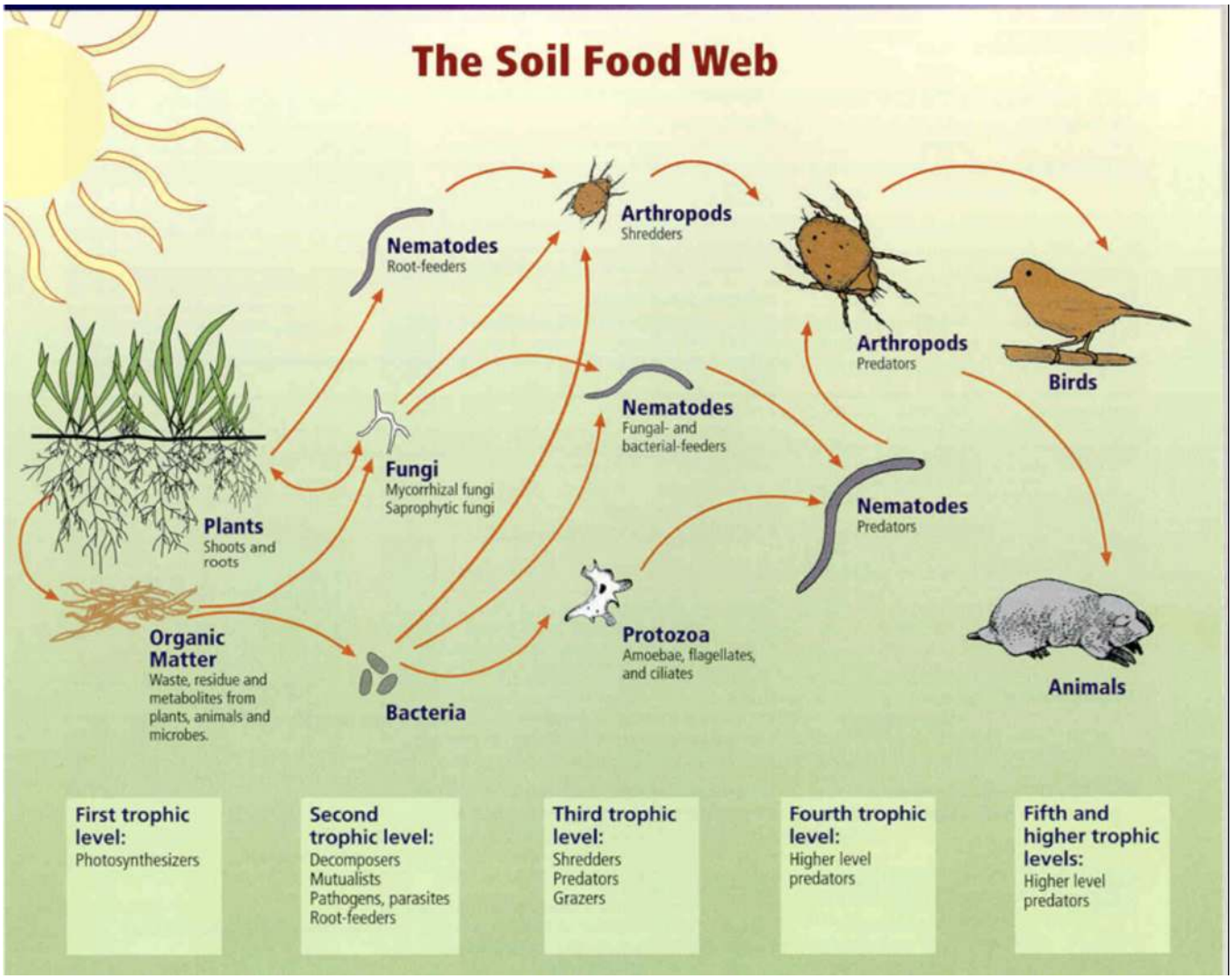


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Ultimately, *Kiss the Ground* reflects the "lifestyle element" of the sustainable movement. It suggests that the transition to a more sustainable future is a process of small, realistic steps that begins with rethinking our relationship with the land and recognizing that animals are indispensable to a highly functioning ecosystem.

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11.6: Summary and Flashcards

Ultimately, achieving a truly sustainable agricultural system requires a fundamental shift in how we value our relationship with the land and the animals that inhabit it. It is a complex process that involves balancing the triple bottom line: maintaining ecological soundness, ensuring economic viability, and upholding social responsibility. By moving toward a systems philosophy that treats the farm as an interconnected ecosystem, producers can better manage natural resources, reduce the need for costly external inputs, and enhance the quality of life for their communities.

While the transition away from modern monoculture systems presents significant economic and logistical challenges, it is not an all-or-nothing endeavor. Progress can be made through a series of small, realistic steps, such as integrating crop rotation, utilizing integrated pest management, and implementing intensive grazing practices. As the global population continues to grow, integrating plants and animals into site-specific, diversified systems remains the most promising path to securing our food supply without compromising the needs of future generations.

Flashcards for Sustainable Agriculture

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11.7: Capstone Project Instructions

Introduction

The *Design a Farm* project is an applied, team-based learning experience designed to help students engage deeply with the complexities of modern animal agriculture. This project asks students to think and act like agricultural professionals—balancing animal welfare, environmental stewardship, regulatory compliance, and economic viability while making decisions grounded in scientific evidence.

This assignment is intentionally interdisciplinary. Students must integrate course concepts with research literacy, ethical reasoning, systems thinking, and collaborative problem-solving. By designing a livestock operation from the ground up, students encounter the real-world tradeoffs inherent in agricultural decision-making and develop a more nuanced understanding of how human, animal, and environmental systems are interconnected.

The project also emphasizes student agency and accountability. While students work collaboratively to design the farm and present a professional pitch, they are individually assessed through a reflective writing component that encourages metacognition, self-assessment, and professional growth. This reflection is critical in helping students articulate how evidence challenged assumptions, how group dynamics shaped outcomes, and how their own perspectives evolved through the project.

By the end of the *Design a Farm* project, students should be able to:

- Apply scientific research to real-world agricultural design decisions
- Evaluate ethical and welfare considerations within production systems
- Communicate complex ideas clearly to both technical and non-technical audiences
- Reflect meaningfully on their learning process and professional skill development

Instructions

Divide the class into five groups. Each group is given one of the five cards below. Using their card, the students then choose a farm type and region to begin designing their farm. Breaking the project up over the course of the semester helps manage student cognitive load and allows instructors to provide actionable feedback to improve each part of this capstone project.

Farm Type	Region
Goat Farm (Milk & Meat)	Mediterranean Region
Fish Farm (Aquaculture)	Sub-Saharan Africa
Horse Breeding Farm	California, USA

Farm Type	Region
Pig Farm (Swine Production)	Southeast Asia
Sheep Farm (Wool & Meat)	Siberia (Russia)
Reindeer Farm	Texas, USA

Farm Type	Region
Livestock ranching (Cattle)	Southern France
Dairy Buffalo Farm	Midwest, USA
Duck Farm (Eggs & Meat)	Amazon Basin (Brazil)

Farm Type	Region
Poultry Farm (Chickens/Turkeys)	Norway
Dairy Farm (Cows)	Iowa, USA
Aquaponics Farm (Fish & Plants)	Kenyan Savanna

Farm Type	Region
Mixed Crop & Livestock Farm	Appalachian Mountains (USA)
Alpaca or Llama Farm	New Zealand
Cattle Ranch (Beef Production)	Patagonia (Argentina/Chile)

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11.8: Part 1 -- The Farm Feasibility Study

Your group will create a feasibility report that explains *what* your farm looks like and *why* each major decision makes sense. Support design choices with peer-reviewed data or industry standards.

