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Bradford.

ROCHESTER INSTITUTE OF TECHNOLOGY

A Thesis Submitted to the Faculty of  
The College of Fine and Applied Arts  
in Candidacy for the Degree of

MASTER OF FINE ARTS

THE HORSE:  
Structure and Form in Nature

By

Karen Ackoff

Date:

21 June 1984

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## PROPOSAL

I intend to combine scientific knowledge with my fascination and respect for nature through the study of the horse.

Through research, study, and direct observation, I will develop a body of work that explores structure and form of the horse, both in motion and at rest.

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## PREFACE

My thesis is the culmination of applications of aspects of varied disciplines. And while the word "culmination" suggests a finalization, this study is only a beginning--a scratch in the surface. It suggests the potential for further study and exploration.

My work has provided me with the opportunity to develop and incorporate these disciplines. I have been able to explore my roles as both scientist and artist while indulging in a fascination for the equine world.

Throughout the course of my study, I have found these disciplines to be caught up in a circularity. One encourages and nurtures the exploration of the other. Starting from artistic concerns, I found a body of information necessary to draw on so that my pieces could communicate accurate fact as well as answering aesthetic concerns. Science has provided me with this body of information. Both science and art have encouraged my interest in the equine world. This interest, in turn, has inspired me to further my grasp of science and art.

The purpose of this thesis has been to study and expand my field of knowledge concerning equine science and medicine and to express this through art. As I learn and broaden my understanding, in the past and future, I hope also to pass

this information on to others, to express my enthusiasm for the subject matter, and, of course, to please the eye.

I would like to call the reader's attention to the fact that although this paper may proceed in a rather academic fashion, one should remember that marks made on paper come not from the hand, but from the heart. The time and care taken, the attention to detail, and the thoroughness are all expressions of this.



## I. INTRODUCTION

### The Horse in Art History

Horses have served various needs and purposes from pre-history to present day. Through time, they have held the interest and fascination of kings, poets, artists, scientists, and sportsmen.

Looking at horses and their artistic treatment has provided me with valuable insight for my own work. It has sharpened my sensitivities and awareness. Also, it has pointed out several major influences important to the development of my work. And so, I shall begin this paper with an overview of the horse in art.

In his book, The Horse in Art, David Livingstone-Learmonth says:

One may group painters of horses roughly into three categories: those who put art before the horse; those who are determined to produce a work of art as well as a faithful representation of horses; and those of whom there have unfortunately been quite a number . . . who definitely put the horse before art.<sup>1</sup>

In my work, I strive to be among those who produce a work of art as well as a faithful representation of horses. I have taken it a bit further by applying myself to scientific and medical concerns.

Hundreds of years before Christ, the ancient Greeks

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<sup>1</sup>(London: The Studio Publications, 1958), p. 10.

produced likenesses of horses in realistic positions. Although this ability or desire for believable horses was not completely lost, it did fall by the wayside. By the Middle Ages, the horse became important as a heraldic symbol. As time progressed onward, the artistic treatment of the horse was not indicative of accurate observation on the part of the artist. David Livingstone-Learmonth goes as far as saying, "most of them [horses] look as though made of wood or stuffed leather."<sup>2</sup>

This lack of awareness and poor observation can be attributed to the fact that horses were not considered important. They were an everyday means of locomotion and were taken for granted. It was not until the Renaissance that there was any indication of an artist making an intense study of the horse and its anatomy.<sup>3</sup>

Most of the great masters have included horses in their work. Leonardo da Vinci is noted for his sketches of horses and for the attention to form and structure he afforded them. Da Vinci and his work, more importantly, his approach to his work, has strongly influenced my own work.<sup>4</sup> Many critics consider Paolo Uccello's "Rout of San Romano" spoiled by the appearance of two unlikely looking horses in the foreground.

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<sup>2</sup>The Horse in Art, (London: The Studio Publications, 1958), p. 10.

<sup>3</sup>This refers to Leonardo da Vinci.

<sup>4</sup>For further discussion of da Vinci and his work, see pp. 8-11.

Michelangelo da Caravaggio's "Conversion of St. Paul" is considered a masterful blend of skill and talent. The result is a believable horse.

Rembrandt, Rubens, and Velazquez are noted for their successful handling of equestrian subjects. However, Velazquez's well-known portrait of the five-year-old Infante Baltasar Carlos has been a source of controversy. The painting was originally designed to be viewed from below, and so, the effect of the animal's distorted and bulging barrel was an intentional one. Livingstone-Learmonth, severe in his criticism, noted:

. . . [Velazquez] hands out impossible flattery in a manner so convincing that one forgets it is flattery. It is as though someone painted Mussolini winning the Derby or Hitler coming over the final fence before winning the Grand National.<sup>5</sup>

Somewhat kinder in his criticism, Werner Schmalenbach, in his book, The Noble Horse, offers the following description:

. . . a delightful piece of painting, no longer involved in study of details, but enjoying its own freedom.<sup>6</sup>

Velazquez understood, as well as any of his contemporaries, the anatomy of the horse and how the horse moved. His education as a gentleman included horsemanship. For Velazquez and other artists, it was easier to depict high school airs<sup>7</sup> as

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<sup>5</sup>The Horse in Art, p. 17.

<sup>6</sup>As cited by Walter D. Osborne and Patricia H. Johnson, The Treasury of Horses, (New York: Golden Press, 1966), p. 44.

<sup>7</sup>Complex movements of the horse belonging to dressage, a sport that requires the horse to be agile and supple while developing an understanding with the rider. High school airs, movements of the greatest difficulty, include such accomplish-



they were more readily observed than common gaits such as the canter and gallop. Uncertainty, in regards to equine movement, was not resolved until the advent of photography.

German artist Albrecht Durer was praised highly for his treatment of equestrian subjects. In "The Knight, Death and the Devil," he depicted the hero faced with eternal problems of death or dishonor. Death's horse is wearied to the point of foundering, while the knight's mount steps confidently and holds its head high with alert ears. It appears that the knight draws his strength of purpose from the courage of his horse. It is apparent that Durer chose to render a particular horse rather than a stereotypical one. This reinforces the fact that he was a realist.

Artists of more recent vintage, also finding the horse a subject worthy of their interests, are Goya, David, Delacroix, Degas, Manet, and Toulouse-Lautrec. More recent still are Rouault, Chagall, Braque, Eakins, and Picasso.

The art of the East characterized a meticulous but simple style. Following in this style, the painters and sculptors of Persia, India, and China left a treasury of equestrian art behind. The Chinese greatly admired beautiful horses. They were particularly adept at representing horses in artistic forms. Li Lung-mien, of the Sung Dynasty in the late eleventh

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ments as the piaffe, passage, and levade. The piaffe is an elevated trot with cadence and performed on the spot. A passage is an elevated trot in slow motion. A levade is a movement where the horse rears, draws its forefeet in, and deeply bends its hindquarters at the haunches. The hindquarters support the full weight of the animal.

century, and Chao Meng-fu, from a hundred or so years later, are two artists well remembered for their scroll paintings of horses.

A school of specialization in art arose and produced a profusion of "sporting prints." This arose mainly in England and from almost entirely within the world of those concerned with horses. Although the connection is not always made, this movement may be linked to Velazquez and Rubens, both of whom painted sporting pictures. The Spanish, Flemish, and Dutch produced pictures of sports popular in their own countries. They did not have the necessary at hand to paint pictures of the sports that appealed to the English gentry. Those sports were racing and fox hunting. The artists of these countries may be credited with giving this movement a start, but could not perpetuate it. They were unable to meet the demand of the English market.

