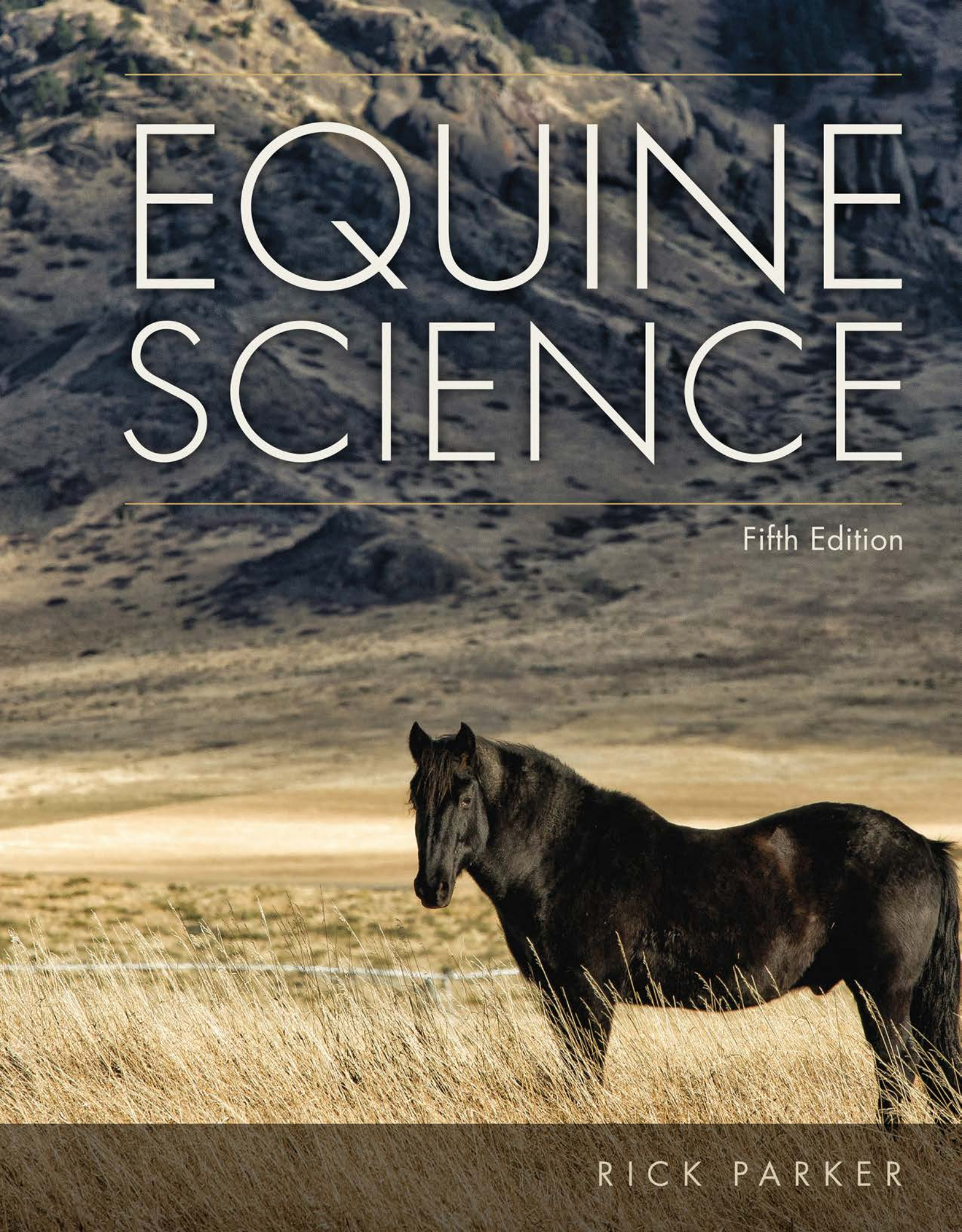
EQUINE SCIENCE

Fifth Edition



RICK PARKER

EQUINE SCIENCE

Fifth Edition

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RICK PARKER

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***Equine Science,* 5th Edition**
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Dedicated to the people who provide meaning and happiness in my life—my wife and our growing extended family.

CONTENTS

Preface ■ xi

About the Author ■ xv

Acknowledgments ■ xvi

Chapter 1 HISTORY AND DEVELOPMENT OF THE HORSE ■ 1

Objectives • Key Terms • Evolution of the Horse • Domestication of the Horse • Mythology and the Horse • History of Horses and Mules in the United States • The Twentieth Century • Summary • Chapter Review • Additional Resources • References

Chapter 2 STATUS AND FUTURE OF THE HORSE INDUSTRY ■ 28

Objectives • Key Terms • World Distribution of Horses, Donkeys, and Mules • Growth and Decline of the U.S. Horse, Donkey, and Mule Industry • Status of the U.S. Horse Industry • Future of the U.S. Horse Industry • Research in the Horse Industry • Summary • Chapter Review • Additional Resources • References

Chapter 3 BREEDS, TYPES, AND CLASSES OF HORSES ■ 48

Objectives • Key Terms • Breeds • Classifications and Types • Common Breeds of Horses • Miniature Horses • Rare Breeds • Wild Horses • Donkeys • Mules • Summary • Chapter Review • Additional Resources • References

Chapter 4 CELLS, TISSUES, AND ORGANS ■ 69

Objectives • Key Terms • Cells • Tissues • Organs • Summary • Chapter Review • Additional Resources • References

Chapter 5 FUNCTIONAL ANATOMY ■ 85

Objectives • Key Terms • Animal Surfaces and Body Systems • The Skeletal System • The Muscular System • The Digestive System • The Urinary System • The Respiratory System • The Circulatory System • The Nervous System • The Reproductive System • The Endocrine System • Summary • Chapter Review • Additional Resources • References

Chapter 6 BIOMECHANICS OF MOVEMENT ■ 118
Objectives • Key Terms • Nervous System Control • How Muscles Contract • Muscle Fibers • Fatigue of Muscles • Heat • Muscles Involved in Gaits • Gaits and Action • Conformation and Action • Common Gait Defects • Center of Gravity • Summary • Chapter Review • Additional Resources • References

Chapter 7 UNSOUNDNESS ■ 136
Objectives • Key Terms • Blemishes Versus Unsoundness • Causes of Unsoundness • Location of Common Blemishes and Unsoundnesses • Stable Vices Affecting Usefulness • Examining Horses for Soundness • Summary • Chapter Review • Additional Resources • References

Chapter 8 SELECTING AND JUDGING HORSES ■ 159
Objectives • Key Terms • Parts of a Horse • Selecting a Horse • Adopting Wild Horses • Judging • Colors and Markings • Horse Scorecard • Qualities of a Judge • How to Become a Horse Judge • Summary • Chapter Review • Additional Resources • References

Chapter 9 DETERMINING AGE, HEIGHT, AND WEIGHT OF HORSES ■ 185
Objectives • Key Terms • Importance of Age • Using Teeth to Determine Age • Structure of the Tooth • Number and Type of Teeth • Other Indicators of Age • Measuring Horses • Summary • Chapter Review • Additional Resources • References

Chapter 10 GENETICS ■ 201
Objectives • Key Terms • Basic Genetics • Coat Color • Genetic Abnormalities • Mules • Summary • Chapter Review • Additional Resources • References

Chapter 11 REPRODUCTION AND BREEDING ■ 223
Objectives • Key Terms • Physiology of Reproduction • Care and Management of the Stallion • Care of the Pregnant Mare • Artificial Insemination • Embryo Transfer • Artificial Control of Breeding • Summary • Chapter Review • Additional Resources • References

Chapter 12 DIGESTION AND NUTRITION ■ 247
Objectives • Key Terms • Evolution of Horse Nutrition • Digestive System—Anatomy and Function • Needs for Feed • Nutrient Needs • Water • Requirements and Allowances • Summary • Chapter Review • Additional Resources • References

Chapter 13 FEEDS AND FEEDING HORSES ■ 268
Objectives • Key Terms • Determining What to Feed • Feeds for Horses • Water • Commercial Feeds • Sample Rations • Calculating Nutrients • Feeding Management Recommendations • Summary • Chapter Review • Additional Resources • References