- Name your Farm.
- Research your farm's location and describe the climate and geographic features.
- Choose a species of livestock that your farm will produce.
- Provide a detailed description of your farm's infrastructure. At minimum, this should include information about housing, pens, feeding areas, water sources, labor, market options, etc.
- Create drawings or detailed images of housing and handling facilities.
- Explain how location and infrastructure factors will influence farm operations.
- Will you raise crops alongside your livestock, and if so, what kind?
- Explain why you chose that type of crop, and what benefits your farm receives.
- Research and explain the regulations that apply to your farm, including information on how you will ensure that your farm is compliant.
- Explain and support all choices with cited scientific literature and data. A minimum of three peer-reviewed sources are required.

? Template for Part 1 11.8.1

Use this template to complete your feasibility study. Respond to each section thoroughly and support your farm design with peer-reviewed sources.

1. Farm Name

Provide the official name you have chosen for your farm.

2. Farm Location, Climate, and Geographic Features

Research your farm's specific location and describe:

- The region, terrain, and major geographic characteristics
- Seasonal climate and weather patterns
- Any environmental factors that will influence livestock or crop production

3. Livestock Species Selection

Choose one species that your farm will raise. Then explain:

- Why this species is suited to your climate and location
- Expected production (meat, milk, wool, eggs, etc.)
- Any space, housing, or management considerations

4. Farm Infrastructure Description

Provide a detailed description of the infrastructure your farm requires. At a minimum, include:

- Housing facilities
- Pens or enclosures
- Feeding systems
- Water supply systems or sources
- Equipment and tools
- Labor requirements
- Market access options (buyers, processors, distribution routes)

5. Facility Drawings or Images

Insert hand-drawn or computer-generated drawings, diagrams, or detailed images of your farm's:

- Livestock housing
- Handling facilities
- Feed or storage areas

6. Influence of Location and Infrastructure on Operations

Explain how your chosen location and farm infrastructure will impact:

- Daily farm operations
- Animal health and welfare
- Production efficiency
- Labor and transportation

7. Crop Production Plan (If Applicable)

Indicate whether you will raise crops alongside your livestock.
If yes, explain:

- What crops will you grow?
- Why did you choose the crops?
- How will the crops benefit your farm (e.g., feed production, soil improvement, revenue diversification)?

8. Regulations and Compliance

Research and explain the regulations that apply to your type of farm, including:

- Zoning laws
- Animal welfare regulations
- Environmental or water-quality standards
- Required permits or licenses
- Food safety/processing requirements (if applicable)

Describe how your farm will comply with these requirements.

9. Evidence and Scientific Support

Support all major decisions in this part of the project with:

- At least three (3) peer-reviewed scientific sources
- Data or statistics relevant to livestock production, climate, or infrastructure
- Include full citations in APA format.

Deliverables Checklist for Part 1

The following items are the deliverables for part one, The Feasibility Study:

1. At least three sources that pass the CRAAP test for each section.
2. An explanation of the regulations that apply to your farm, including information on how to ensure that your farm is compliant.
3. A detailed description of how location and infrastructure factors will influence farm operations.
4. Choice of livestock and, if chosen, crops. Provide justifications for the choices.
5. A visual representation of your farm, including the farm name, description of the climate, geographic features, and infrastructure.

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11.9: Part 2 -- Environmental SWOT and Site Engineering

Your group will evaluate your farm's design using a SWOT analysis of your farm's geography and livestock.

SWOT Analysis

- **Strengths:** What advantages does your location or livestock choice provide?
- **Weaknesses:** What challenges or limitations exist?
- **Opportunities:** What external factors or innovations could benefit your farm?
- **Threats:** What risks could negatively affect your operation?
- Explain how your farm design helps reduce or manage environmental and regional stressors.

Risk Mitigation Plan

- Create a risk-mitigation plan for ***one*** of the following:
  - Market crash
  - Infectious disease outbreak
  - Drought

Bio-Economic Utilization Plan

This section focuses on how animals (and, if applicable, crops) move through your system.

- Develop a production flow chart from the start of the production cycle to the market.
- How do you plan to utilize your animals? Include details on processing and distribution.
- Describe your plan for transporting animals to market or slaughter, including information on vehicles, routes, and handling during transport
- If your group also chose to produce crops, how will they be utilized?
- Describe your plan for transporting crops to market, including information on vehicles, routes, and handling during transport.
- Explain and support all choices with cited scientific literature and data. A minimum of three peer-reviewed sources are required.

Biosecurity

- Design a Biosecurity Protocol that starts with livestock-appropriate vaccinations and health requirements.
- Describe how your farm will address the addition of new animals or if an animal gets sick?
- The protocol should include the steps your farm will take to prevent infectious diseases from affecting animals, property, and people. Including ways to protect neighboring farms, farm employees, and consumers.
- Research local environmental regulations and explain the steps your farm will take for compliance.
- Explain and support all choices with cited scientific literature and data. A minimum of three peer-reviewed sources are required.

? Template for Part 2 11.9.1

Farm Name:

Group Members:

Farm Type and Location:

1. Environmental SWOT Analysis

1.1 Strengths

Identify internal strengths related to your farm's geography, livestock species, climate advantages, soil quality, water resources, or infrastructure.

1.2 Weaknesses

Identify internal limitations or challenges that may affect production (terrain, resource limitations, infrastructure gaps, livestock vulnerabilities, etc.).

1.3 Opportunities

Identify external environmental or economic factors that could benefit farm operations (market trends, local demand, climate suitability, emerging technologies, etc.).

1.4 Threats

Identify external threats such as disease risks, weather events, regulatory changes, predators, or market instability.

2. Problem Solving and Site Engineering

2.1 Farm Design and Engineering Features

Explain how your farm's layout and structural design help mitigate environmental or operational stressors (windbreaks, pasture rotation, drainage systems, shelter design, fencing, manure management, etc.).

2.2 Environmental Stressors and Mitigation

Describe the specific environmental stressors your farm faces, and the engineering or management solutions applied.

3. "What If" Scenario: Risk Mitigation Plan

Choose ***one*** scenario: market crash, infectious disease outbreak, or drought. Then complete the following:

3.1 Scenario Chosen:

3.2 Description of Risk:

3.3 Immediate Response Strategy:

3.4 Long-Term Risk Mitigation Plan:

3.5 Expected Outcomes and Resilience Improvements:

4. Bio-Economic Utilization Plan

4.1 Production Flow Chart

Insert or draw a flowchart showing production from start of cycle to market (e.g., breeding → raising → processing → distribution).
(A flow chart is required.)

4.2 Utilization of Animals

Describe how animals will be used and processed (meat, dairy, fiber, breeding stock, etc.). Include processing steps and distribution strategies.

4.3 Transportation Plan for Livestock

Describe vehicles, routes, safety measures, handling practices, and regulatory considerations.

4.4 Crop Utilization (if applicable)

Describe crop use (sale, feed, value-added products, rotation benefits, etc.).

4.5 Crop Transportation Plan

Describe vehicles, routes, handling safeguards, and compliance requirements.

5. Biosecurity Plan

5.1 Vaccination and Health Requirements

List required vaccinations, testing, or certifications for your livestock species.

5.2 Protocol for Adding New Animals

Describe quarantine length, testing, gradual integration, and monitoring procedures.

5.3 Response Plan for Sick Animals

Explain isolation procedures, veterinary involvement, sanitation steps, and communication protocols.

5.4 Preventing Infectious Disease Spread

Detail how the farm will protect animals, property, employees, neighboring farms, and consumers.

- Visitor controls
- Equipment sanitation
- Worker hygiene
- Waste management
- Wildlife mitigation

5.5 Environmental Regulation Compliance

List local environmental regulations and describe your compliance strategy (waste management, water protection, land use, emissions, etc.).

6. References

List at least three peer-reviewed scientific sources used to create this section of the project.

Deliverables Checklist for Part 2

The following items are the deliverables for part two, Environmental SWOT and Site Engineering:

1. Detail the farm's compliance with the local environmental regulations.
2. A comprehensive biosecurity plan.
3. A risk plan for either a market crash, an infectious disease outbreak, ***or*** a drought.
4. An explanation of how the farm's design mitigates local stressors.
5. A detailed SWOT analysis.