These sporting prints were very popular. English critic John Cadfryn-Roberts comments:

The artistic merit of the sporting print has often been questioned . . . But the English sporting print has an invaluable position in the field of art. At worst, it is a unique record of a unique period in sport with its detail and often its humour, conscious or unconscious. And at best the quality of some of the leading artists and painters--Stubbs and Marshall, Morland and Alken, Pollard and Turner to name but a few--can only be described as superlative. . . . <sup>8</sup>

The time period in which this specialization occurred was the Golden Age of racing and fox hunting in England. It

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<sup>8</sup>Osborne and Johnson, The Treasury of Horses, p. 46.

was an age of exaggerated decorum giving way to the amusing combination of pomposity and pratfall comedy. Artist Henry Alken drew on this sense of the ridiculous. He often depicted riders obviously affected with extreme elegance in clothes and manners sprawled on the ground in an undignified manner while the backsides of their horses were visible from the far side of a hedge. Alken characterized the fox as a swift and crafty creature--often sporting a smug, self-satisfied expression on its face.

The combination of elegance with pomposity provided fertile ground for caricature. The response was brilliant and it was a large one. Notable satirical artists were Gillray, Cruikshank, Tenniel, Daumier, and Thomas Rowlandson.

Horse racing took a firm hold on the public's interest in the nineteenth century. This was apparent in England, continental Europe, and America. Equine celebrities became fitting subjects for portraiture. Even the poorer examples of this portraiture show humor that is intentional. It is reflected in the subject's arrogant bearing and in camouflaging defects thereby making a flattering statement.

The best portraiture, of course, should stand on its own as good painting. George Stubbs's work ranks among the best. George Stubbs is also known for his book, Anatomy of the Horse, published in 1776. Although the drawings were made under conditions considered impossible today, the results were excellent. In the original work, tracings accompanied the plates and designated the names of bones and muscles. In Stubbs's day, the



functions of the muscles were not understood as they are today. And so, much of his anatomical description is not in agreement with present day standards. It is interesting to note that there is a noticeable change in Stubbs's work before and after his study of anatomy. His approach to his art was one leaning towards realism as observed through nature. He began a trend that lasted.

Also noted for excellent portraiture are Rosa Bonheur, from France and a specialist in animal painting, and Edward Troye in the United States. Bonheur was an important influence in Thomas Eakins's work,<sup>9</sup> as was Edward Muybridge, a photographer noted for sequential studies of animals in motion.

During this era, there was a great deal of change and development. The position the horse enjoyed in the public's eye changed with the advent of this progress and the invention of the steam locomotive, and later, the automobile. The horse became a creature indicative of luxury rather than necessity. As perspectives changed, so did artistic attention and treatment of horses.

### The Scientific Artist

The artists most influential to my work are da Vinci, Ellenberger, Muybridge, and Eakins. They shall be approached in that order.

The common thread tying the above mentioned artists to-

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<sup>9</sup>For further discussion of Thomas Eakins and his work see pp. 15-19 and also appendix A.

gether is their approach--that of the scientific artist. It seems only natural to me that science and art should merge in certain respects and share common concerns. Science leads to, and logically so, the understanding of a subject. This entails gaining a greater understanding for what goes on underneath the surface of a form. In essence, the scientific artist is concerned with what causes form and how this influences the movement of the subject.

In his lifetime, Leonardo da Vinci was able to expand a great many areas of knowledge. He did this despite the lack of a formal education and during an era stressed by war and tyranny. I am impressed most with the way he approached his work. He had awe-inspiring intelligence and a disciplined aesthetic sense, and applied this to the field of nature. Most of his life was spent exploring and discovering the world. His thirst for knowledge was reason for his study of both the animal and human forms. This eventually led to his dissections.

His detailed study of the horse was, in large part, inspired by Lodovico Sforza granting him the task of making a giant statue of Francesco Sforza on horseback. Prior to this, he had made an illustrated textbook on military maneuvers for Gentile die Borri, the leading armorer of Lodovico's court.<sup>10</sup> In the course of working on this text, da Vinci saw many horses and carefully studied them. The task of creating the Sforza statue was given to him conditionally. He first had to demon-

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<sup>10</sup> An armorer is one who makes or repairs armor.



strate his skill. To accomplish this he made drawings, models, sculptures, and studied the anatomy of the horse. In order that his study of anatomy be thorough, he undertook dissecting the horse. Drawings and studies of these dissections made up his book on equine anatomy. The book was, unfortunately, lost when his manuscripts were dispersed.

The anatomical studies of the horse were da Vinci's first studies on anatomy. Later, he studied humans. Since little is known of his book on equine anatomy, one can only assume that he conducted himself in a manner similar to his later studies involving humans. He was meticulous and thorough in his work. Drawings of a particular joint or anatomical structure were made from many angles. He used many colors of ink and wash in an effort to make the information read clearly and easily. This concern for complete, accurate information was expressed when he wrote:

. . . if you wish to know thoroughly the parts of a man after he has been dissected you must either turn him or your eye so that you are examining from different aspects, from below, from above and from the sides, turning him over and studying the origin of each limb; and in such a way the natural anatomy has satisfied your desire for knowledge. But you must understand that such knowledge as this will not continue to satisfy you on account of the very great confusion which must arise from the mixture of membranes with veins, arteries, nerves, tendons, muscles, bones and the blood which of itself tinges every part with the same colour, the veins through which this blood is discharged not being perceptible by reason of their minuteness. The completeness of the membranes is broken during the process of investigation of the parts which they enclose, and the fact that their transparent substance is stained with blood prevents the proper identification of the parts which these cover on account of the similarity of the blood-stained colour, for you cannot attain to any knowledge of the one without confusing and destroying the other.

Therefore it becomes necessary to have several dissec-

tions: you need three in order to have a complete knowledge of the veins and arteries, destroying all the rest with very great care; and three others for a knowledge of the membranes, 'panniculi,' three for the tendons, muscles and ligaments, three for bones and cartilages, three for the anatomy of the bones, . . .

Therefore by my plan you will become acquainted with every part and every whole by means of a demonstration of each part from three different aspects; for when you have seen any member from the front with the nerves, tendons and veins which have their origin on the opposite side, you will be shown the same member either from a side view or from behind, just as though you had the very member in your hand and went on turning it from side to side until you had a full understanding of all that you desire to know.<sup>12</sup>

Conditions that da Vinci worked under were far from ideal. But he considered these studies his great contribution to mankind, and so, was able to overlook the hardships and carry out his work. Even so, sometimes a weariness crept in. The following passage expresses this weariness and also acknowledges the necessity of various skills in order that the study be comprehensive and complete.

And if you should have a love for such things, you might be deterred by loathing, or if this did not sufficiently deter you, you might be restrained by the fear of living through the night hours in the company of these corpses, quartered and flayed and horrible to behold. And if this does not deter you, then perhaps you may lack the ability to make good drawings essential for such a presentation, and even if you possess the ability to draw, it might not be combined with a knowledge of perspective, and if it were so, you might not understand the methods of geometrical demonstration or the method of estimating the forces and strength of muscles; patience also may be wanting, so that you will lack perseverance.<sup>13</sup>

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<sup>12</sup>"Quaderni d'Anatomia I-VI," Royal Library, Windsor, I 2 r., from the work by Edward MacCurdy, comp., trans., The Notebooks of Leonardo da Vinci, 2 vols., (New York: Reynal and Hitchcock, n.d.), 1:167-168.