Chapter 14 HEALTH MANAGEMENT ■ 289
Objectives • Key Terms • Signs of Health • Managing Health through Proper Nutrition • Horse Health Program • Immunity • Vaccinations • Causes of Disease • Diseases of Horses • Zoonosis • Poisonous Plants • First Aid for Horses • Summary • Chapter Review • Additional Resources • References

Chapter 15 PARASITE CONTROL ■ 333
Objectives • Key Terms • Internal Parasites • External Parasites • Flying Insects • Prevention and Control • Summary • Chapter Review • Additional Resources • References

Chapter 16 COMMON MANAGEMENT PRACTICES ■ 354
Objectives • Key Terms • Recognizing Stress in Horses • Marking or Identifying Horses • Minimizing Theft of Horses • Neonatal Procedures • Weaning and Castration • Bedding • Fly Control • Management of Pastures • Wound Management and Basic First Aid • Summary • Chapter Review • Additional Resources • References

Chapter 17 SHOEING AND HOOF CARE ■ 382
Objectives • Key Terms • Structure of the Foot • Care of the Hoof • Horseshoeing • Summary • Chapter Review • Additional Resources • References

Chapter 18 BUILDINGS AND EQUIPMENT ■ 400
Objectives • Key Terms • Recommended Environment • Planning • Space Requirements for Horses • Buildings • Horse Stables • Stalls • Arenas and Indoor Training Facilities • Shelters • Feed and Water Facilities • Fences • Safety First, and Always • Summary • Chapter Review • Additional Resources • References

Chapter 19 HORSE BEHAVIOR AND TRAINING ■ 424
Objectives • Key Terms • Behavior Defined • Learning • Imprinting • Senses • Working with Horse Behavior • Communication and Training • Longeing • Fitness • Summary • Chapter Review • Additional Resources • References

Chapter 20 EQUITATION ■ 448
Objectives • Key Terms • Saddles • Western Equitation • English Equitation • Equitation Competition • Therapeutic Horseback Riding • Loading and Hauling • Haltering • Tying the Horse • Summary • Chapter Review • Additional Resources • References

Chapter 21 BUSINESS ASPECTS ■ 478
Objectives • Key Terms • Evaluating the Costs of Doing Business • Budgets • Records Improve Profitability • Using an

Accounting System for Analysis • Uses and Interpretations of the Statements • Income Tax and Business Type • The Computer in Management Decisions • Credit • Management • Planning—The Secret of Business Success • Setting Goals for Business Management Decisions • Human Resources and the Business • Marketing • Boarding Agreements • Insurance • Summary • Chapter Review • Additional Resources • References

Chapter 22 CAREER OPPORTUNITIES ■ 515

Objectives • Key Terms • Basic Skills and Knowledge • Information Literacy • Personal Qualities • Intangible Skills • Entrepreneurship • Standards • Employment in the Horse Industry • Education and Experience • Equine Industry—Supervised Agricultural Experience • Internships • Identifying a Job • Getting a Job • Occupational Safety • Summary • Chapter Review • Additional Resources • References

Appendix A ■ 542

Appendix B ■ 559

Appendix C ■ 565

Appendix D ■ 579

Glossary/Glosario ■ 581

Index ■ 625

PREFACE

Featuring many new enhancements, *Equine Science*, 5th Edition, continues to expertly weave the scientific principles behind equine growth and development along with the practical matters of owning, caring for, and training horses, and even the aspects of managing an equine business. Appropriate for both general animal science and equestrian programs in secondary and post-secondary levels, this new edition provides the necessary background and the most current information to introduce learners to the equine industry.

SCIENCE AND THE EVOLVING EQUINE INDUSTRY

As the title implies, the focus of these chapters is on science—more specifically, science as it relates to horses. Science represents the knowledge of horses gained through investigation, arranged logically and systematized. Wherever possible, the science of horses is integrated into the discussion so the learners will have a better understanding of reproduction, inheritance, development, growth, training, feeding, nutrition, aging, health, illness, and general management.

Yet that is only the beginning. As we explore the rich culture and history of the equine industry in North America, we discover that the horses are indeed a valuable, if not essential, factor in the development and progression of our society.

Historically, horses contributed to the economy by providing power for transportation and industry. Today, horses still contribute to the economy but in a much different way. The 9.5 million horses in the United States contribute $39 billion annually in direct economic impact and support 1.4 million jobs on a full-time basis. When indirect spending is included, the horse industry's economic impact reaches $102 billion annually. The overall economic impact of horses comes from racing, recreation, sports, rodeos, farm work, pleasure riding, and competitions.

While millions of people participate in the horse industry as spectators, almost 5 million Americans are involved in the industry as horse owners, service providers, employees, and volunteers. Horses are found in every state, and 45 states have at least 20,000 horses. The horse industry is vital and growing. With this vitality and growth comes the need for information about horses, so the numbers of horse-related educational programs, books, pamphlets, videos, and Internet sites are increasing rapidly.

NEW TO THIS EDITION

The fifth edition of *Equine Science*

- **Aligns to National Agriculture, Food and Natural Resources (AFNR) Standards for Animal Systems**—Each chapter opens with correlations to the National AFNR Animal Systems Standards,

linking content to the knowledge and skills essential to preparing students for success in the industry. A complete correlation to the AFNR Standards is also included in Appendix D for easy reference.

- **Strengthens Math and Science Skills**—"Math Connections" and "Science Connections" are integrated throughout the chapters linking the equine industry to math and science concepts and reinforcing learning across the curriculum.
- **Reports Current Statistics**—The latest information from trusted sources, such as the United States Department of Agriculture (USDA) and the Food and Agriculture Organization of the United Nations (FAO), reflect the status of the industry and provide context for topics presented in the chapters.
- **Discusses Current and Relevant Topics**—New and expanded information on current practices and advancements are included, such as the horse genome project, DNA testing, RFID, planning for facilities, QR codes, and more.
- **Provides New Listicles**—Various new informational tables for aspects of managing the health and nutrition of horses, as well as training, riding, and showing horses, and managing an equine facility, are included as handy references for learners.

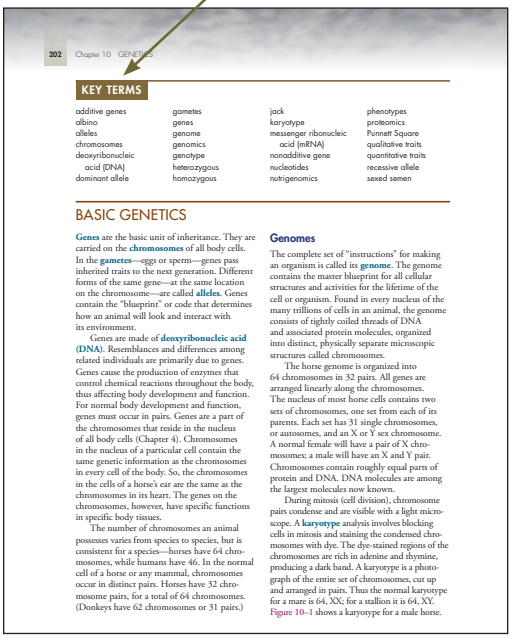
FEATURES OF THIS EDITION

Objectives

Learning is difficult without knowing what is required. Each chapter opens with a list of **learning objectives**. These help the student and instructor identify the most important concepts from all the information in the chapter.

Key Terms

Each chapter also opens with a list of **key terms**. Knowing the meaning of these terms is essential to reading and understanding the chapter.



202 Chapter 10 GENETICS

KEY TERMS

additive genes, albino, alleles, chromosomes, deoxyribonucleic acid (DNA), dominant allele, gametes, genes, genome, genomics, genotype, heterozygous, homozygous, jack, karyotype, messenger ribonucleic acid (mRNA), nonadditive gene, nucleotides, nutrigenomics, phenotypes, proteomics, Punnett Square, qualitative traits, quantitative traits, recessive allele, sexed semen

BASIC GENETICS

Genes are the basic unit of inheritance. They are carried on the **chromosomes** of all body cells. In the **gametes**—eggs or sperm—genes pass inherited traits to the next generation. Different forms of the same gene—at the same location on the chromosome—are called **alleles**. Genes contain the "blueprint" or code that determines how an animal will look and interact with its environment.