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11.10: Part 3 -- Integrated Livestock Welfare

For this step, your group will demonstrate how your farm prioritizes animal welfare while maintaining productivity.

- Outline the diet for your animals and how it will be sourced. Explain how you will ensure your animals receive a nutritionally appropriate diet. Include feeding schedules and quantities.
- Explain how you will ensure your farm has sufficient water.
- Detail how your farm will balance production and profitability with the five domains.
- Describe animal handling methods. This should include information on training, equipment, protocols, and who is doing the labor.
- Describe the measures you will take to ensure the welfare of your animals, including details on living conditions, humane treatment, and ethical considerations.
- Explain and support all choices with cited scientific literature and data. A minimum of three peer-reviewed sources are required.

? Part 3 Template 11.10.1

Farm Name:

Group Members:

Farm Type and Location:

Summarize the ration(s) for each life stage of the livestock on your farm (e.g., growth, maintenance, gestation/lactation, and senior care). Identify how your farm will address the nutritional requirements of your livestock.

Specify suppliers and risk management for availability, quality, and price volatility.

Explain how diets will be adjusted for growth, reproduction, gestation, lactation, finishing, and heat/cold stress.

Provide feeding schedules, amounts, bunk/feeder space, and access control.

Identify your farm's primary water source. Estimate your livestock's daily water needs. Account for seasonal fluctuations and if more water will be needed for cleaning and/or processing the livestock. Detail your farm's water quality management plan.

Address how you will optimize welfare and farm viability across the Five Domains. Account for both negative and positive experiences.

Describe animal handling methods. Include information on training techniques, equipment, protocols, and how many people will be doing the labor.

Deliverables Checklist for Part 3

The following items are the deliverables for part three, Integrated Livestock Welfare:

1. Outline animal-handling methods to ensure the safety of livestock and humans.
2. Describe the measures your farm will take to ensure livestock welfare, including details on living conditions, humane treatment, and ethical considerations.
3. Livestock handling guidelines.
4. Explain the choice of handling equipment or housing types based on the Five Domains of Animal Welfare.
5. A nutritional plan for the farm's livestock (including water resources).

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11.11: Part 4 -- The Pitch Presentation

As the final step of the group portion of this project, each group will present its findings to the rest of the class as a professional pitch. Your peers will reflect on your work and grade your presentation, using the Pitch Presentation Rubric. Then the class will vote on the winning farm design.

- **The Task:** Detail your group's farm design, sustainability, and profitability.
- **The Goal:** Demonstrate how your group's livestock choices create a circular economy on the farm, reducing waste and external inputs.
- Information should be presented compellingly.
- The presentation text should be in an easy-to-read font, grammatically correct, and free of spelling errors.
- The design and layout should use space wisely; colors should complement one another, be attractive, and be professionally formatted and error-free.
- Graphics should be high-quality and enhance viewers' interest and understanding.

? Part 4 Guidelines 11.11.1

Farm Name:

Group Members:

Farm Type and Location:

- **Farm name**
- **Group members**
- **Farm type and location**
- **Representative image of your farm**
- Optional tagline summarizing your farm's mission

Purpose: Provide an overview of your farm concept.
Include:

- Type(s) of livestock you selected
- General description of farm size and layout
- Your farm's mission (e.g., sustainability, efficiency, community support)

Purpose: Explain *why* your group selected the livestock species.
Address:

- Primary products produced
- Advantages of the species in your farm's climate or system
- How these animals support your sustainability goals

Purpose: Show how your farm creates a circular economy, reducing waste, and external inputs.
Explain:

- How the livestock species contributes to a circular system
- How outputs from one part of the farm become inputs for another
- How your farm's circular system reduces expenses
- Any additional systems
- Suggested visual: a simple diagram with arrows showing nutrient and resource flow.

Describe:

- How your farm minimizes waste
- How manure is reused
- How feed or bedding is repurposed
- Any recycling or composting approaches used on your farm
- Environmental impacts (soil health, reduced runoff, lower emissions)

Explain:

- How your farm reduces reliance on outside feed, fertilizers, energy, or labor
- Systems that make the farm more self-sufficient
- Cost savings created by these practices

Include:

- A map, diagram, or labeled sketch of the farm
- Locations of buildings, pastures, manure areas, water systems, etc.
- Clear labels and a simple legend
- *Tip: Use colors thoughtfully—enough to clarify, not distract.*

Slide 8 — Sustainability Benefits

Summarize how your farm design improves:

- Soil health
- Animal welfare
- Water efficiency
- Biodiversity
- Long-term environmental stewardship

Identify:

- Challenges your farm may face
- Risks (weather, disease, market fluctuations)
- Practical strategies to address these issues

Make your pitch!

- What makes your farm design innovative?
- How does it stand out from other groups?
- Why is your approach the most sustainable and profitable?
- Information should be presented compellingly.
- The presentation text should be in a 30-point font, easy to read, grammatically correct, and free of spelling errors.
- List sources, images, articles, or data used
- Proper APA formatting
- Information is accurate, clear, and well-organized
- Livestock choices are well-justified
- Circular economy concepts are clearly illustrated
- Easy-to-read 30-point font
- Correct spelling and grammar
- Bullet points instead of long paragraphs
- Professional, consistent visual style
- Colors complement each other and enhance readability
- Slides are not overcrowded—use space intentionally
- High-quality images and diagrams
- Graphics support understanding, not distract
- All visuals are relevant and clearly labeled

Part 4 Deliverables Checklist

The following items are required to be part of your group's Pitch Presentation:

1. Is your group prepared to answer questions about your farm's design and protocols?
2. Does your farm presentation have a "hook" that will sell your farm design to the rest of the class?
3. The presentation explains all aspects of your group's farm. Detailing your group's farm design, sustainability, and profitability in a compelling manner.
4. The presentation fonts are easy to read, grammatically correct, and without spelling errors.

5. The presentation design is attractive, professionally formatted, and error-free.

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11.12: Reflection Paper

The reflection paper is your opportunity to step back and think critically about your experience with the *Design a Farm* project. This is not a summary of what your group did—it is a ***personal reflection*** on how you learned, contributed, struggled, adapted, and grew throughout the process.

The reflection paper requires everyone to individually reflect on each phase of the Design a Farm process. The reflection paper (approx. 1,000–1,500 words, double-spaced, 12-point font, with standard margin) is ***due at the class session following your group's pitch presentation.***

You must make an appointment with the Academic Support Center for help with your reflection paper. The Academic Support Center must review your reflection paper (this is part of your grade).

? Part 5 Guidelines 11.12.1

- Discuss the most significant technical challenge your group faced when designing your farm. How did your group address that challenge?
- Provide one specific example of an "evidence-based finding" that forced your group to pivot from your original design idea.
- How did your own beliefs, opinions, or feelings influence the choices your group made?
- Reflect on the entire group presentation process. What did you learn from this experience?
- What assumptions about the group presentation experience were supported or refuted?
- Provides specific examples.

- How did this project help you better understand the challenges facing agriculture in ways that motivate you to learn more?
- Review the challenges your group faced (provide examples).
- Discuss how your group handled challenges (provide examples).
- Discuss what you would do differently next time or areas where you could improve your presentation (provide examples).

The conclusion of your reflection paper should summarize your thoughts, feelings, or opinions regarding what you learned about yourself from the group project and presentation process.

A final component of your grade will be based on your classroom participation during other groups' presentations. I do not expect everyone to ask a question or make a comment about each presentation, but over the course of all the presentations, I expect everybody to participate meaningfully. In assigning this portion of your grade, I will consider how well you have contributed to and motivated further classroom discussion by being present for peer grading on days when your group is not presenting.