<sup>13</sup>From the writings of Leonardo da Vinci as cited by Robert Payne, Leonardo, (New York: Doubleday & Company, Inc.,



The methodical tedium with which da Vinci applied himself to his studies was responsible for the discovery of much knowledge. The fact that he recognized the necessity of the application of different skill areas is what I strongly associate with. In my own work, I try to foster an awareness for the need of various skills and concerns. I admire da Vinci's sense of dedication and his systematic approach to studying and understanding his subjects. I have addressed myself to this concern by being thorough in my own research of horses.

In 1905, Ellenberger published a work on animal anatomy consisting of five volumes. These drawings are, even today, a mainstay of veterinary medical illustration. The Ellenberger plates have been reproduced many times over in various veterinary texts. Many of the plates are included in the book titled An Atlas of Animal Anatomy.<sup>14</sup> This book is, despite its outdated and/or incorrect labelling, still utilized as a text in veterinary colleges. These drawings communicate the information with a sense of clarity.

I am particularly taken with the beauty of the Ellenberger plates. They show precision and an attention to detail--almost photographic in quality. Often, a failing of anatomical studies is that they look like drawings of corpses. It is the artist's job to breathe life into his drawings. Ellenberger's drawings breathe.

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1978), p. 233.

<sup>14</sup>Lewis S. Brown, ed., (New York: Dover Publications, Inc., 1956).

George Stubbs is also noted for his anatomical studies of horses. In 1776, he published The Anatomy of the Horse. His studies are unique because he posed the horses as if in motion. He also tackled the more difficult three-quarter view. Despite his attempts to make his drawings live, I find they resemble corpses. They lack the life apparent in the Ellenberger plates. I find this particularly obvious in Stubbs's anatomical tables five through twelve.<sup>15</sup> These studies show muscle structure in various stages of dissection. I find that these drawings do not read clearly. It is sometimes difficult to differentiate between muscles. Therefore, I have tried to emulate the quality of the Ellenberger plates and feel relatively little influence from Stubbs's work.

Despite the advent of photographic technology, little has been learned about the sequence of motion that Edward Muybridge did not discover. His two books, Animals in Motion and The Human Figure in Motion, are abridgements of the larger work titled Animal Locomotion. This larger work was published in 1887 under the auspices of the University of Pennsylvania. It contained 781 plates with each plate consisting of from ten to forty-eight photographs.

Muybridge's initial studies on animal locomotion were inspired by the revival of an old controversy: at the trot, does the horse have all four feet off the ground at any one moment? The controversy came to Muybridge's attention, and he

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<sup>15</sup>George Stubbs, The Anatomy of the Horse, (1776).

resolved to settle it. His problem was to obtain a well-developed and contrasted photographic image on a wet collodion plate<sup>16</sup> after a brief exposure, so that a horse's foot would result in a clear image. There was the additional problem of technology. During Muybridge's time, photographers were often their own chemists. They prepared their own chemicals and plates.

The controversy was resolved in 1872. Muybridge conducted an investigation at the Sacramento, California race-track with a horse named Occident. He took a series of photographs which clearly exhibited all four feet lifted off the ground at the same time.

Each of Muybridge's photographs showed a different phase of the trot. He selected a number of these photographs and arranged them in sequential order. He surmised that he could settle conflicting points of view regarding the sequence of motion by taking a series of photographs in rapid succession to show movement. He submitted a plan to Leland Stanford and was assured of his cooperation for this research.<sup>17</sup>

Muybridge's research was carried on as time permitted<sup>18</sup> and was principally for his personal use. It was not until 1878 that his work was published. The Washington Library of

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<sup>16</sup>A collodion is a solution of pyroxylin in ether and alcohol used for making photographic plates.

<sup>17</sup>Leland Stanford was the owner of a stock farm.

<sup>18</sup>Muybridge's official duties were as a photographer for the government.



Congress published a number of photographic sheets showing the horse in motion under the title of The Horse in Motion. Many of these photographs found their way to the pages of various publications around the world including Scientific American out of New York and La Nature out of Paris.<sup>19</sup>

In the course of his work, Muybridge experimented with the zoetrope. The zoetrope was an apparatus originated by Plateau, a Belgian physicist, to show the persistency of vision. It was an apparatus with which Muybridge produced the image of a small horse trotting and another galloping. Muybridge modified and adapted the zoetrope thereby correcting the vertical distortion of the image. The result of his refinements was the zoopraxiscope--an apparatus expressly designed for demonstrating movements photographed from life.

Muybridge travelled and lectured extensively, projecting his images on a screen. He interrupted his lecture tours to undertake research under the auspices of the University of Pennsylvania. This enabled him to explore the capabilities of the newly discovered dry-plate process and thereby improve upon the clarity of photographic detail, particularly regarding muscle definition. It also enabled him to develop an apparatus adjusted to complete a succession of circuits at predetermined intervals of time. When the subject passed a designated point,

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<sup>19</sup>Photographs appeared in the following publications: Scientific American, New York, October 19, 1878; La Nature, Paris, December 14, 1878; Berliner Fremdenblatt, Berlin, April 26, 1879; Wiener Landwirthschaftliche, Vienna, April 26, 1879; The Field, London, June 28, 1879.

an operator pressed a button thereby completing an electrical circuit, setting the apparatus into action, and causing a series of cameras to go off. Muybridge acknowledged his indebtedness to numerous professionals including doctors, electricians, and chemists. His labors, resulting in over one hundred thousand photographic plates, were culminated into the work called Animal Locomotion.

Although Muybridge's initial inspiration was not, perhaps, out of artistic concern, his work is noteworthy on many counts. One is his systematic approach. He built upon and explored his initial studies expanding his field of expertise. He utilized fields of knowledge outside of his own--an example being his acknowledging the need and delegating responsibilities for both electrical and developing departments while conducting studies at the University of Pennsylvania. Another example is his recognition of the need to consult medical professionals in the course of his work. The influence of Muybridge's work has expanded upon as many fields as he drew from. Artists use his photographs as reference even today to aid them in accurately depicting subjects in various positions and stages of movement. No doubt, his work was/is also an aid to both scientists and medical professionals, helping them better understand movement and all that it entails. In my work, I have drawn from many fields and hope that I am able to give some knowledge and increased understanding back.

The work of Muybridge was of interest to many, including

the painter Thomas Eakins.<sup>20</sup> Eakins had spent time in Paris with Rosa Bonheur, a noted painter of animals. Bonheur conducted dissections of the horse to serve as reference for her paintings. Eakins, upon returning to Philadelphia, began his own dissections which led to his eventual teaching of horse anatomy at the Pennsylvania Academy of the Fine Arts. Eakins's interest in the work of Muybridge was so recognized that he was asked to serve on the supervisory commission overseeing Muybridge's studies at the University of Pennsylvania.

Fairman Rogers, an ANSP member,<sup>21</sup> a horse enthusiast, and owner of a four-in-hand coach,<sup>22</sup> commissioned Eakins to paint his coach in action. Muybridge's photographs were to serve as reference for the painting, reinforced by additional studies. In order to thoroughly research his subject matter, Eakins made landscape studies, observed the coach with a camera, and built a wax model to serve as reference for his preparatory sketches.

Eakins's use of the photograph as reference for his work was, at that time, a controversial matter. Many artists considered the use of photographs beneath their dignity. But despite the disapproval of the artistic community, Eakins continued the use of this approach.

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<sup>20</sup>For further discussion on Thomas Eakins and his studies of anatomy, see appendix A.