Genes are made of **deoxyribonucleic acid (DNA)**. Resemblances and differences among related individuals are primarily due to genes. Genes cause the production of enzymes that control chemical reactions throughout the body, thus affecting body development and function. For normal body development and function, genes must occur in pairs. Genes are a part of the chromosomes that reside in the nucleus of all body cells (Chapter 4). Chromosomes in the nucleus of a particular cell contain the same genetic information as the chromosomes in every cell of the body. So, the chromosomes in the cells of a horse's ear are the same as the chromosomes in its heart. The genes on the chromosomes, however, have specific functions in specific body tissues.

The number of chromosomes an animal possesses varies from species to species, but is consistent for a species—horses have 64 chromosomes, while humans have 46. In the normal cell of a horse or any mammal, chromosomes occur in distinct pairs. Horses have 32 chromosome pairs, for a total of 64 chromosomes. (Donkeys have 62 chromosomes or 31 pairs.)

Genomes

The complete set of "instructions" for making an organism is called its **genome**. The genome contains the master blueprint for all cellular structures and activities for the lifetime of the cell or organism. Found in every nucleus of the many trillions of cells in an animal, the genome consists of tightly coiled threads of DNA and associated protein molecules, organized into distinct, physically separate microscopic structures called chromosomes.

The horse genome is organized into 64 chromosomes in 32 pairs. All genes are arranged linearly along the chromosomes. The nucleus of most horse cells contains two sets of chromosomes, one set from each of its parents. Each set has 31 single chromosomes, or autosomes, and an X or Y sex chromosome. A normal female will have a pair of X chromosomes; a male will have an X and Y pair. Chromosomes contain roughly equal parts of protein and DNA. DNA molecules are among the largest molecules now known.

During mitosis (cell division), chromosome pairs condense and are visible with a light microscope. A **karyotype** analysis involves blocking cells in mitosis and staining the condensed chromosomes with dye. The dye-stained regions of the chromosomes are rich in adenine and thymine, producing a dark band. A karyotype is a photograph of the entire set of chromosomes, cut up and arranged in pairs. Thus the normal karyotype for a mare is 64, XX; for a stallion it is 64, XY. Figure 10–1 shows a karyotype for a male horse.

Chapter 16

COMMON MANAGEMENT PRACTICES

Successful ownership and enjoyment of horses depends on a solid knowledge of horses and good management practices. Management is knowledge in action. Many of the management practices for horses have already been discussed in other chapters. This chapter covers management topics not discussed elsewhere: dealing with stress in horses; identifying horses; neonatal, weaning, and castration decisions; stall maintenance; fly control; pasture maintenance; and wound management.

ANIMAL SYSTEMS CAREER CLUSTER CONTENT STANDARDS
AS.02 Utilize best-practice protocols based upon animal behaviors for animal husbandry and welfare.
AS.07 Apply principles of effective animal health care.

OBJECTIVES

After completing this chapter, you should be able to:

- Recognize stress in horses
- Describe methods of marking and identifying horses
- Discuss procedures for the neonatal foal
- List methods of fly control
- Describe common fly problems and the habits of several species
- Explain the best management practices for pastures and forages
- Describe wound types and their proper management
- Discuss the management considerations when weaning a foal
- Explain the importance of records to the management of horses

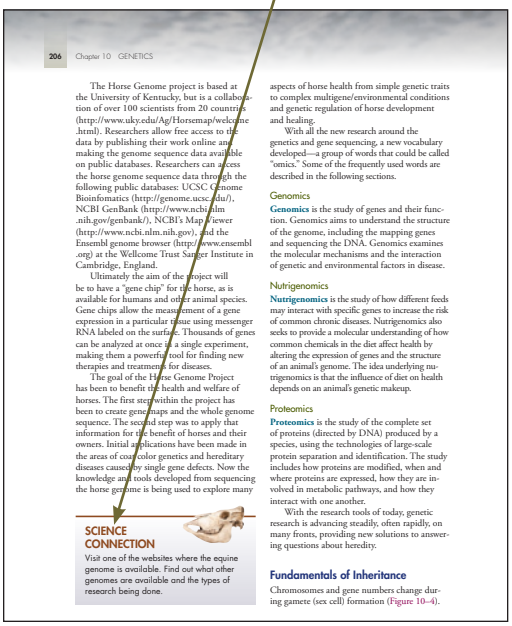
354

National AFNR Standard

Correlations at the beginning of each chapter link content to the **National AFNR *Animal Systems* Content Standards** for ease of reference.

Math and Science Connections

New to this edition, the **Math and Science Connections** link what students are learning to essential math and science skills.


206 Chapter 10 GENETICS

The Horse Genome project is based at the University of Kentucky, but is a collaboration of over 100 scientists from 20 countries (http://www.uky.edu/Ag/Horsemap/welcome.html). Researchers allow free access to the data by publishing their work online and making the genome sequence data available on public databases. Researchers can access the horse genome sequence data through the following public databases: UCSC Genome Bioinfomatics (http://genome.ucsc.edu/), NCBI GenBank (http://www.ncbi.nlm.nih.gov/genbank/), NCBI's Map Viewer (http://www.ncbi.nlm.nih.gov), and the Ensembl genome browser (http://www.ensembl.org) at the Wellcome Trust Sanger Institute in Cambridge, England.

Ultimately the aim of the project will be to have a "gene chip" for the horse, as is available for humans and other animal species. Gene chips allow the measurement of a gene expression in a particular tissue using messenger RNA labeled on the surface. Thousands of genes can be analyzed at once in a single experiment, making them a powerful tool for finding new therapies and treatments for diseases.

The goal of the Horse Genome Project has been to benefit the health and welfare of horses. The first step within the project has been to create gene maps and the whole genome sequence. The second step was to apply that information for the benefit of horses and their owners. Initial applications have been made in the areas of coat color genetics and hereditary diseases caused by single gene defects. Now the knowledge and tools developed from sequencing the horse genome is being used to explore many aspects of horse health from simple genetic traits to complex multigene/environmental conditions and genetic regulation of horse development and healing.

With all the new research around the genetics and gene sequencing, a new vocabulary developed—a group of words that could be called "omics." Some of the frequently used words are described in the following sections.

Genomics

Genomics is the study of genes and their function. Genomics aims to understand the structure of the genome, including the mapping genes and sequencing the DNA. Genomics examines the molecular mechanisms and the interaction of genetic and environmental factors in disease.

Nutrigenomics

Nutrigenomics is the study of how different feeds may interact with specific genes to increase the risk of common chronic diseases. Nutrigenomics also seeks to provide a molecular understanding of how common chemicals in the diet affect health by altering the expression of genes and the structure of an animal's genome. The idea underlying nutrigenomics is that the influence of diet on health depends on an animal's genetic makeup.

Proteomics

Proteomics is the study of the complete set of proteins (directed by DNA) produced by a species, using the technologies of large-scale protein separation and identification. The study includes how proteins are modified, when and where proteins are expressed, how they are involved in metabolic pathways, and how they interact with one another.

With the research tools of today, genetic research is advancing steadily, often rapidly, on many fronts, providing new solutions to answering questions about heredity.

Fundamentals of Inheritance

Chromosomes and gene numbers change during gamete (sex cell) formation (Figure 10–4).

SCIENCE CONNECTION

Visit one of the websites where the equine genome is available. Find out what other genomes are available and the types of research being done.


274 Chapter 13 FEEDS AND FEEDING HORSES

are lost from shattering, and the leaves become wiry and low in digestibility.

Grass Hays. Grass hays yield less per acre and are lower in protein, calcium, and vitamins, but they are less likely to be moldy and dusty than legume hays. They are usually cut too late to yield quality hay and often are priced higher than their feeding value justifies.

Grass hays (Figure 13–1) often are grown and harvested in mixtures with legumes to produce an excellent combination suitable for almost any kind of horse feeding program.