Part 5 Deliverables Checklist

The following items are required to be part of your Reflection Paper

1. An email confirming you attended an appointment with the Academic Support Center to review your paper.
2. An APA-formatted bibliography listing your sources and all LLM use.
3. An APA formatted 1,000–1,500-word paper using at least three supporting sources for each section (twelve sources total). Your paper should be double-spaced, in 12-point font, and with standard margins.

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Glossary

1493 | Christopher Columbus brought livestock to the West Indies

1519 | Hernando Cortez introduced cattle and sheep to Mexico

1539 | Hernando DeSoto brought horses and hogs to Florida

1641 | William Pynchon of Massachusetts became the first meat packer to export salt pork

1760 | Robert Bakewell in England began breeding animals for specific purposes, developing distinct breeds

1861-1865 The American Civil War |

The significant changes the American Civil War brought to animal agriculture in the U.S.

1. The expansion of railroads reduced the need for horses and mules and allowed for livestock to be raised further from where they would be consumed.
2. Refrigerated railcars allowed shipping of meat carcasses to population centers. This meant animals could be raised in one location, processed in another, and consumed in another.
3. Beef became more popular than pork due to improved preservation methods

1862 | The Land Grant Act provided public lands for universities to teach agriculture

1872 | The Hatch Act established agricultural experiment stations

1914 | The Smith-Lever Act created the Cooperative Extension Service

3 R's of animal research | 1. Replacement (substitute something else for higher animals)
2. Reduction (reduce the number of animals needed)
3. Refinement (decrease in inhumane procedures)

abolitionists |

Animal rights proponents who advocate for the total abandonment of any animal use

abomasum | The true glandular stomach in the ruminant

accuracy |
The measure of reliability associated with an EPD, expressed as a value between 0 and 1; a higher value indicates more information and reliability

across-breed EPD (AB-EPD) | A prediction of the difference between the performance of an individual's progeny compared to all contemporaries for that progeny across breeds

active immunity | long-term protection to an infectious agent developed in response to exposure to an infectious agent or a vaccine for a specific disease

acute disease | Sudden or severe in onset and effect on the animal

adaptive immunity | Allows the body to recognize infectious agents it has encountered before and mount a quicker and stronger protective response (also known as acquired immunity)

aggressive behavior | Threatening or harmful behavior towards others of the same or different species

agricultural systems | Determined by a number of factors, including climate, topography, soil type, and socioeconomic issues such as level of economic development, demand for products, political systems, and religions

agriculture | The combination of science and art used to cultivate and grow crops and livestock, and process the products

agroecology | Sustainable farming that works with nature

agroforestry |
Land-use systems and practices that integrate woody perennials with livestock and/or crops on the same unit

all-in | Adding animals to a facility, such as a farrowing house, at the same time, and then removing them at the same time

alleles | One of two or more alternative versions of a gene found at the same location on paired chromosomes

alloenzymatic | Digestion that relies on enzymes produced by microorganisms

ampullary-isthmic junction | The area where the ampulla and isthmus connect, it is considered the site of fertilization

anaerobic | Conditions that lack molecular oxygen

animal behavior | The study of animal welfare assessment, optimizing production, behavioral control, behavioral disorders, and behavioral genetics

animal breeding | The use of biometry and genetics to improve farm animal production

animal health | The study and practice of maintaining animals as near to a constant state of health as is possible and feasible

animal rights | The belief that animals have the right to live free from human use or exploitation

animal science | The combination of disciplines that together comprise the study of domestic animals

animal welfare | An animal's well-being and care while they provide for human needs; humane use

anorexia | Inappetence or unwillingness to eat

anthropomorphism | Attributing human thoughts, emotions, and characteristics to animals

anti-use philosophy | An absolute position that allows no animal use whatsoever

antibodies | Proteins produced by the body that attack and neutralize infectious agents

antimicrobial agent | Natural or synthetic drugs that inhibit or kill bacteria; this capability makes them unique for controlling infectious diseases caused by pathogenic bacteria

applied ethology | The study of domestic animal behavior, usually companion species and livestock

applied or production nutritionist | The practical nutritionist. An applied nutritionist addresses practical questions such as cost-effectiveness, delivery methods, and carcass effects.

artificial insemination (AI) | Placing semen into a female's reproductive tract artificially to achieve pregnancy

artificial selection | Selecting which animals in a population are allowed to reproduce

artificial vagina (AV) | A device used to collect semen from a male

ash | It is a crude measure of the total mineral content of a diet

asymptomatic disease | Disease without signs or symptoms

atresia | The degeneration of follicles that do not make it to the mature stage, otherwise known as the Graafian stage

auditory | Related to hearing

autoenzymatic |
Digestion using the animal's own enzymes

autosomes | All chromosomes other than sex chromosomes

aversive event | A negative experience that may be painful, frightening, or nauseating

bacteria |
Tiny, single-celled microorganisms that live in almost every environment

bacteriophages | A virus that attacks bacteria

balance trial | A type of metabolism trial designed to determine the retention of a specific nutrient in the body

barter | Trading services or commodities

basic nutritionist | A nutritionist focused on understanding how nutrients are processed and interact in the body

behavioral ecology | The study of the relationships between a species' behavior and its environment

biofuel | Gas or liquid fuel made from biological materials, such as crops and animal waste

biometry | The application of statistics to topics of biology

biopharmaceuticals | Medicines and vaccines made using living organisms

biopharming | The use of genetically-engineered plants or animals to produce valuable medical or therapeutic compounds such as drugs, vaccines, and antibodies; also called pharmaceutical farming or pharming

biopsy | Surgical removal and microscopic examination of a tissue specimen

biotechnology | The use of science and technology to modify or improve animals—or their products—for agricultural, medical, or industrial purposes

blastocyst |

A ball of cells that forms early in a pregnancy

body condition score | A tool designed to assess body fat accumulation on an animal

bolus | A rounded mass of food ready to swallow or regurgitate

bomb calorimeter |

A laboratory instrument used in animal nutrition to measure the total potential energy (gross energy) in feed by burning a dried sample in a sealed, oxygen-rich chamber and measuring the heat released

breech birth | A butt-first or tail-first presentation of offspring at birth

breed | Animals with common ancestry that have distinguishable characteristics, and when mated with others of the same breed, produce offspring with the same characteristics

breeding soundness examination | A physical examination to determine the readiness of an animal for breeding purposes

breeding value |
An individual's worth as a parent

broad ligament | The ligament that keeps the reproductive tract in position

by-products | Valuable materials left over after the primary products have been removed from a carcass

carbohydrates (CHO) | The primary, plant-derived energy source in animal diets, composed of carbon, hydrogen, and oxygen

carnivore |
An animal that subsists primarily on meat

cash crop | A crop grown specifically with the intent of marketing its product

ceca | (plural of cecum) Two large ceca are present at the junction of the small and large intestine in birds; used to digest fiber

cecotrophy | The process of expelling and consuming mucus-covered soft fecal pellets

cecum | A pouch-like structure at the beginning of the large intestine

cell cloning | Also known as somatic cell nuclear transfer (SCNT)

cellulase | An enzyme that digests cellulose

cellulose | A complex carbohydrate that forms plant cell walls and is composed of thousands of glucose molecules

centromere |
The region of a chromosome where spindle fibers attach

Charles Darwin | An English naturalist (1809-1882) - he proposed the theory of evolution by natural selection

chromosome | The DNA-containing structures in cells

chronic disease | Disease continuing over a long period or having a gradual effect

chyme | Material consisting of food, saliva, and gastric secretions

civilization | An important contribution of farming to the process of civilization was providing people with the time and lifestyle that led to the development of written language, record-keeping, and artistic endeavors

classical conditioning |

A learned response triggered by a neutral stimulus, as demonstrated by Pavlov's famous experiments

clinical infection | An infectious disease with observable signs

clinical sign | An observable difference in an animal's normal function or health

cloaca | The common orifice for waste elimination, copulation, and egg laying in birds

cloning | The process of creating a genetically identical copy of an organism, often using somatic cell nuclear transfer (SCNT)