<sup>21</sup>Academy of Natural Sciences Proceedings, Philadelphia, Pennsylvania.

<sup>22</sup>A vehicle drawn by four horses and driven by one person.



Eakins's twenty-five years of study in the field of anatomy laid the groundwork for his paper "The Differential Action of Certain Muscles Passing More Than One Joint" which was presented at the Proceedings of the Academy of Natural Sciences of Philadelphia in 1894. The paper and its supporting research was borne out of an inconsistency between written observation and Eakins's own. Eakins's research for this paper included the building of models to illustrate and to promote better understanding of principles of leverage as applied to the leg of the horse. It also included photographs Eakins made at the University of Pennsylvania in 1883 showing the leg of the horse, despite the removal of the musculature, sustaining weight. Expressing the necessity of understanding musculature so as to understand form, Eakins closed his paper with the following passage:

On the lines of the mighty and simple strains dominating the movement, and felt intuitively and studied out by him, the master artist groups, with full intention, his muscular forms. No detail contradicts. His men and animals live. Such is the work of three or four modern artists. Such was the work of many an old Greek sculptor.<sup>23</sup>

Eakins's paper was well received by ANSP members, and they acknowledged the compatibility of his work with scientific knowledge--the underlying tie being a preoccupation with analysis. This inquisitive and curious nature regarding the scientific was something Eakins had in common with his fellow Central High School classmates who later became ANSP members.

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<sup>23</sup>Thomas Eakins, "The Differential Action of Certain Muscles Passing More Than One Joint," Proceedings of the Academy of Natural Sciences of Philadelphia, (1894): p. 180.

Solomon Solis-Cohen, M.D., a Central High School graduate, reminisced about the educational philosophy with which his high school professors concerned themselves:

Natural Science, too, is the basis upon which other studies must be built. Only with the just ideas of cause and effect, and the knowledge of the universal reign of law, gained in the laboratory and the observatory, does the student become prepared to understand the facts of language, history, art and literature, which thus find their natural relations, no longer isolated fragments of knowledge, but the records of the movements of the great tide of human endeavour . . . <sup>24</sup>

This intellectual heritage from high school days constituted a strong tie between Eakins and his fellow classmates and remained a common bond on into their professional lives.

Many of Eakins's classmates became ANSP members and were active in both scientific and artistic fields. They recognized the possible applications of science to art. Eakins characterized this merging of science with art through his concern for movement. He found movement not only in the locomotion of the horse, but also in the human appearance. He found movement of the mind and spirit through time. This movement was suggested in his portraits by the intentional aging of his subjects--an accumulation of physical evidence much akin to the sequential frames in one of Muybridge's plates.

Eakins's work is an excellent example of the concerns of the scientific artist. It is the nature of intellect to wonder,

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<sup>24</sup>"The Central High School as a Teacher of Science," address on October 29, 1888 at the semi-Centennial Celebration of Central High School, Philadelphia, as cited by Elizabeth Johns, "'I, A Painter': Thomas Eakins at the Academy of Natural Sciences," *Frontiers* 3 (1981-1982):51.

to question, and to discover. Da Vinci, Ellenberger, Stubbs, Muybridge, and Eakins all exhibited an intellect which entailed concerns for aspects of varied disciplines. A sound knowledge of science forms a basis for many artistic concerns from the scientific to the abstract. Even if one wishes to abstract forms or distort them, this basis serves as a point from which to take off. In my own work, I strive to establish a solid understanding of my subject and associated concerns upon which to draw. This serves to satisfy my own sense of curiosity and responsibility--a responsibility to both myself and to those who observe my work. It is a responsibility to be accurate in regards to the information I choose to convey and also to answer to aesthetic concerns.

The end result, a final drawing, represents the merging of these aspects of varied concerns of which I speak: scientific, medical, technical, and aesthetic. This merging is the ideal with which I am concerned and to which I apply myself. And I do so with reverence and respect.



## II. CONSIDERATIONS: HISTORICAL, AESTHETIC, AND TECHNICAL

Contemplating the body of work that lay ahead, the first thing I needed to resolve was the general character I wished the work to convey. I wanted the work to express a sensitivity towards both scientific accuracy and aesthetic concerns. And since I feel the da Vinci notebooks accomplish this particularly well, I decided to use them as a point of departure. So, I decided to use a format suggesting a notebook page, but perhaps a bit more formal in character. In keeping with the character of the da Vinci notebooks, I wanted my drawings to have a somewhat antiquated appearance. This led me to consider what media would best accomplish this, and how it should be presented.

Before working out the particulars of papers, paints, etc., I chose a size to work with. I chose to work with a uniform size of 19 1/2-by-25 inches for my final drawings. I find anything much larger than that is awkward to work on. This size was small enough, then, to allow for working with relative ease, and large enough to allow for compositions consisting of a number of smaller studies, drawings, and notations--reminiscent of the pages by da Vinci.

Although my approach is generally one of using mixed media, I have recently become particularly enthralled with

pastels. The technique I use with pastels is one that evolved from my initial contact with carbon dust technique.<sup>1</sup> Carbon dust technique is a mainstay of medical illustration, and I was introduced to it early in my medical illustration training. I feel that this technique affords a very rich tone, but it is a bit dark and "sooty" for my own taste. So, I modified this technique to allow for lighter tones; hence, giving a more delicate character. I began by grinding grey chalk pastels and mixing them with the carbon dust to lighten the tones. This made quite a difference and lightened the tones considerably, but it still wasn't quite what I wanted. By substituting graphite dust for carbon dust, I was afforded a great variety of silvery grey tones--enabling me to go quite dark, but extending the lighter range immensely. The occasional use of carbon dust for dark areas of a drawing added depth and richness, balancing the light tones. Also, an opaque white paint worked well to highlight the subject matter. The result of all of this was a drawing that was middle to high key, but balanced by rich darks. As my training progressed, I started working more with color. It seemed only natural to me that this technique might be adapted to color. I tried grinding colored chalk pastels on sandpaper, "dipping" my brush in the "dust," and applying it to the paper in a light scrubbing motion.<sup>2</sup> This resulted in a lovely, rich "wash" of

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<sup>1</sup>Information on carbon dust technique may be found in Scientific Illustration, a book by Phyllis Wood, (New York: Van Nostrand Company, 1979), pp. 58-61.

<sup>2</sup>This technique is called scumbling.

color.

Brushes and papers are two important considerations with pastel dust technique. Unlike carbon dust with which only one set of brushes is necessary, several sets are required for basic color groups when working with colored pastels. This prevents the colors from getting "polluted" with other, incompatible colors. I found it necessary to have a brush set for the red-orange range, blue-green range, and for the grey range. I also found it helpful to keep several brushes on hand for the very lightest colors. Occasionally, it may be necessary to wash a brush. This may be done with a brush soap or mild dish detergent. The brushes should be dried thoroughly, and then may be used in whatever color is desired. I also experimented with trimming the brush bristles shorter. This makes the brush stiffer and better for applying color at an edge as there is less overspray.<sup>3</sup> Brushes trimmed very close to the ferrule are very good for getting into small spaces with. The choice of paper upon which to work seems to be a highly individual matter. A smooth bond paper, tracing paper, and cold press illustration board provide surfaces that are popular. I find I am most comfortable with a ledger layout bond. The color covers large areas evenly, and blends equally as well. Although sometimes, I find the white of the paper too harsh of a background. So, I looked for an alternate surface and was quite pleased with Canson charcoal papers. Not only are there

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<sup>3</sup>Overspray is excess dust that scatters outside of the desired border.



a great variety of colors available in Canson papers, but they provide a fairly durable surface that is able to withstand erasures, reworking, and the application of wet media in moderation. I found that I preferred to work on the "wrong" side of this paper as it is not as coarse in texture as the "right" side,<sup>4</sup> and so interferes with the drawing to a lesser degree. For my final drawings, I decided on a soft, pale grey Canson paper. The choice of a toned background was also in keeping with the character of the da Vinci studies.