Timothy. No other hay has had the lasting popularity of timothy. Its wide range of climatic adaptability, ease of curing, bright color, and freedom from dust and mold make it the horse owner's favorite. Since it is low in protein, it is a better feed for mature work horses than for stallions, mares, or young, growing stock. If it is fed as the only roughage, it should be supplemented with protein or fed with a high-protein grain such as oats instead of corn. Special effort need not be made to obtain timothy; it can be satisfactorily substituted for in all horse rations. Mature, late-cut timothy is a poor feed for any class of livestock.

MATH CONNECTION

Good quality orchard grass hay can be purchased for $200.00 per ton and early bloom alfalfa hay can be purchased for $310.00 per ton. Which hay is a better purchase in terms of the cost of the digestible energy (DE)?

Prairie Grass. Some horse owners substitute prairie hay satisfactorily for timothy. However, it is lower in protein, less bright in color, and usually less palatable than timothy.

Bromegrass. Bromegrass makes good horse hay. It is palatable when harvested in the bloom stage.

Orchard Grass. Orchard grass is much like bromegrass but not quite as satisfactory.

Cereal Grasses. Cereals make good hays when cut early. They should be cut in the soft to stiff dough stage. They are seldom cut early enough. Oats, barley, wheat, and rye hays are preferred, in that order. Extensive use is made of these in the Pacific Coast region.

Figure 13–1 Grass hays mixed with legumes provide an excellent combination suitable for almost any kind of horse feeding program.

Feature Articles

Each chapter includes an **engaging article** related to the chapter topic that serves to spark student enthusiasm and encourage further learning.


64 Chapter 3 BREEDS, TYPES, AND CLASSES OF HORSES

SEABISCUIT

From a dubious start, Seabiscuit became an unlikely champion and a symbol of hope to many Americans during the Great Depression. Seabiscuit was foaled on May 23, 1933, from the mare Swing On and sired by Hard Tack, a son of Man o' War. Seabiscuit was named for his sire, Hard Tack. "Sea biscuit" is the name for a type of cracker eaten by sailors.

The bay colt grew up on Claiborne Farm in Paris, Kentucky. He was owned by Gladys Mills Phipps. He was undersized, knobby-kneed, and lazy. Initially, he was trained by Sunny Jim Fitzsimmons, the trainer who had taken Gallant Fox to the U.S. Triple Crown of Thoroughbred racing. Fitzsimmons saw some potential in Seabiscuit, but felt the horse was too lazy. Seabiscuit was consigned to a punishing schedule of smaller races. He failed to win his first ten races, usually finishing back in the field. As a two-year-old, Seabiscuit raced 35 times, coming in first five times, and finishing second seven times. These included three claiming races, in which he could have been purchased for $2,500, but no one wanted to buy him. The next season, Seabiscuit was again less than spectacular. His owners sold the horse to the California automobile entrepreneur Charles S. Howard for $8,000. His new trainer, Tom Smith, gradually brought Seabiscuit out of his lethargy.

In 1937, Seabiscuit won 11 of his 15 races and was the year's leading money winner in the United States. However, it was War Admiral, having won the Triple Crown that season, who was voted "Horse of the Year."

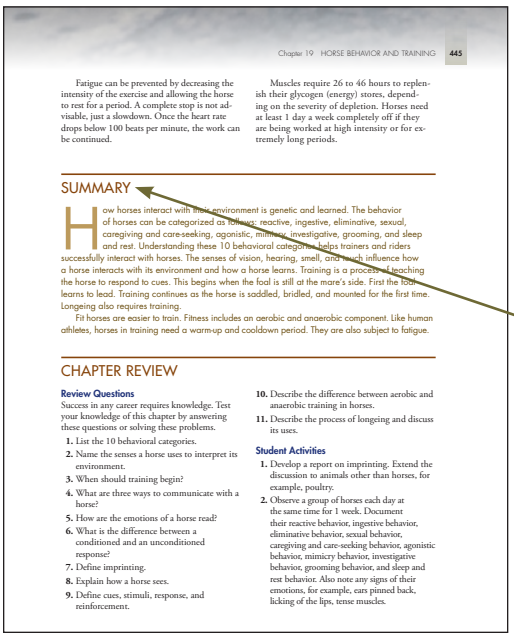
On November 1, 1938, Seabiscuit raced War Admiral in the "Match of the Century." The race was run over 13/16 miles (1.91 km), at the Pimlico Race Course in Baltimore, Maryland. Trains were run from all over the country to bring fans to the race. The estimated 40,000 at the track were joined by some 40 million listening on the radio. War Admiral was the near unanimous favorite.

When the bell rang, Seabiscuit ran away from the Triple Crown champion. Halfway down the backstretch, War Admiral started to cut into the lead, gradually pulling level with Seabiscuit, and then slightly ahead. The jockey had eased up on Seabiscuit, allowing his horse to see his rival, and then asked for more effort. Two hundred yards from the wire, Seabiscuit pulled away again and continued to extend his lead, finally winning by four lengths, despite War Admiral running his best time for the distance. (Watch Seabiscuit vs. War Admiral on YouTube [http://www.youtube.com/watch?v=WVT2MPNCqgM].)

As a result of his races that year and the victory over War Admiral, Seabiscuit was named "Horse of the Year" for 1938. Seabiscuit was also the number one newsmaker of 1938. On April 10, 1940, Seabiscuit's retirement from racing was officially announced. At the time of his retirement, Seabiscuit was horse racing's all-time leading money winner. Put out to stud, Seabiscuit sired 108 foals. He died May 17, 1947. On June 23, 2007, a statue of Seabiscuit was unveiled at his home and final resting place, Ridgewood Ranch near Willits, California.

Seabiscuit became the subject of a 1949 film, *The Story of Seabiscuit*, starring Shirley Temple; a 2001 book, *Seabiscuit: An American Legend*; and a 2003 film, *Seabiscuit*.

In the *Blood-Horse* magazine's ranking of the top 100 U.S. Thoroughbred champions of the 20th century, Seabiscuit was ranked twenty-fifth. War Admiral was thirteenth, and Seabiscuit's grandsire and War Admiral's sire, Man o' War, placed first.


Chapter 19 HORSE BEHAVIOR AND TRAINING 445

Fatigue can be prevented by decreasing the intensity of the exercise and allowing the horse to rest for a period. A complete stop is not advisable, just a slowdown. Once the heart rate drops below 100 beats per minute, the work can be continued.

Muscles require 26 to 46 hours to replenish their glycogen (energy) stores, depending on the severity of depletion. Horses need at least 1 day a week completely off if they are being worked at high intensity or for extremely long periods.

SUMMARY

How horses interact with their environment is genetic and learned. The behavior of horses can be categorized as follows: reactive, ingestive, eliminative, sexual, caregiving and care-seeking, agonistic, mimicry, investigative, grooming, and sleep and rest. Understanding these 10 behavioral categories helps trainers and riders successfully interact with horses. The senses of vision, hearing, smell, and touch influence how a horse interacts with its environment and how a horse learns. Training is a process of teaching the horse to respond to cues. This begins when the foal is still at the mare's side. First the foal learns to lead. Training continues as the horse is saddled, bridled, and mounted for the first time. Longeing also requires training.

Fit horses are easier to train. Fitness includes an aerobic and anaerobic component. Like human athletes, horses in training need a warm-up and cooldown period. They are also subject to fatigue.

CHAPTER REVIEW

Review Questions

Success in any career requires knowledge. Test your knowledge of this chapter by answering these questions or solving these problems.

1. List the 10 behavioral categories.
2. Name the senses a horse uses to interpret its environment.
3. When should training begin?
4. What are three ways to communicate with a horse?
5. How are the emotions of a horse read?
6. What is the difference between a conditioned and an unconditioned response?
7. Define imprinting.
8. Explain how a horse sees.
9. Define cues, stimuli, response, and reinforcement.
10. Describe the difference between aerobic and anaerobic training in horses.
11. Describe the process of longeing and discuss its uses.

Student Activities

1. Develop a report on imprinting. Extend the discussion to animals other than horses, for example, poultry.
2. Observe a group of horses each day at the same time for 1 week. Document their reactive behavior, ingestive behavior, eliminative behavior, sexual behavior, caregiving and care-seeking behavior, agonistic behavior, mimicry behavior, investigative behavior, grooming behavior, and sleep and rest behavior. Also note any signs of their emotions, for example, ears pinned back, licking of the lips, tense muscles.