codominance | Both alleles are expressed in the phenotype when present in the heterozygous state

colic |
Digestive disturbance, especially in horses

colostrum | The first nutrient-dense milk produced by female mammals immediately after giving birth

combined maternal EPD | A genetic prediction of a bull's ability to produce superior daughters, it reflects the total maternal impact of a cow on her calf's weight

commercial livestock finishing | A further specialization of agriculture, the modification of commercial crop and livestock farming that emerged in the last half of the 20th century

commercial plantation | A form of commercial agriculture that uses large landholdings and labor-intensive practices, most often in developing countries, to produce a single crop for the commercial market

companion animal | An animal with which an owner has an intense emotional tie

comparative method of study | A systematic method of comparing the behavior of different species to understand how and why behaviors occur

comparative psychology | The study of how animals think, learn, and behave, and what that reveals about humans and other species

compost | Decayed organic matter used for fertilizing land

conditioning | The learned response of an animal to a stimulus

conservation | The study of the preservation of nature and of Earth's biodiversity with the aim of protecting species, their habitats, and ecosystems

contagious disease |

A disease capable of being transmitted from animal to animal

contemporary group | A group of animals of a given sex and age, having similar treatment, are given an equal opportunity to perform

coprophagy | The act of eating feces

corpus luteum (CL) | The ovarian structure responsible for the production of progesterone for the support of pregnancy

cortisol | A stress hormone produced by the adrenal gland, often used to measure an animal's stress levels

cribbing | A behavior in horses where they bite or hold on to objects such as posts

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) | A gene-editing tool that uses a guide RNA and a Cas9 enzyme to find and cut specific DNA sequences

critical period | Similar to sensitive periods, but with a definite beginning and end

crop |

In birds, an expandable, muscular pouch located at the base of the neck that serves as a specialized storage area for food before digestion

crop rotation | Planting different crops in a field each year to reduce weeds, disease, and insect pests provides alternative sources of soil nitrogen, reduces soil erosion, and reduces risks of water contamination by agricultural chemicals

crossbreeding | The breeding of two different breeds from the same species to create a new breed

crude fiber (CF) |
In proximate analysis, the insoluble carbohydrates remaining in a feed after boiling in acid and alkali

crude protein (CP) | An estimate of protein content obtained by multiplying the nitrogen content of a substance by 6.25

culture | The set of occupational activities, economic structures, beliefs/values, social forms and material traits that define our actions and activities

dairy herd improvement (DHI) system | A national record-keeping and data analysis program that helps dairy farmers monitor, manage, and improve the health, milk production, and genetics of their herds

dairy product science | The science of providing milk and milk products as food

defecation | Expelling fecal matter from the large intestine via the rectum or cloaca

Deglutition | Swallowing

deoxyribonucleic acid (DNA) | The molecule that carries the genetic instructions for the development, functioning, growth, and reproduction of all organisms

developed agriculture types | To earn a profit by engaging in agriculture, this includes:
1. livestock ranching
2. commercial grain farming
3. commercial livestock and grain farming
4. commercial livestock finishing
5. commercial dairy farming
6. commercial plantation
7. specialized horticulture
8. Mediterranean agriculture
9. market gardening
10. aquaculture

diagnosis | The process of determining the nature and severity of a disease or distinguishing one disease from another

diagnostician | An expert on diagnosing disease

dichromat | The ability to perceive only two colors

diet | All the feeds being consumed by an animal, including water.

dietary essential nutrient | A nutrient required for normal physiological function that must be obtained from the diet.

digestibility |

The degree to which a feedstuff can be chemically simplified and absorbed by the digestive system of the body

digestion | The physical, chemical, and enzymatic breakdown of feed for absorption

digestion trial |
An experimental tool used to determine the digestibility of a specific feedstuff, nutrient, or ration

diploid | Having two sets of chromosomes

direct cause of disease | Exposure to or contact with pathogens or other substances that cause a decrease in animal health

disease |

An abnormal condition that prevents the body from functioning normally, causing specific signs or symptoms

disease-resistant animals | Genetically modified or selectively bred animals that are less susceptible to infections

diversification |

A farm with multiple income-generating enterprises enhancing its biological and economic stability

DNA ligase | An enzyme that acts as a "molecular glue" to join broken or separate pieces of DNA together

DNA polymerase | An enzyme that acts as a cell's builder for DNA

DNA replication | The cellular process of making a copy of a DNA molecule

Dolly | The first cloned sheep produced through nuclear transfer from differentiated adult sheep cells

domestic animals | Animal species that have been brought under human control and that have adapted to life with humans

dominance | An animal's rank within a social group, where the most dominant individual has the greatest influence over others

dominant | One member of a gene pair is expressed to the exclusion of the other

donor | The female from whom fertilized embryos are nonsurgically collected during the embryo transfer process

downer cow | A nonambulatory cow

draft | To move loads by drawing or pulling.

draft animal | An animal whose major purpose is to perform work that involves hauling or pulling

dry matter |
Everything in a feed other than water

drylot | A confined area generally equipped with feed troughs, automatic watering devices, shelter, and working facilities where animals are fed and managed

duodenum | The first segment of the small intestine

dystocia | Difficulty giving birth

ecology |

The study of how living things interact with each other and their environment

economic Indexes |

A numerical value that ranks animals based on their overall genetic potential for profitability

electric prods | Small handheld devices designed to give an electrical shock to animals

embryo transfer (ET) | The process of transferring fertilized embryos from one female to another female

endemic | A disease or condition regularly found among animals of a particular population or in a certain area

energy | The potential to perform work

enucleated | A cell with the nucleus removed that is used in cell cloning

environmentalism |

A movement and ideology that aims to reduce the impact of human activities on the Earth

enzymes | Specialized proteins that act as biological catalysts

epididymis |

The duct connecting the testis with the ductus deferens and is responsible for sperm storage, transport, and maturation

episodic | The pulsatile manner in which the gonadotropic hormones are secreted by the anterior pituitary gland. Controlled by the pulse-generating center of the brain

epistasis | One gene masks, inhibits, or modifies the expression of another, separate gene

ES cells (Embryonic Stem Cells) |

Stem cells derived from the inner cell mass of a blastocyst, an early-stage embryo

essential amino acids | Amino acids required by the body that must be consumed in the animal's diet

essential fatty acids | Fatty acids required in an animal's diet

estrous cycle | The time from one period of sexual receptivity in the female (estrus or heat) to the next

estrus | The period when a female is receptive to mating; synonymous with heat

ether extract | In proximate analysis, the portion of a sample that is removed by extraction with a fat solvent

ethogram | A catalog or inventory of all of the behaviors an animal exhibits in its natural environment

ethology |

The study of animal behavior in natural surroundings, focusing on instinctive or innate behavior

expected progeny difference (EPD) | A prediction of the future progeny performance of one individual compared to another individual *within a breed* for a specific trait, it is equal to half the breeding value

expression | The manifestation of a characteristic that is specified by a gene

extensive agriculture | Agriculture systems practiced in a manner that spreads human time and attention across vast acreages and/or large numbers of animals

extensive rearing systems | A low-intervention management style where hardy animals, such as beef cattle, receive minimal individual care and may only be handled once or twice a year

farmer | Anyone who practices agriculture by managing and cultivating livestock and/or crops

fats | Also called lipids. They are a concentrated nutrient that serves as the primary long-term energy storage in animals, providing over twice the energy per gram compared to carbohydrates or proteins.

feed analysis | The laboratory testing of livestock feed to measure nutrient levels, ensuring the feed meets the specific dietary needs of animals

feed efficiency |

A measure of how effectively an animal converts feed into products like meat, milk, or eggs

feeding trail |
An experimental tool used to measure how animals perform on specific diets or feed additives.

feedstuff | Any substance that is used as animal feed.