Referring back to da Vinci's notebooks, I very much like the scrawled notes that surround the drawings. The notations, aside from providing information, are a design element of the page. They add texture and tone, and help balance the composition without detracting from it. So, I chose to include notations as an element of design in my own drawings.

A great many things were taken into consideration regarding the choice of lettering and lettering technique. I began by referring to the da Vinci notebooks. Da Vinci's notations appear textural and tonal because, at first glance, we cannot read them. When the element of legibility is removed, we become aware of different things. The design, texture, and tone become apparent. The illegibility of da Vinci's notebooks is because he wrote in mirror-writing.<sup>5</sup> This was not done in

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<sup>4</sup>The "right" side of the paper is that from which the watermark reads correctly.

<sup>5</sup>Mirror-writing is writing that when held in the mirror reads as normal writing.

an effort to be secretive, as some thought. In fact, he fully intended for his works to be published and left detailed instructions for doing so. The reason da Vinci wrote a mirror image is quite simple. He was left-handed. Left-handed people drag their hands over the ink as they write, and this causes the ink, not yet dry, to smear. If one writes in mirror-writing, one writes from right to left as opposed to the traditional left to right. It was in this way that da Vinci was able to avoid pulling his hand over the wet ink.

Present day methods of lettering being too modern in character, I decided the notations in my drawings would be handwritten. I considered several historical styles of handwriting, and settled on a Secretary Hand, a style consistent with the character of the Renaissance, as well as having been the handwriting from that time. Secretary Hand creates a delicate, lacey texture. And although many of the letter forms are antiquated, upon careful scrutiny, it can be read.

I looked at the history of Secretary Hand so I could better understand the evolution of particular letters as well as to better understand the character of the writing itself. Secretary evolved from twelfth century Gothic script. The Gothic scripts were of two main classes: Text Hand and Court Hand. The Court Hand was an informal hand and written quickly. The Text Hand was formal, precise, and more slowly written. It was used for the making of books. During the late fourteenth century, Court Hand developed into a variety of Gothic scripts called Bastarde Script, or Batarde. Batarde was a merging of



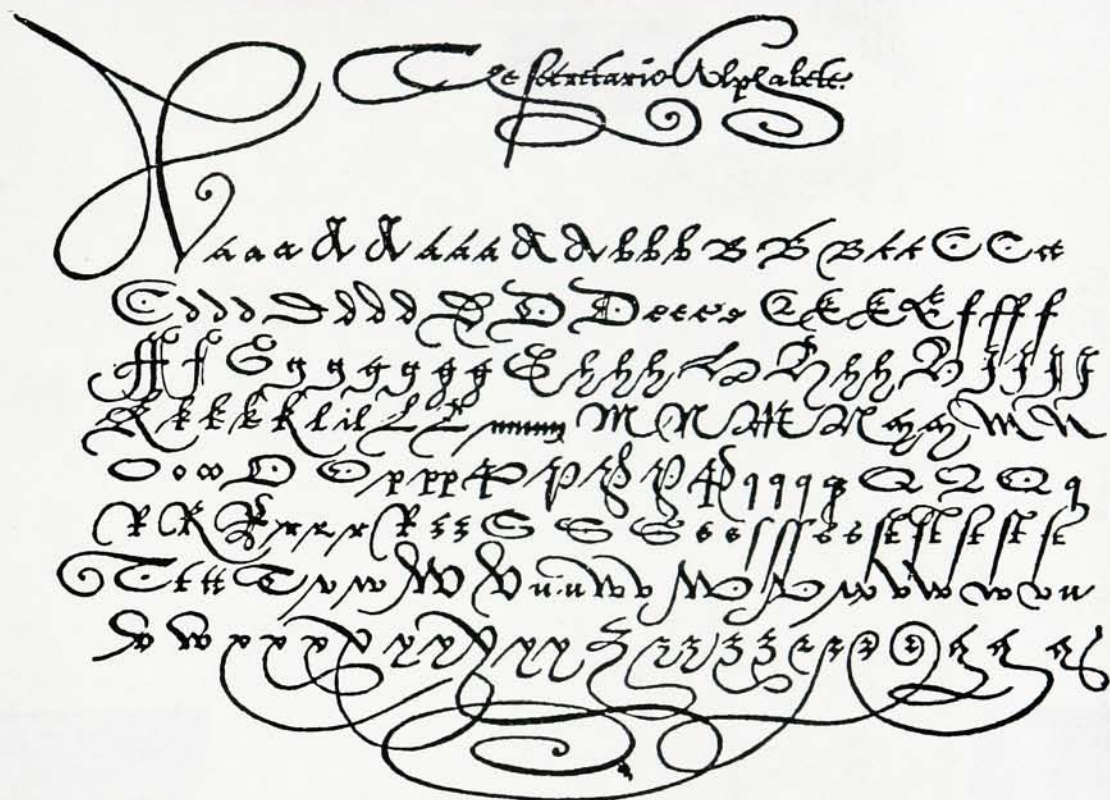


Plate 1.

The Secretary Hand, 1571.

formal and informal hands.

In England, Batarde developed into two varieties of Gothic script: a small Court Hand and several types of large Special Hand. The small Court Hand, borne of the early fifteenth century, later gave rise to English Secretary Hand which in turn merged with the new Italian hand to form the Round Hand of the seventeenth century. The large Special Hands came into being in the late fifteenth century, and were used for certain public and private business.

At the time when Roman type was first being seen in England, the Secretary Hand, a small, informal script, became common. The letter forms of the Secretary Hand were similar to those of a large Bastard Script, but did not share its characteristic overstated angles. Some characteristics of fully-developed Secretary of the sixteenth century are as follows:

1. The x-height is small.<sup>6</sup>
2. In the minuscules, there is a tendency towards roundness.
3. There were two varieties of Secretary Hand in use: one perpendicular and one oblique. Oblique Secretary outlived the perpendicular variety as it could be written with more speed.
4. Almost all individual letters are written without pen-lifts.

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<sup>6</sup>X-height is the height of a minuscule letter without an ascender or descender.

5. Adjoining letters are often connected giving an appearance of effortlessness.
6. There is a sharp contrast between the heavy strokes of the descenders and the fine, diagonal connecting strokes.