Summary and Chapter Review

These chapter features encourage students to review and apply what they have learned in the lesson. In addition to **Review Questions** and **Student Activities**, there are **Additional Resources** and **References** to empower students to further explore the topics presented in the chapter.

EXTENSIVE TEACHING/LEARNING PACKAGE

This package was developed to achieve two goals:

1. To provide students with an engaging experience as they embark on the learning pathway through their equine science course
2. To assist instructors in planning and implementing their instructional program for the most efficient use of time and other resources

Companion Site

NEW! The companion website to accompany *Equine Science* features tools to support learning and facilitate teaching:

- **Answers to Review Questions** appearing at the end of each chapter allow teachers to track and validate student learning.
- **Lesson Plans** provide an outline of the key topics in each chapter, and correlate to the accompanying PowerPoint® presentations.
- **PowerPoint®** presentations align with the Lesson Plans and include photos and illustrations to visually reinforce the key points in each chapter.
- **Testing powered by Cognero,** a flexible online system, provides chapter-by-chapter quizzes and enables teachers to:
  - Author, edit, and manage test bank content from multiple sources
  - Create multiple test versions in an instant
  - Deliver tests from teacher/school-specific learning management system (LMS) or classrooms
- **Image Gallery** offers full-color photos and illustrations from the text to enable teachers to further enhance classroom presentations.

For these instructor-specific resources, please visit CengageBrain.com at http://login.cengage.com and follow the prompts for obtaining access this secure site.

Mindtap for Equine Science 5E

NEW! The MindTap for *Equine Science*, 5th Edition, features an integrated course offering a complete digital experience for the student and teacher. This MindTap is highly customizable and combines assignments, videos, interactivities, and quizzing along with the enhanced ebook to enable students to directly analyze and apply what they are learning and allow teachers to measure skills and outcomes with ease.

- **A Guide:** Relevant interactivities, combined with prescribed readings, featured multimedia, and quizzing to evaluate progress, will guide students from basic knowledge and comprehension to analysis and application.
- **Personalized Teaching:** Teachers are able to control course content—hiding, rearranging existing content, or adding and creating content to meet the needs of their specific program.
- **Promote Better Outcomes:** Through relevant and engaging content, assignments, and activities, students are able to build the confidence they need to ultimately lead them to success. Likewise, teachers are able to view analytics and reports that provide a snapshot of class progress, time in course, engagement, and completion rates.

ABOUT THE AUTHOR

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Chapter 1

HISTORY AND DEVELOPMENT OF THE HORSE

ANIMAL SYSTEMS CAREER CLUSTER CONTENT STANDARD AS.01 Analyze historic and current trends impacting the animal systems industry.

Since prehistoric times, the swift and powerful horse has been domesticated by human beings for use as a draft animal, for transportation, and in warfare, and it has figured notably in art and mythology. Riding horses was not practical until suitable bits and other controlling devices were invented, and the horse did not replace humans and oxen at heavy farm labor until the appearance of an efficient harness. Today, horses are used primarily for sports such as racing, show competition, rodeos, and simple riding for pleasure. Horseflesh has occasionally been consumed by humans since prehistoric times, and it is used as a pet food.

A large herbivore adapted for running, the horse, *Equus caballus*, is a mammal of the family *Equidae*, order *Perissodactyla*.

OBJECTIVES

After completing this chapter, you should be able to:

- Name the major evolutionary horselike animals
- Identify the position of the horse in the zoological scheme
- Describe how humans eventually changed the way they used the horse
- Give the scientific name for the horse and three of its close relatives
- List the four evolutionary trends exhibited by horse fossils
- Identify the Romans' influences on the use of the horse
- Describe the effect of the Middle Ages and the Renaissance on the use of horses
- Name three horses in mythology or legend
- Name three famous horses of the films
- Describe the use and decline of horses in agriculture in the United States
- Discuss how racing started in the United States
- Identify the factors that changed the use of horses in the 20th century
- Name four geologic time periods (epochs) used to discuss the evolution of the horse

KEY TERMS

cavalry
centaur
draft
Eocene epoch
Eohippus
evolution
gelding
hackamore
hippology
hybrids
Miocene epoch
monodactyl
Morrill Land Grant Act
mules
Oligocene epoch
onagers
Paleocene epoch
Pleistocene epoch
Pliocene epoch
Przewalski's horse
rodeo
steppes

EVOLUTION OF THE HORSE

Evolution of the horse did not occur in a straight line toward a goal, like the steps on a ladder. Rather, it was like a branching bush, with no predetermined end. Many horselike animals branched off the evolutionary tree and evolved along various unrelated routes, with differing numbers of toes and adaptations to different diets. Now one genus—*Equus*—is the only surviving branch of a once mighty and sprawling evolutionary bush. Of the several species within that genus, *Equus caballus* is today's true horse. Here's how it fits into the zoological scheme:

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Perissodactyla
Family: Equidae
Genus: *Equus*

Equus asinus—the true asses and donkeys of northern Africa. (The African wild ass is sometimes called *Equus africanus.*)
Equus burchelli—the Plains zebra of Africa, including Grant's zebra, Burchell's zebra, Chapman's zebra, the half-striped Quagga, and other subspecies. The Plains zebra is what people usually think of as the "typical" zebra, with rather wide vertical stripes and thick horizontal stripes on the rump.
Equus caballus—the true horse, which once had several subspecies.
Equus grevyi—Grevy's zebra, the most horselike zebra. This is the big zebra with the very narrow vertical stripes and huge ears.
Equus hemionus—the desert-adapted **onagers** of Asia and the Mideast, including the kiang.
Equus przewalski—the oldest living species of horse, discovered in remote Mongolia. (*Equus caballus* first appeared in Central Asia, probably as **Przewalski's horse**.)
Equus zebra—the Mountain zebra of South Africa. This is the little zebra with the dewlap and the gridiron pattern on its rump.

Study of Horses

The Greek word for horse is *hippos*. **Hippology** is the study of horses, and the term is used frequently to describe contests in which individuals or teams exhibit their knowledge and understanding of equine science and husbandry. Participants demonstrate their experience and knowledge gained in horse judging, quiz bowl, speeches, and practical horse management.

Geologic Time Scale and the Fossil Record

Geologists and other scientists use the geologic time scale to describe the timing and relationships between events that have occurred during the Earth's history.

The Earth is very old—4.5 billion years or more. This vast span of time, called geologic time by earth scientists, is difficult to comprehend in the familiar time units of months and years, or even centuries. The geologic time of Earth's past has been organized into various units according

SCIENCE CONNECTION

Geologic periods are standardized by the International Commission on Stratigraphy (http://www.stratigraphy.org/) and the United States Geologic Survey (http://www.usgs.gov/) or USGS Geologic Time Online Edition (http://pubs.usgs.gov/gip/geotime/). Find the geologic periods for the horse in relation to other geologic period described by these two websites.

to events that took place in each period. Different spans of time on the time scale are usually delimited by major geologic or fossil events. Earth's age is locked up in its rock layers and the fossils in those layers. Scientists studying these layers and fossils have assigned names to the divisions of geologic time. Major divisions are called eras, and eras are divided into periods, and periods are divided into epochs. Each of these divisions is expressed in terms of millions of years.

Eohippus

The earliest ancestor of the present horse, **Eohippus** or **Hyracotherium**, was a small, primitive horse about the size of a fox (Figure 1–1). It had an elongated skull, a moderately arched back, and a shortened tail. There were four functional toes on each front foot, but only three toes on each hind foot. The structure of its teeth suggests that it was a browser. The earliest remains of this extinct animal are found in rocks of the late **Paleocene epoch** (about 54 million years old) in North America. More recent fossils have been found in rocks of the **Eocene epoch** (about 50 million years old) in Europe.