fermentation | The enzymatic decomposition of feedstuffs by microbes

finishing (phase) | The final feeding stage when animals are ready for market

flight zone | The distance that an animal is caused to flee from an intruder

flighty |
The tendency of an animal to take sudden flight when alarmed; also called mobile alarm

flocking instinct | A type of shelter-seeking behavior that has been selected for in sheep; at the least hint of danger, they move close together and move as a group

flow cytometer | AN instrument used to differentiate and separate X and Y chromosome-bearing sperm in amounts suitable for AI

flushing | Feeding extra feed to stimulate estrus and ovulation rates

follicle-stimulating hormone (FSH) | The gonadotropic hormone responsible for growth, development, and maintenance of follicles in females, and the production of sperm in males. Produced and secreted by the anterior pituitary gland in a pulsatile manner in response to GnRH

folliculogenesis | The maturation of the ovarian follicle

Food and Agriculture Organization of the United Nations (FAO) | The largest autonomous agency within the United Nations. FAO works to alleviate poverty and hunger by promoting agricultural development

forestomachs | The three ruminant digestive compartments before the true stomach

founder | A transgenic animal that is subsequently used to establish a transgenic line of animals

freemartin | A condition in cattle in which a female calf is born as a twin with a bull calf, and as a result, is infertile

gametes | The reproductive cells: sperm in the male and the egg or ova in the female

gametogenesis | The formation of gametes

gene |

The basic unit of heredity, composed of DNA sequences located on chromosomes

gene editing | The modification of a cell's DNA to introduce beneficial traits; uses technologies like CRISPR

gene enhancement |

The intentional, high-tech alteration of an animal's DNA to enhance specific traits, such as faster growth, better disease resistance, or higher productivity

gene frequency |

A measure of how common a specific version of a gene is within a population

gene mapping | The process of determining the specific location and relative positions of genes on a chromosome

gene silencing | The inhibition of a gene's expression through natural or artificial means

gene therapy | Transferring specific genes into mammalian cells with the goal of treating genetic disorders

generational interval | The average age of animals within a species when their first offspring are born

genetic code | The set of rules by which information encoded in genetic material (DNA or RNA sequences) is translated into proteins (amino acid sequences) by living cells

genetic correlation | The measure of how much two different traits share the same underlying genetic causes

genetic drift | Random changes in gene frequency within a population

genetic engineering | The direct modification of an organism's DNA using biotechnology; often done to introduce new traits, to improve resistance to disease, or to produce beneficial products

genetic merit |
Inherited productivity of performance qualities

genetic testing |

Using a variety of laboratory techniques to determine if an animal has, or is likely to get, a genetic condition or disease

genetically modified organism (GMO) | An organism whose genetic material has been altered through genetic engineering techniques; any organism that has been modified by altering one or more genes using recombinant deoxyribonucleic acid (rDNA) technology

genetics | The scientific study of heredity and the variation of inherited characteristics

genome | The complete genetic material of an organism

genotype | The genetic makeup of an organism

genotypic frequency | The frequency with which a particular genotype occurs in a population

gizzard | (Ventriculus) or a highly specialized, muscular grinding organ

gonads | Sex organs: testis in males, ovaries in females

Green Revolution | Dramatic improvements in grain production in developing countries during the 1960s to the 1980s because of technological innovation and application

growth | The increase in an animal's size, weight, or tissue mass (muscle and bone) over time, generally from conception to maturity

habituation learning |

A type of operant conditioning; an animal's ability to come to ignore something that occurs often

handling | Any manipulation necessary to care for or evaluate animals; it may or may not include physically touching them

haploid | A cell with half of the usual number of chromosomes. Sex cells are haploid

herbivore | An animal that eats only plant material

herd or flock health management program |

A comprehensive herd or flock-specific program of health management

heredity | The transmission of characteristics from parents to offspring

heritability | The proportion of differences between individuals that is genetic

heterosis | The tendency of a crossbred individual to show qualities superior to those of both parents

heterozygous |

Two different versions of a gene in a pair, one inherited from each parent

hides | Animal skins

high heritability (0.4-0.6) | These traits show little heterosis - carcass merit, composition, and fleece traits

homologous chromosomes |
Chromosomes with the same size and shape, occurring in pairs, and affecting the same traits

homozygous | Two identical versions of a gene in a pair, one inherited from each parent

hunter-gatherer | A group of people who support their needs by hunting game, fishing, and gathering edible and medicinal plants

hybridoma |

A lab-created cell that fuses antibody-producing cells with tumor cells; primarily used to produce monoclonal antibodies (mAbs)

hydroponics | A method of growing plants in water rather than in soil

hypothalamus | The area of the brain responsible for maintaining internal balance (homeostasis) by acting as the body's main control center

ileum |
The last portion of the small intestine

imprint learning | A process where a newborn animal forms a strong, lasting bond with the first moving object it sees

in vitro | In a test tube or other environment outside the body

inbreeding | The mating of closely related individuals

inbreeding depression | A loss or reduction in vigor, viability, or production that usually accompanies inbreeding

incomplete dominance | A condition in the heterozygote where both genes are expressed in a way different from either homozygous condition

infectious disease | An illness caused by germs that invade and multiply in or on the body and cause damage

inflammation |

The body’s natural reaction to injury, infection, or irritation; the body part becomes reddened, swollen, hot, and painful

inheritance | The transfer of gene-containing chromosomes from parent to offspring

inner cell mass | A group of cells found within the blastocyst stage of embryonic development, a source of ES cells

Institutional Animal Care and Use Committee (IACUC) |

A board that reviews research protocols to ensure they meet animal welfare standards

integrated pest management | An approach to managing pests that combines multiple strategies to reduce the need for pesticides

intensive agriculture | Any agriculture system in which much human attention and focus is directed to a small plot of land or to each animal

jejunum | The second and longest portion of the small intestine

Jeremy Bentham | (1789) - British theorist and philosopher who argued that the ability to suffer entitles animals to legal rights

Judeo-Christian philosophy | The basis for pro-animal use in the Western world, it is tied to the concept of human dominion over animals

lesion |
Abnormal body tissue caused by injury or disease

libido | Sexual drive

lifestyle |
The way a person or group lives

limiting amino acid |
The essential amino acid present in the diet at the lowest level relative to the animal's requirement

linebreeding |

The selective breeding of animals for a desired feature involves mating them within a closely related line

Livestock Revolution | Large increases in supply and demand of livestock and animal products worldwide at the end of the 20th century and into the 21st century

locus |
The specific location of a gene on a chromosome

lordosis | The posture assumed by females in estrus is standing still and accepting pressure on their backs

low heritability (0-0.2) | These traits show high levels of heterosis such as reproductive traits

luteinizing hormone (LH) | A gonadotropic hormone that triggers ovulation in females and stimulates testosterone production in males

luteolysis | The breakdown or degeneration of the corpus luteum. Occurs at the end of the luteal phase of the estrous cycle if pregnancy is not detected

maintenance | The nutritional needs of the animal, exclusive of those required for a productive function such as growth, work, milk, or production

marker-assisted selection | Using DNA analysis to identify specific genes and improve the accuracy of selection

market gardening | Specialized production of fruits, vegetables, or vine crops for sale

mastication | Chewing

maternal effect | Any environmental influence that the dam contributes to the phenotype of her offspring

maternal EPDs | In beef cattle, it includes the **Milk EPD** (expected difference in calf weaning weight due to dam's mothering ability/milk production) and the **Combined Maternal EPD** (reflects both milking ability and direct weaning growth transmitted through daughters)

meat | The flesh of animals used for food

meat science | The science of handling, distributing, and marketing meat and meat products. The study of meat, including its production, preparation, and preservation

meiosis |
The process that forms sex cells. Cells formed through meiosis have half the chromosomes of the parent cells

messenger RNA (mRNA) | The nucleic acid that carries instructions to a ribosome for the synthesis of a particular protein

metabolism trial | An advanced form of a digestion trial that measures the body's use of nutrients

micropropagation | a biotechnology that takes cells of a desired plant and uses them to generate genetically identical plants

micturation | Urination

migration |
Introducing new breeding stock into a population

milk EPD | The expected difference in calf weaning weight due to the dam's mothering ability/milk production

minerals | A specific set of inorganic elements that has been established as necessary for life in one or more animal species.