I have had a keen interest in calligraphy for many years, and have an understanding of lettering and lettering technique. Of course, practice is always an important element of mastering a hand. I worked to develop a natural and believable Secretary handwriting. I referred to facsimilies to aid me in decisions concerning the weight of strokes, line spacing, and variations of letter forms. I found many variations in letters of the Secretary Hand. Secretary is a handwriting, and so, one makes choices as to what style of character to employ. Often, the placement of a letter within a work influences the style of that particular letter. An example of this is the minuscule "s." There are two basic styles of "s": the long "s" and the short "s." The long "s" was used at the beginning and middle of words, and a variety of the short "s" was used at the end. Yet, sometimes this general rule was disregarded. The long "s" is often confused with the "f." This confusion is a common source of error in Elizabethan texts. The short "s" developed from the Greek sigma which consists of three lines meeting in acute angles. One variety of the final "s," and one I particularly like, was known as the "legal s." Refer to figure 2-1. The back curve of the "legal s" was made first, the pen was raised from the paper, and then the upper two strokes of the



**P**ersonne ne savaie de qui il venait a don merv-

u a ac av ar b c ce cr d one stroke only!

c C Notice the subtle difference between the c and C f F g G You need not loop the descender on the g h H HA A HA R H i I as with the g you need not loop the descender on the i j J as with the g you need not loop the descender on the j k K you can shorten your k, the more you like, the more l L as with the g you need not loop the descender on the l m M as with the g you need not loop the descender on the m n N as with the g you need not loop the descender on the n o O as with the g you need not loop the descender on the o p P as with the g you need not loop the descender on the p q Q as with the g you need not loop the descender on the q r R as with the g you need not loop the descender on the r s S as with the g you need not loop the descender on the s t T as with the g you need not loop the descender on the t u U as with the g you need not loop the descender on the u v V as with the g you need not loop the descender on the v w W as with the g you need not loop the descender on the w x X as with the g you need not loop the descender on the x y Y as with the g you need not loop the descender on the y z Z as with the g you need not loop the descender on the z

l m n o p q r s t u v w x y z

l m n o p q r s t u v w x y z

u a ac av ar b c ce cr d

u a ac av ar b c ce cr d



- a Infection with chigoe fleas is extremely irritating and usually produces inflammation and ulceration; the latter is primarily due to the development of secondary infection. Diagnosis is made by detecting the dark portion of the flea's abdomen on the skin surface. Surgical removal of the flea is indicated.
- b

FIGURE 2-3.

Samples of line spacing.

"A" shows an open spacing, and is the spacing I used in the notations of my final drawings. "B" shows a tight spacing.



FIGURE 2-1.  
The "legal s."

The long "s."

The short "s."



FIGURE 2-2.

Styles of the minuscule "s" employed in  
the notations of my final drawings.

sigma were added. The styles of "s" I used in the notations in my drawings are pictured in figure 2-2. Plate 2 is an exemplar showing the particular letters I chose to employ and also some examples of how letters connect.

Facsimilies show the spacing between lines of writing both tight and open. As I began to write, I placed the lines close together. This created two problems. One problem was that it hindered the readability because of the clutter of characters. Another problem was the colliding of ascenders and descenders, also resulting in a decreased legibility. So, I increased the space between lines and this alleviated these problems, and showed off the lacey ascenders and descenders. Refer to figure 2-3.

I wanted the notations to be written in a small, delicate hand, so particular attention had to be paid to my writing materials. I first turned my attention to the type of pen I would use. Dip pens require a lot of fussing to achieve the desired ink flow. So, I decided to use a fountain pen. However, I found that the ink flow in a fountain pen was not as consistent as I needed. By experimentation, I found that by dipping the fountain pen, wiping the excess ink from the nib, and then writing with it, I could achieve the desired ink flow with relative ease. Another consideration was the pen nib itself. The nib was not fine enough to give a good contrast between thick and thin strokes. So, I honed down the point on a

sharpening stone to achieve the desired contrast.<sup>7</sup>

Ink also had to be considered. I chose to use a sepia-colored ink to maintain the antiquated character of my drawings. I mixed black and brown inks together to get a very dark brown--almost black--ink. Consistency of ink is important to the flow of ink from the pen, and I added water as necessary to make the solution flow easily.

Paper is an important factor in calligraphy. The Canson paper I had chosen for my drawings is rather coarse for such a small hand. The sharpening of the nib, thinning of the ink, and a light hand on my part all facilitated the ease of writing. I found that it was important to keep the area of the paper to be written on free from fixative. Layers of fixative create a rough surface very difficult to work on. If an area was to contain both writing and drawing, the writing had to be executed first so that the drawing could be sprayed with fixative as necessary. Otherwise, I was careful to keep the area to be written on free from fixative or adhesive residue until after the writing had been executed.

All these decisions regarding choice of paper, media, and lettering have an underlying tie. They are all a setting of limitations. Limitations are necessary to any work of art, whether they are self-imposed or imposed by a client. So, having set the limitations for my drawings, I proceeded

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<sup>7</sup>For information on sharpening pen nibs, refer to the article, "The Bookhands of Sheila Waters," by Linda Allen in Alphabet: The Journal of the Friends of Calligraphy 9 (Spring 1984): pp. 2-3.



with the work itself.

### III. THE WORK

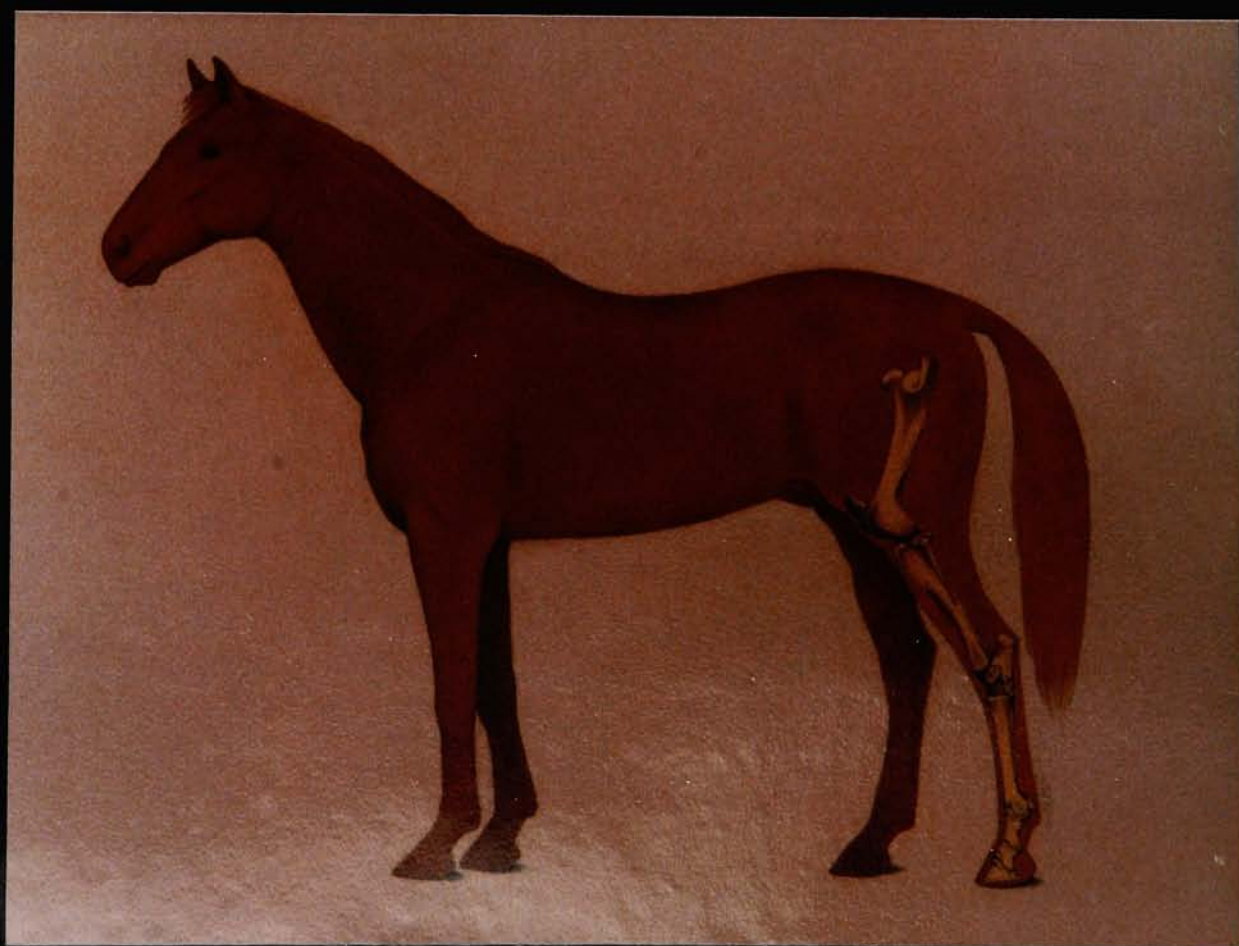
In the course of my research, my main concern has been with motion and analysis of gait. So, I decided to emphasize the leg, concerns thereof (anatomy, physiology, movement/biomechanics), and sequence of movement.