Mesohippus

During the **Oligocene epoch**, about 35 million years ago, Earth's temperature and climate changed; conifers began to outnumber deciduous trees. The forest thinned, grass became more prevalent, and *Mesohippus* appeared (Figure 1–2). This animal was larger than *Eohippus*. Its teeth had further evolved. It had only three toes on its front feet and was better suited to outrunning its enemies. As swamp gave way to soft ground, toes became less essential. On *Mesohippus*, the lateral supporting toes decreased in size while the middle toe strengthened. The toes now ended in little hooves that still had a pad behind them.
In both Europe and North America, these browsing horses became extinct about 7 million years ago.

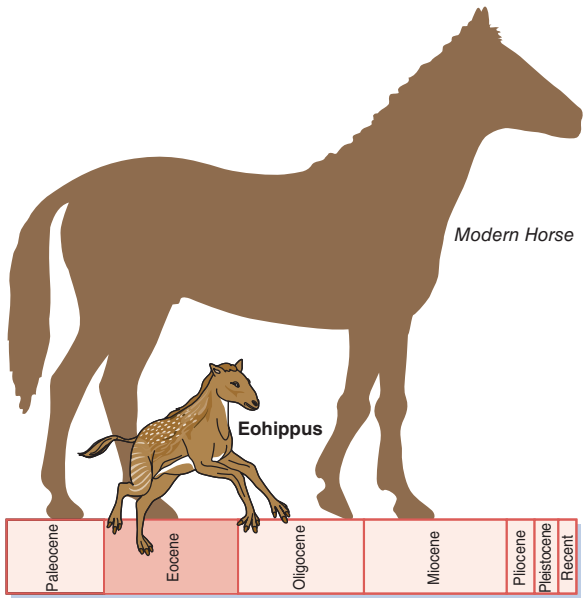

Figure 1–1 *Eohippus.*

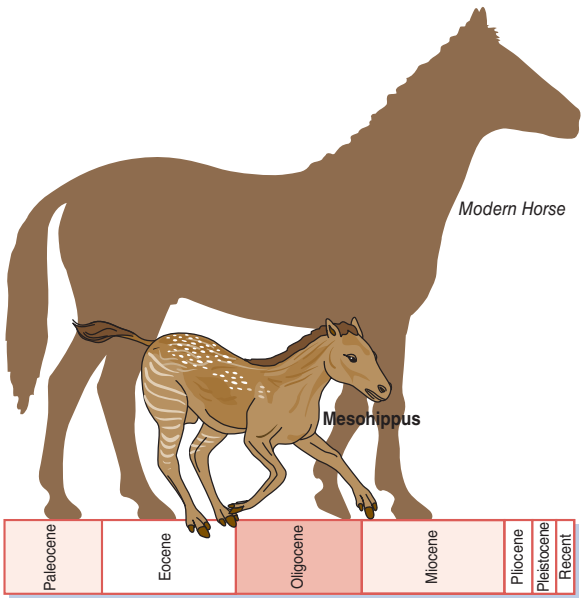

Figure 1–2 *Mesohippus.*

Merychippus

In the **Miocene epoch**, about 20 million years ago, a new type of horse appeared. *Merychippus* evolved in North America and adapted to the grasses of the plains (Figure 1–3). This was the beginning of the grazing horse of today, and its height was about 35 inches. *Merychippus* was increasingly gregarious and lived in herds. To chew the rough grass, *Merychippus* developed complicated grinding teeth similar to those of present-day horses. Its lateral toes shrank and no longer reached the ground. The main toe thickened and hardened for swift travel on the dry ground. The feet had no pads and the weight was carried on an enlarged single hoof on the central toe.

Pliohippus

At the beginning of the **Pliocene epoch**, about 5 million years ago, one branch of the horse ancestor crossed into Asia, quickly multiplied, and spread to Europe. Meanwhile, in North America, the horse developed into its final form. *Pliohippus* was the first true **monodactyl** (one-toed animal) of evolutionary history (Figure 1–4). *Pliohippus* needed speed to outrun its enemies, so the hoof evolved from the continued overdevelopment of the middle toe. Its teeth and limbs were the nearest to our present-day horses. This horse now spread into South America, Asia, Europe, and Africa.

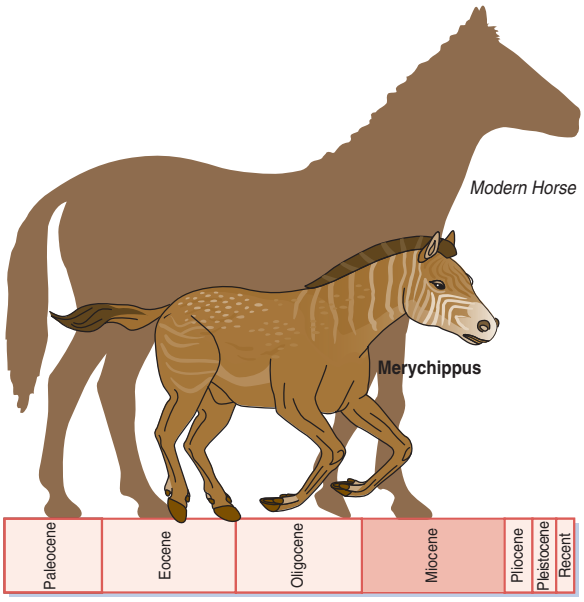

Figure 1–3 *Merychippus.*

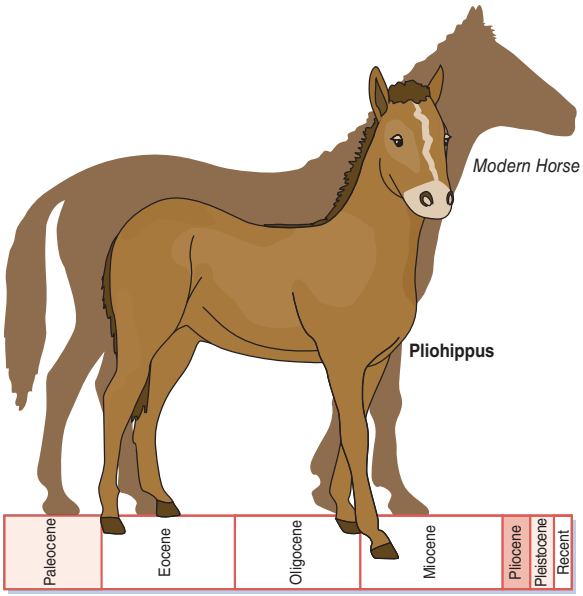

Figure 1–4 *Pliohippus.*

The last 2 million years, from the present to the **Pleistocene epoch**, represent the final evolutionary stage of *Equus.* About 8,000 years ago, *Equus* became extinct in the Western Hemisphere, returning when the Spanish brought horses to the New World in the 1400s.

Some examples of extinct horses that once roamed the western hemisphere include the Hagerman Horse (*Equus simplicidens*) found in the Hagerman, Idaho, Fossil Beds National Monument (Figure 1–5). Two more examples of extinct western hemisphere horses (Figure 1–6) were found in the Rancho La Brea, California, tar pits: the Western Horse (*Equus occidentalis*)

MATH CONNECTION

A discussion of evolution involves millions to thousands of years. Mathematically compare 50 million years ago to 20 million years ago, 5 million years ago, 2 million years ago, and 8,000 years ago.

Figure 1–5 Horse bones found in the Hagerman, Idaho, fossil beds. These have been on display at the Smithsonian Institute. Photo courtesy of Dr. Greg McDonal

Figure 1–6 Skeleton of Western horse found in the Rancho La Brea tar pits.

and the smaller Mexican donkey (*Equus conversidens*). Both of these species died out near the end of the Pleistocene epoch, approximately 11,000 years ago.

Skeletons of the Western horses found in the tar pits at Rancho La Brea suggest that the horse stood about 14.5 hands high and probably weighed about 1,150 pounds (http://www.tarpits.org/).

How Evolution Works

Because evolution is not linear but branching, common evolutionary trends are not seen in all of the horse lines. Overall, horses got progressively larger, but some (*Archeohippus, Calippus*) then got smaller again. Many evolved complex pits in their facial bones only to have some of their descendants lose them again. Most of the recent (5 to 10 million years) horses were three-toed, not one-toed. One-toed animals prevailed only because all the three-toed lines became extinct.