mitosis | The process of somatic cell division

moderate heritability (0.2-0.4) | These traits show moderate levels of heterosis, such as growth traits

monoculture | Producing only one crop or livestock species

monoestrus | Exhibiting only one estrous cycle per year or breeding season

monogastric | An animal with one stomach, a nonruminant

monoploidy | Having a single set of chromosomes

morula | The early-stage embryo, after cell division

mutation | A permanent change in the DNA sequence of an organism

natural selection | Animals better adapted to their environment tend to survive and produce more offspring

necropsy | The examination of an animal's body after death

net merit dollars (NM$) | An economic index calculated by the USDA that measures the relative lifetime profit of a dairy cow

nitrogen-free extract (NFE) | In proximate analysis, a measure of readily available carbohydrates calculated by subtracting all measured proximate components from 100

nose tongs | A small clamp-like restraining device put in an animal's nose

nutrient | A chemical substance that provides nourishment to the body. Essential nutrients are those necessary for normal maintenance, growth, and functioning

nutrient density | A measurement of the nutrients found in a food compared to the caloric content

nutrient requirement | A set of nutrient amounts or concentrations that is needed to maintain health or prevent disease for various species of animals commonly used in agriculture, research, and companion animals

nutrition | The study of the body's needs and mechanisms of acquiring, digesting, transporting, and metabolizing nutrients

olfactory | Relating to the sense of smell

omasum |

The third compartment of the ruminant stomach (found in cows, sheep, and goats) that acts as a filter and absorbs water, electrolytes, and VFAs while reducing feed particle size. Many folds

omnivore | An animal that eats both plant matter and meat

oocyte | The gamete from the female

operant or instrumental conditioning | Learning that occurs through rewards and punishments for behavior

organic agriculture | A farming method that avoids synthetic pesticides and artificial fertilizers

outbreeding |

Mating of unrelated or distantly related individuals

ovulation | The release of the ova or egg from the ovary

pacifier cow | A cow that has been trained to accept moving, restraint, and other types of handling

palatability | The acceptability of a feed or ration to livestock

papillae | Small fingerlike projections that greatly increase the surface area of the small intestine

parent average | An estimate of a young dairy cow’s genetic merit, calculated as the average of its sire's and dam's genetic evaluations

parity | The number of times a female has given birth (a litter counts as one birth)

parturition | Giving birth

passive immunity | Temporary protection against disease provided by antibodies produced outside the animal's own immune system — for example, the antibodies passed from mother to offspring through colostrum

pastoralism | Herding grazing animals

pathogen |
Any disease-producing microorganism; germs

pathogenicity | An organism's capability to produce disease

pathology | The branch of medicine that studies the nature of disease

per capita | Per unit of population

percentile | The percentage of individuals in a group who have achieved a certain quantity or developmental milestone

peristalsis | Progressive muscular contractions that move material through the digestive tract

pesticides | Any agent or poison used to destroy pests, including fungicides, insecticides, herbicides, and rodenticides

Peter Singer | 1975 - wrote the book, Animal Liberation; if a being can suffer, its suffering deserves equal consideration to similar suffering in any other being, regardless of species; he had a tremendous influence on modern animal rights philosophy

pharmacogenomics | A branch of pharmacology that looks at how a variation in animal genetics leads to a variation in response to drugs

pharming | Using transgenic livestock to produce biologically active pharmaceuticals for human medicine

phenotype | The set of observable characteristics, traits, or physical features of an animal

phenotypic frequency |
The proportion of individuals in a population that express a particular phenotype

phenotypic value | The measured or observed amount of a specific trait in an individual

phobia | Excessive and unwarranted fear

physiology | The study of the physical and chemical processes of an animal or any of the body systems or cells of the animal

pica | A craving for and willingness to eat unnatural feedstuffs

pituitary gland | The small, master gland located at the base of the brain in vertebrates

placenta | The organ that surrounds the fetus and unites it to the female while it develops in the uterus

plasmid | A small circular DNA molecule found in bacteria and other microscopic organisms

polyestrus | Exhibiting more than one estrous cycle per year or breeding season

polymerase chain reaction (PCR) | A molecular biology technique used to amplify DNA

polyploidy | Having more than two full sets of chromosomes

population genetics | The study of how gene and genotypic frequencies change, and change the genetic merit of a population

Porcine Stress Syndrome (PSS) | A genetic defect in which heavily muscled pigs have poor carcass quality and may die when subjected to stress

possible change | The measure of the potential error associated with EPD values

postpartum |
After parturition

postpartum interval | The period of time from parturition to the first estrus

predicted transmitting ability (PTA) | An estimate of the genetic merit a dairy bull will pass on to its offspring compared to the breed average

predicted transmitting ability net merit dollars | An economic index that measures the relative lifetime profit of a dairy cow

predisposing cause of disease | Any condition that makes an animal more likely to get sick

pregnancy toxemia | A form of ketosis that occurs in late pregnancy because the female cannot eat enough of the feed she is provided, or is not provided enough feed

prehension | Seizing and grasping food, the first step of digestion

primitive agriculture | Subsistence agriculture, but supplemented with non-agricultural food sources such as hunting and gathering

principle of independent assortment |
Mendel's second law. The alleles for different traits are inherited independently of one another during the formation of gametes

principle of segregation | An organism has two alleles for each gene, but only passes one of those alleles to each offspring

prion | Infectious, abnormally folded proteins that cause fatal neurodegenerative diseases in humans and animals, such as bovine spongiform encephalopathy (BSE)

pro-use philosophy | A stance on animal use that can change as social expectations and scientific understanding evolve

production | The general term that describes the output of usable products and services by animals.

progesterone | A female sex steroid produced by the ovaries

prostaglandin | A group of fatty acid hormones, one of which is prostaglandin F2alpha, which breaks down the corpus luteum, allowing the female to return to estrus

protein | Essential nitrogen-containing compounds composed of long chains of amino acids, acting as the primary building blocks for an animal's body

protozoa | Single-celled organisms that can be parasitic

proventriculus | The glandular stomach in fowl**;** the site of gastric juice (HCl and pepsin) production

proximate analysis | A set of traditional chemical/analytical procedures designed to partition feedstuffs into various nutrient components, including water, ash, crude protein, ether extract, crude fiber, and nitrogen-free extract.

puberty | The transition from reproductive immaturity to maturity, which varies by species but is mainly influenced by age and weight

qualitative traits | Traits, such as coat color, that can be classified into groups

quality grade | The scale that indicates the quality and value of the carcass, such as prime or choice

quantitative traits | Traits that are numerically measured and are usually controlled by many genes, each having a small effect, such as milk or egg production

rate of gain | The pounds an animal gains per day over a specified period

ration | The specific feed allotment given to an animal in a 24-hour period. The use of the term *ration* should be in conjunction with specific quantities of feed.

reassortment | The mixing of genes from two different viruses to create a new virus

recessive | The member of a gene pair that is only expressed when the dominant allele is absent from the animal's genome

recipients | Females used to carry the embryos of a donor animal throughout gestation

recombinant bovine somatotropin (rbST) | Synthetic bovine growth hormone produced by recombinant DNA technology and given to dairy cows to increase milk production

recombinant DNA (rDNA) | A combination of DNA molecules from different biological sources

recombinant DNA technology | Joining together DNA molecules from two different species

reformists | Animal rights proponents who focus on changing and improving the methods of animal use to make them more humane

reliability |
A measure of accuracy for dairy records and evaluations

renewable resources |
Resources that can be replaced or produced by natural ecological cycles or management systems

reproductive cloning | Cloning that uses SCNT technology to create identical animals for research, agriculture, or conservation

resistance | The natural ability of an animal to remain unaffected by pathogens, toxins, irritants, or poisons

restriction enzyme | An enzyme used to recognize a specific DNA sequence and cut it to produce DNA fragments

reticulum | The second, smaller, honeycomb-lined stomach compartment of ruminants acts as a filter and fermentation chamber, helping to break down fibrous foods

ribonucleic acid (RNA) | A vital molecule that acts as a messenger, carrying instructions from DNA to direct the synthesis of proteins

ribosomes | A component of cells that contains protein and tRNA and synthesizes proteins