#### Research

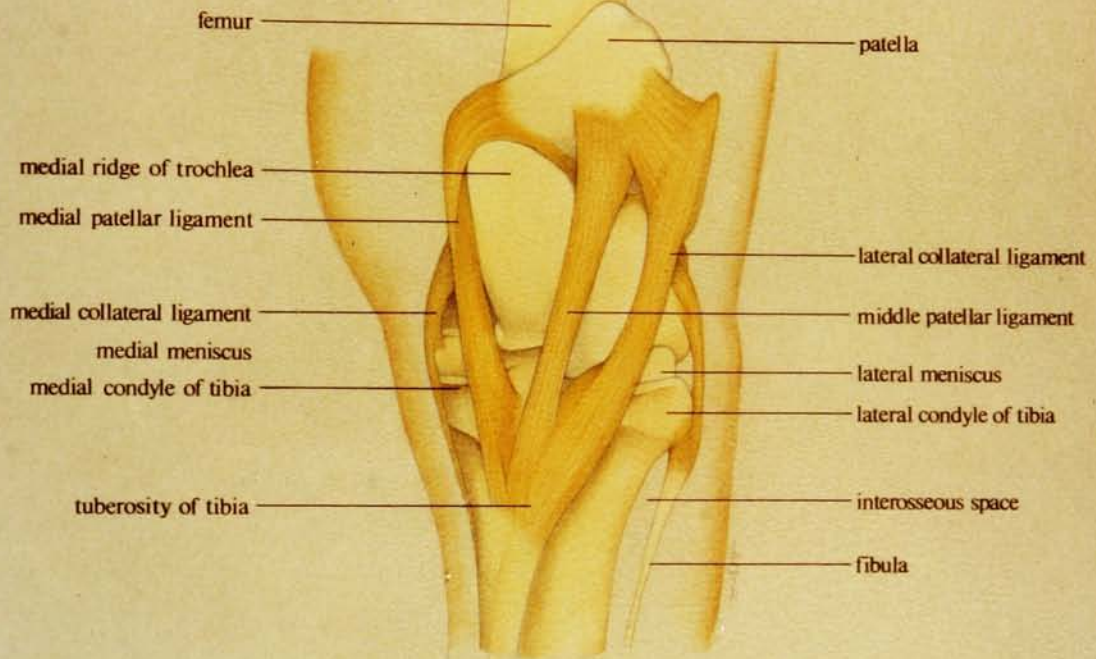
I found it necessary to establish a body of reference material upon which to draw. This would allow me to be selective and to choose material most appropriate to my goals. Reference material for my work may be divided into three categories. The first category consists of material from past and current interests and pursuits. It also includes studies important to my final drawings (refer to plates 3 and 4). The studies shown in "B" of plate 3 and plate 4 are from a slide presentation I wrote and produced titled "Care of the School Horse." This presentation dealt not only with the basic care of the horse, but also covered medical concerns. I spent time observing two veterinarians and saw both routine veterinary care as well as surgical procedures. All of this experience served to form part of a broad base of reference. The studies shown in "B" of plate 3 and in plate 4 were especially important to my work as they were the first pieces which were done in the pastel technique discussed in



A. Study: thoroughbred gelding.



B. Study: skeletal anatomy of the pelvic limb.



LEFT STIFLE JOINT  
anterior view

Plate 4

Study: left stifle joint.



chapter II. The second category consists of material directly applicable to my drawings, and this is included in the text of this paper. The third category is made up of extraneous material. Although this material was not specifically utilized in my drawings, it was part of the broad base of reference that made selectivity of subject matter possible. Some of this material is included in the appendices.

Before beginning my drawings, I began research. There were many aspects to this research. I started with a general approach by familiarizing myself with the veterinary library at Cornell University. I purchased standard textbooks that were unavailable through the library but necessary to my work.

I established a body of photographic reference in the style of Edweard Muybridge. I did this to improve upon the resolution of the Muybridge plates. Many of his photographs were little more than silhouettes, and were retouched to define which leg was in front of which. For my drawings, I wanted photographic reference that afforded sharp detail and clarity of muscle definition. I also wished to improve upon his choice of models. Many of the horses Muybridge chose to photograph were of less than ideal proportions. Keeping this in mind, I chose a well-proportioned horse as my model.

There were many things to consider in establishing a body of photographic reference. The first thing necessary to this work was to arrange for a model. Once this was done, the availability of the owner was a consideration. The weather also had to be taken into account. Many an attempt was rained

out. A setting had to be considered. The most satisfactory setting would have been a large field. This would have provided a background free from distracting detail. However, this was not available to me, so I photographed the subject matter against a fence. But because the photographs have good contrast and the images are clear, the fence in the background did not interfere with the use of the photographs as reference.

It was necessary to decide what type of film to use: color or black and white, print or slide. I chose to make slides because a projected image is easy to work from. Scale is easily changed by adjusting the distance between the projector and the screen. Cost and method of processing were additional considerations. I decided to use Panatomic-X film and a reversal processing. This produced black and white slides. The procedure for the reversal process is given in appendix B. In processing the film, care had to be taken that correct technique was used. Rapid selenium toner was used to make the tones deep and rich.

I photographed with a Nikon system. The automatic drive made shooting three frames per second possible. I shot with a relatively fast shutter speed as well as having panned with the horse to alleviate blurring of the image. I knelt while shooting to achieve the desired eye level--an eye level of approximately 3 1/2 feet from the ground. I scheduled two shooting sessions, and shot sequences of the walk, trot, canter, gallop, buck, and jump. Sample sequences are shown in plates 14 through 18 in appendix A.

I took one particular sequence a step further by actually animating it. This was done with the use of an optical printer. The appearance of the images was timed to simulate actual lapse of time. Each image dissolved into the next. The result was a rather primitive moving picture. If I had been able to shoot more than three frames per second in my initial photographic studies, the movement of the horse in the animated sequence would have appeared smoother. Also, the placement of the fence in the background changed slightly throughout the sequence and was distracting to the movement. Despite these drawbacks, this animated study was the principal inspiration for the sequence of the bucking horse in my second drawing (refer to plate 7).