Additionally, these traits did not necessarily evolve together, or at a steady rate. Various structural characteristics evolved in an interrupted series of changes. For example, throughout the Eocene epoch, feet changed little, and only the teeth evolved. During the Miocene, however, both feet and teeth evolved rapidly. Rates of evolution depended on the ecological pressures facing the species.

Evolving along with the modern horse were other species of *Equus,* such as the ass, or donkey, the onager, and the various zebras.

Tracing a line of descent from *Eohippus* to *Equus,* fossils reveal four trends (Figure 1–7):

- Reduction in the number of toes
- Increase in the size of the cheek teeth
- Lengthening of the face
- Increase in body size

Przewalski's Horse

The oldest species of horse still in existence is the wild Przewalski's horse, pronounced "sheh-val-skee" (*Equus ferus przewalski*). Ironically, it was not discovered until 1879, when the Russian Army captain Nikolai Mikailovich Przewalski sighted it in the remote valleys of Mongolia. The modern Przewalski's horse resembles many of the animals appearing in the cave paintings at Lascaux, France. It stands 12 to 14 hands high, has a dun (yellowish) coloring, a light-colored muzzle, a short, upstanding mane, a dark streak along its back, and dark legs (Figure 1–8). In its native Mongolia it feeds on tamarisk, feather grass, and the white roots of

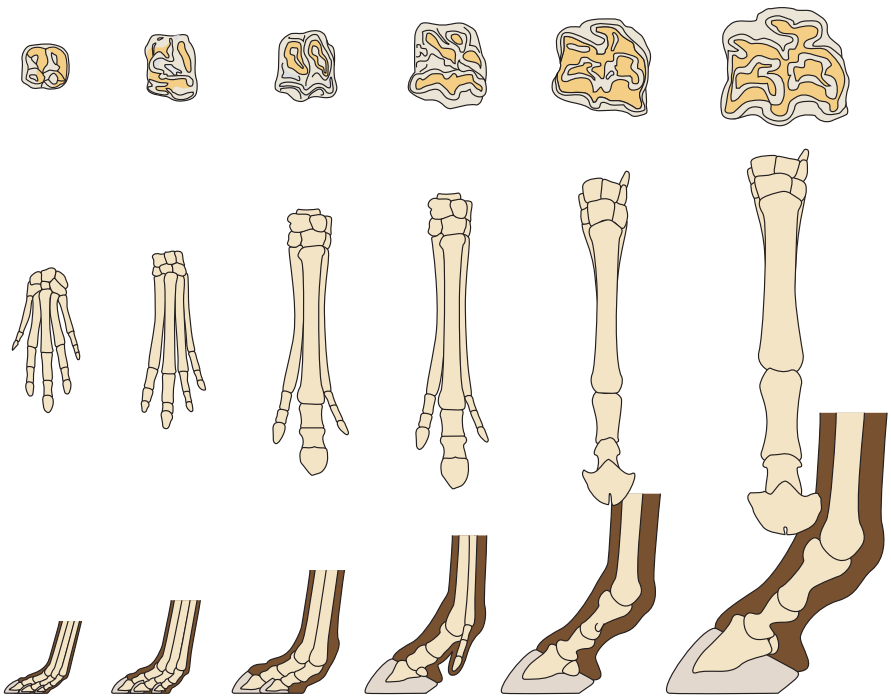

Figure 1–7 Evolution of the horse hoof and tooth.

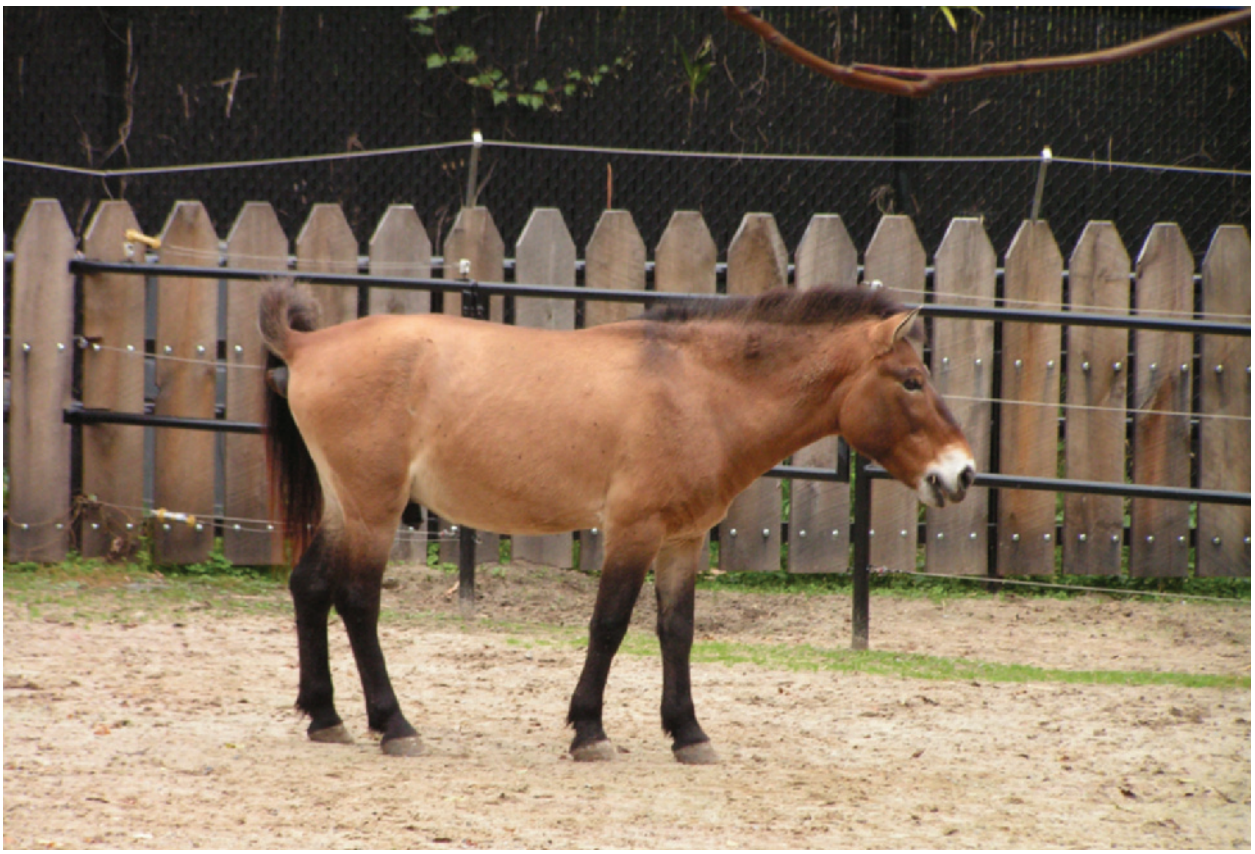

Figure 1–8 Przewalski's horse at the Smithsonian National Zoological Park in Washington, DC.

rhubarb. The former Soviet Union established a refuge for the horse in the late 1970s to ensure both its continued existence and its freedom.

Although held in captivity in many zoos around the world, the Przewalski's horse has never been effectively tamed or domesticated. The horse can be seen at the Smithsonian National Zoological Park in Washington, DC (https://nationalzoo.si.edu/animals/przewalskis-horse).

The Hunted Horse

Humankind's first relationship with the horse comes from Stone Age paintings on the walls of caves in Western Europe. Although frequently showing the horse as an object of prey, these prehistoric cave paintings also reveal the majesty the artists saw in the horse as well as the effort to capture its beauty.

Cro-Magnons primarily considered the horse an important source of food. Lacking the speed to pursue it or a way to kill it from a distance, prehistoric hunters learned to drive the prey to its death. Evidence of this can be found at Salutre in France, where the bones of some 10,000 horses dating from that period have been found at the base of a cliff.

DOMESTICATION OF THE HORSE

For perhaps half a million years, humankind's only contact with the horse was as a hunter in search of food. Between 4000 and 3000 B.C., humans began to domesticate horses on the **steppes** north of the Black Sea. Oxen were already being yoked in draft in Mesopotamia, and by the early third millennium B.C., asses and onagers (wild donkeys of central Asia) had been similarly harnessed there (Figure 1–9). When the horse was introduced to the region in numbers during the early second millennium B.C., a tradition of driving was already well established.