RNA interference | A lab technique used to target specific mRNA molecules for degradation

ructation |

Belching that removes gas from the rumen

rudimentary sedentary tillage | Permanent, small-scale subsistence farming where farmers cultivate the same plot of land continuously, rather than moving between locations

rumen | The largest of the ruminant forestomachs. Contains microorganisms that degrade complex carbohydrates, produce volatile fatty acids, amino acids, and vitamins

ruminal bloat | An overdistention of the rumen with fermentation gases, also called tympany

ruminant | Hooved animals with a rumen that chew their cud

rumination | Regurgitating, remastication, and reswallowing rumen contents (chewing the cud)

salivation | Secretion of saliva from the salivary glands

savanna | Tall-grass vegetation belts in the hot areas of the world. The same zone found in temperate zones is referred to as prairie.

secondary sex characteristics | Characteristics that differentiate the sexes from each other

selection | The process where animals with advantageous genetic traits are more likely to survive and reproduce, passing those specific genes to the next generation

selection differential | The phenotypic advantage of those chosen to be parents.

selection index | Equations commonly used in swine breeding to simultaneously evaluate two or more traits based on their economic value and selection objectives

self-sufficient | Providing for one's own needs

semen |

Fluid from the male that contains sperm from the testis and other secretions

sensitive periods | Times in an animal's life when certain types of learning are more easily accomplished

Sentient | Creatures that experience or are capable of experiencing pain and pleasure

serologic screening | Antibody identification in blood serum that indicates an immune response against an infectious agent

seropositive |

A level of antibodies in the serum that indicates previous exposure to a microbial agent, either through infection or vaccination

sex-influenced inheritance | The same genotype is expressed differently depending on the sex of the animal

sex-limited traits | Traits expressed in one sex or the other, but both sexes carry genes for the trait. Milk production is an example.

sex-linked inheritance |
Traits inherited on the X or Y chromosome and are inherited only when that respective chromosome is passed on

shelter-seeking behavior | Behaviors animals exhibit to escape from weather, insects, or danger

shifting cultivation | Farmers clear small plots of land, farm them for a few years until the land's fertility declines, then abandon that plot and clear another

single-trait selection | Selection for only one trait or characteristic

sire summary | Publications from breed associations that include EPDs, accuracies, breed averages, and other genetic information on available sires

slash-and-burn agriculture | The practice of clearing a plot of land from the forest by cutting the trees and shrubs and then burning them. Ash from burning fertilizes the soil.

small intestine |

Where absorption primarily occurs, divided into: *Duodenum*, *Jejunum*, and *Ileum*

social structure | The organization of a group

sociobiology |

The study of the biological aspects of social behavior in animals and humans

somatic cell | All cells in the body other than gametes

somatic cell nuclear transfer (SCNT) | A process in which a diploid nucleus from a donor cell is transferred into an enucleated recipient egg

speciesism | Placing the interests of one species above those of another

squeeze chute | A restraining device used to handle livestock

STAGES (Swine Testing and Genetic Evaluation System) | A performance resource developed by the National Swine Registry to help improve the genetics of pigs by calculating traits and predicting genetic value

starch | A complex carbohydrate produced by plants, and they serve as a primary, high-energy feed component

steppes | Short-grass vegetation zones. Steppe vegetation accounts for most of the land area of the world devoted to range livestock production

stereotyped behavior | A nonfunctional, repetitive, intentional, and often rhythmic behavior

stress | A physical, emotional, or chemical factor causing body or mental strain or tension

subclinical infection |

A disease that shows no obvious symptoms

submissive behavior | Behaviors a less-dominant animal exhibits toward a more-dominant animal to prevent being subjected to aggression

subsistence agriculture types | 1. subsistence crop and livestock farming
2. paddy rice farming (intensive subsistence tillage with paddy rice)
3. peasant grain, tuber, and livestock farming (intensive subsistence tillage without paddy rice)
4. urban agriculture
5. aquaculture

sustainable agriculture | Farming that meets today's needs without compromising the ability of future generations to meet theirs

symbiosis | A relationship where dissimilar organisms live in close association. If the relationship is beneficial to both, it is referred to as mutualism. (Symbiotic relationship)

temperament | An animal's nature

testcross | Mating with a fully recessive tester animal to determine if an individual is homozygous or heterozygous

testosterone | The male steroid sex hormone

therapeutic cloning | Cloning that uses SCNT technology for the isolation of embryonic stem cells

Tom Reagan | 1983 - Subject-of-a-Life (S-O-L): animals, like humans, who have beliefs, desires, memory, a sense of the future, and an emotional life, are subjects-of-a-life and possess inherent value; he had a tremendous influence on modern animal rights philosophy

total performance index (TPI) | An economic index used by the Holstein Association to rank sires based on a balance of production and type traits

toxin |
A poisonous compound produced by microorganisms, plants, or animals

transfection | The process of introducing foreign DNA (or RNA) into animal cells using chemicals

transfer RNA (tRNA) | A small RNA molecule that acts as an adapter during protein synthesis, bridging the gap between messenger RNA (mRNA) and amino acids

transgenic | An animal or plant that has had DNA from an external source inserted into its genetic code

transgenic animal | An animal that carries genes from another species, typically used for research, medicine, or agriculture

transgenic organism |
A term used to refer to genetically modified animals

transhumance | The practice of moving animals seasonally from a permanent base to more abundant feed and water and then returning to the permanent base when the season changes.

trisomy | A genetic abnormality where a cell contains three copies of a specific chromosome instead of the normal two

type production index (TPI) | Values that are used to evaluate and rank individual bulls for their ability to transmit production and type to their daughters

ultrasonic scan measures | Measurements of body tissues taken with an ultrasound machine

undernourished | Receiving inadequate nourishment for proper health and growth

urban agriculture | Agriculture is integrated into the urban economic and ecological system; vegetables, fruit, herbs, ornamental plants, meat, eggs, and milk are commonly raised in backyards

utilitarianism | The greatest good for the greatest number; equal weight to similar interests regardless of species

vaccination | An inoculation given to stimulate the immune system to protect against future infection

Van Soest method | A laboratory analysis developed by P.J. Van Soest that provides a method to further partition fiber components within feeds using neutral and acid detergents

vector | An animal, usually an arthropod, that transfers an infectious agent from one host to another ***OR*** a DNA vehicle used to carry foreign genetic material into another cell

vegan | A person who does not eat any food derived from animals or other animal products

ventriculus | A highly specialized, muscular grinding organ that is also known as the gizzard

veterinary feed directive | Written authorization from a licensed veterinarian is required for the use of certain antimicrobial drugs in animal feed

villi | Small fingerlike projections increase the surface area of the small intestine

virulence | Degree of pathogenicity

Vitamin | Essential organic compounds that animals need in small amounts to function, grow, and develop normally

volatile fatty acid (VFA) | A product of ruminal fermentation that is absorbed and supplies 50-70% of ruminant energy requirements

wool | The fiber that grows instead of hair on the bodies of sheep

wool chewing | Often referred to as wool pulling, sheep nibble at their fleece and make bald spots

wool sucking | A prolonged sucking syndrome most frequently observed in cats, where they continue to suck on objects

work |
Physical exertion as a production function

xenotransplantation | The use of organs from genetically engineered animals that are transplanted into humans

zoonotic |
The ability to be passed from animals to humans

zygote | A cell resulting from the fusion of the sperm and the oocyte

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