While some of the history of the domestic horse is rather obscure, our knowledge of the donkey is more certain. Artifacts suggest that donkeys were first domesticated in Egypt as early as 3400 B.C., and by 1000 B.C. had spread from Egypt into Asia.

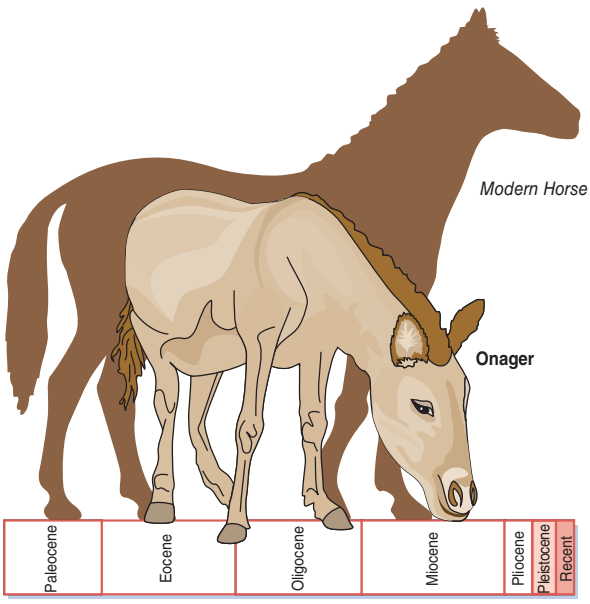

Figure 1–9 Onager.

From Cow of the Plains to Pack Animal

Archaeological excavations show that the horse became progressively important in the economy of the people of the plains of Europe and Asia. Still considered a source of food, tame horses were evidently first kept for meat and possibly their milk. Later, as these domesticated animals began to carry the goods of nomadic tribes, their importance grew. The horse was now a worker—not just a meal on the hoof.

Role of the Wheel

Oxen were yoked to the pole of a plow probably early in the fourth millennium B.C., in the Near East. Toward the end of the millennium, they were yoked to sledges that were eventually mounted on rollers and then on wheels. Vehicles

with disk wheels appeared near the beginning of the third millennium B.C., drawn by oxen, onagers, or donkey **hybrids** (males or hinnies). The four-wheeled war wagon from Ur, in southern Mesopotamia, of about 2500 B.C., was pulled by a yoked team of four donkeys with nose-ring control.

Probably imported from the steppes of southern Asia, the horse first appeared as a domesticated draft animal in the Near East between 3000 and 2000 B.C. Because of its speed, it soon became the favorite draft animal. By the time horses were numerous in the region, a light chariot with spoke wheels had been developed for war and hunting. Yoked to it, the horse rapidly gained favor over its other relatives in harness for these purposes.

Learning to Control and Harness Horses

The ability to control the horse and effectively connect it to useful implements depended on developing appropriate **draft** systems that would allow the horse to work at its best.

The Yoke

The first draft systems were developed for oxen and were not well adapted to equine anatomy. At first horses were harnessed in pairs, with each horse on either side of a pole and under a yoke. The yoke was secured by a strap around the throat that tended to press on the horse's windpipe. By the 15th century B.C. in Egypt, the yoke saddle was introduced. This was a wishbone-shaped wooden object, lashed to the yoke by its "handle" with its "legs" lying along the horse's shoulders. This design took considerable pressure off the horse's throat and allowed it to breathe more easily. The yoke saddles rested on pads, and their ends were joined by crescent-shaped straps that went across the lower part of the horse's throat.

Early Bits

All-metal bits were first used in the Near East around 1500 B.C. Increased use of the light chariot in warfare called for stronger and more effective control of the teams. Two types of snaffle bits appeared almost simultaneously—the plain bar snaffle and the jointed bit. Both bits usually had studs on the inner surfaces of the cheek pieces to enforce directional control when one rein was pulled.

Learning to Ride

Learning to drive horses came before learning to ride in the Near East. Large chariot forces required schooled, disciplined, and highly conditioned horses. Riding was still pursued only in a casual fashion. Disciplined military mounts, trained to function with their riders in formation, were used only after 1000 B.C. Horseback riders before 1000 B.C. were depicted as scantily clad, unarmed riders, probably grooms or messengers.

At first, riders may have controlled their mounts with no more than a rope around the jaw or some sort of **hackamore**. Antler cheek pieces, which served as toggles to soft mouthpieces of rope, rawhide, or sinew, have been found at sites of the earliest domesticated horse on the steppes north of the Black Sea.

The Scythians

The Scythians unified as a group of nomadic horsemen with common customs and interests about 800 B.C. During the 7th century B.C., they invaded the Near East, riding as far south as Palestine, and occupied part of northern Iran for some 40 years.

Scythians were primarily archers, skilled at using the powerful composite bow from horseback. One warrior technique they mastered was that of shooting backward over their horses' hindquarters as they turned away from the enemy.

The Scythians' nomadic way of life, which enabled them to burn and destroy all their property when they retreated, allowed them to survive encounters with two of the greatest invading armies of the time, those of Darius I

of Persia (512 B.C.) and Alexander the Great (325 B.C.)—all made possible by the mobility provided by vast herds of horses. A Scythian's wealth was measured in horses. Belief in the continuation of material life after death caused the wealthy to take horses (in one case, 400) with them into the grave.

Scythian horses are the first recorded **geldings**. Horses in the Near East were not castrated at that time.

The Roman Army

During the more than four centuries of its existence, the Roman army changed from essentially an infantry to a predominantly cavalry-led force. A **cavalry** is a military force mounted on horseback. The change was brought about primarily by the type of enemy the Romans faced on the frontiers. To the east, rivals such as the Persians, who employed all-cavalry armies, had inflicted serious defeats to Roman infantry. The only way to effectively counter these armies was with more and better cavalries. The same was true when facing the mounted Germanic tribes to the north and west, and eventually the mounted nomadic tribes of the steppe.

China

Horse-drawn war chariots were first used in China during the Shang dynasty (about 1450 to 1050 B.C.). But repeated invasion and devastating plunder by barbarians of the northern steppes and by the Huns led to the development of a Chinese light cavalry, which provided a more effective defense against invaders. Despite completion of the Great Wall in 209 B.C., continued clashes with the Huns prompted China to adopt and refine their enemy's riding technique based on the use of a saddle.

The Chinese did not use the horse in great numbers until the 3rd century B.C. (well after its use was common in the West). But by the 7th century A.D., the T'ang emperors had huge stud farms holding as many as 300,000 horses, with each horse given seven acres of pasture. Paintings from the 10th and 11th centuries show the Chinese as complete horsemen. Their equipment is rather modern in appearance, and they seem at ease on their mounts.

Europe After the Romans

The fall of the Roman Empire in A.D. 476 began the Middle Ages, a period that lasted some 700 years. The early portion of this period is sometimes called the Dark Ages because the glories of the former Roman empire had virtually vanished, with learning and invention stagnating except in a few isolated monasteries. These were times of religious wars and barbarian invasion. The horse became largely used for battle or hunting as the Roman roads, which had previously united Europe, fell into disrepair. Travel from one area to another was dangerous due to the hostile relations between kingdoms. Generally, chariots fell from use and the wagon remained a farm vehicle. Despite a decline in the quality of technological innovation in many spheres of life during the Middle Ages, the horse adapted to new roles, particularly in agriculture.

Horses were expensive both to buy and to keep when compared to oxen and donkeys, which are foragers. The feudal system of the Middle Ages placed the farmer of the land under the control of a lord. Since the lord had the financial means to supply his farmers with horses to work his fields, the era saw the horse used on a large scale in agriculture for the first time in history.

During the Middle Ages, hunting deer on horseback became a popular sport, especially in Norman France. By the time of the Norman conquest of England in 1066, the deer hunt was enjoyed by most noble Norman gentlemen. William the Conqueror brought the sport, with all its rules and traditions, with him to Britain. "Ty a Hillaut," the old Norman phrase used to warn hunters that a deer had been found, became the "Tally-ho" familiar to the fox hunter of today (Figure 1–10).