Another important influence to my work was the television show titled "A Magic Way of Going: The Story of Thoroughbreds."<sup>1</sup> This program dealt with the thoroughbred racehorse and considered gait analysis as an important part of the racing industry. Not only was the show beautifully written and produced, but it was informative as well. In the course of the show, various professionals were consulted. George Pratt, a professor in the School of Electrical Engineering at the Massachusetts Institute of Technology, was one of these. Professor Pratt's work considers many aspects of gait analysis: the monitoring of bone strength and heart rate, the monitoring of the force of impact with which the foot of the horse contacts the ground,

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<sup>1</sup>PBS, "NOVA," No. 1014.



and the measurement of the resiliency of the ground on which the animal runs. I was fascinated by this work and arranged an interview with Professor Pratt so I could learn more about his work (notes from this interview appear in appendix D). And although the information from this interview was not applied directly to my drawings, it did point out some important facts. It showed that the study of gait is an active area of research and is important to both animals and people. Professor Pratt's studies also serve as an example by showing that an interest in horses in combination with professional interests can result in information relevant and beneficial to animal and man. Professor Pratt was also helpful by referring me to the Mammal Department at the Museum of Comparative Zoology of Harvard University. There I was able to photograph skeletal specimens which proved valuable as reference for my drawings. And needless to say, all of this information contributed to the broad base of reference necessary to my work.

Panel 1  
Aspects of Equine Conformation

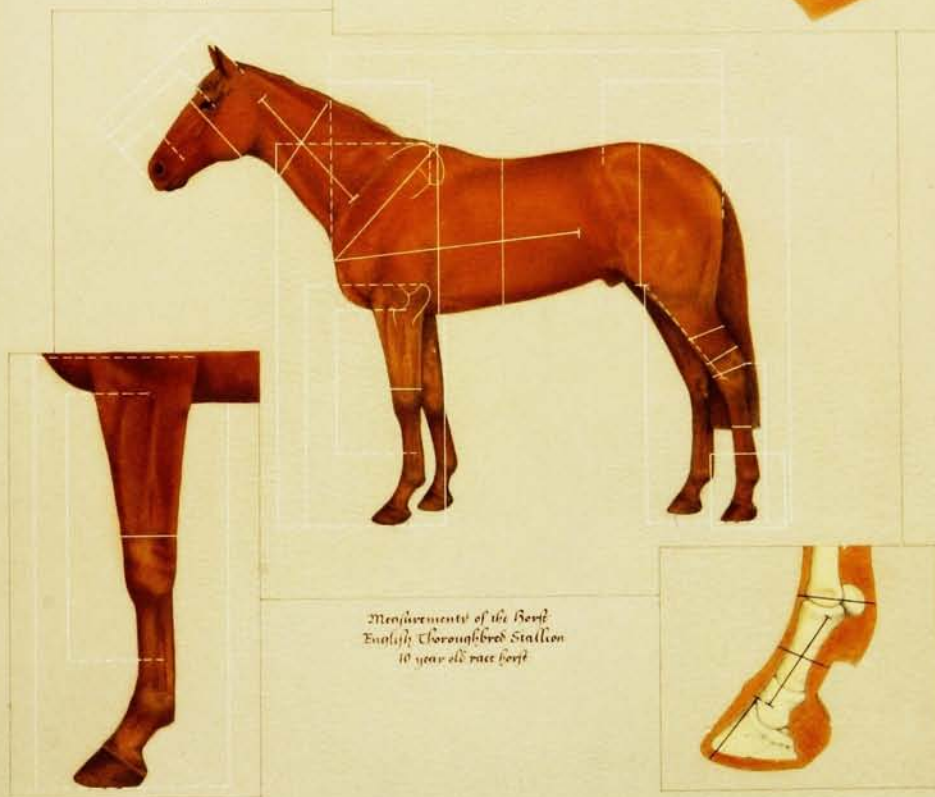
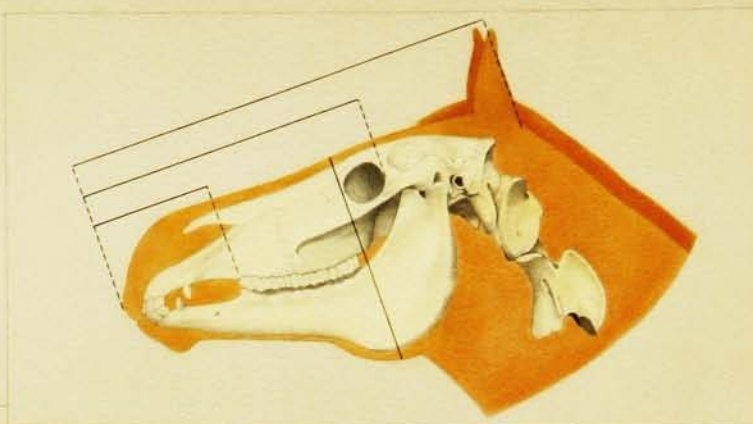
This first drawing deals with aspects of conformation of the horse. I chose to deal with conformation as it is the key to how a horse moves. In order to be thorough in my approach, I found it necessary to research conformation and the role it plays in equine movement. An overview of fundamental principles follows.<sup>2</sup>

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<sup>2</sup>For a detailed discussion on conformation, the following books may be consulted:



English and Irish breeders indeed consider that the Thoroughbred is a better made animal than the Arab, whose shoulders are too upright, giving him a short front, and whose hind legs are too bent in the shape of a sickle for deer-like. They set great store by the shape of the hind leg, in particular the hock, that is after all, the canine hocks which are hooked are liable to strain in the form of curbs, spavins and thoroughpins. They aim for a strong and muscular stout thigh, a large bonny hock, free from fleshiness, and then like the hind leg to drop straight down to the ground from the hock, so no forward curve so that a straight plumbline can be dropped vertically from the tail to the ground which will touch the point of the hock at the fetlock joint. This is the type of hind leg which has proved to be the most durable in the hunting field.



Measurements of the Best  
English Thoroughbred Stallion  
10 year old race horse

## Conformation

Conformation is a significant factor to the method of progression of the horse as well as being an important consideration in breeding. Poor conformation of the limbs can contribute to lameness. Aspects of conformation may be inherited and can predispose an animal to various conditions such as upward fixation of the patella, navicular disease, and carpal bone fracture.<sup>3</sup> Of course, conformation is only one of several important concerns in regards to the horse. Speed is a consideration. An animal that possesses both speed and good conformation stands a better chance at a long career in racing, competition, or as a pleasure or work horse. "Heart," defined as a sense of desire and competition, is another consideration. In a quality horse, the combination of good conformation, speed, and heart is apparent.

### Body Conformation

Body conformation varies among the different breeds.

Evaluation of body conformation should be based on the speci-

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- (1) Horses of the World edited by Pamela MacGregor Morris and Nereo Lugli, (New York: A Division of Crown Publishers, 1973), pp. 19-27.
  - (2) Lameness in Horses, 3rd ed., by O. R. Adams, (Philadelphia: Lea & Febiger, 1974), pp. 1-27.

<sup>3</sup>Upward fixation of the patella is a condition characterized by the hind limb locking in extension. Navicular disease is the progressive degeneration and erosion of the fibrocartilage of the tendinous surface of the distal sesamoid bone, also known as the navicular bone. This disease occurs only in the front feet and is an important cause of lameness in horses. The carpal joint is the "knee" of the front limb. Plates 20 through 23 provide anatomical reference.

fications of the breed being considered. But regardless of the type of breed, there are certain essential characteristics. In general, the body should be well proportioned and in pleasing balance with the limbs.

The shape of the head is a distinguishing factor between breeds. Regardless, a quality horse should have a bony, finely-chiselled head ending in a small, sensitive muzzle with nostrils capable of wide dilation. Wide dilation of the nostrils allows for rapid inhalation. The forehead should be long and wide. The eyes should be large and dark, and should be set level with the head. As well as being moderately long, the ears should be widely spaced and very mobile. They should be held in a forward position indicating good character and attentiveness.

The neck should be wide at the base and nicely curved on the crest. It should form a right angle to the head. The length of the neck should be moderate, not too long or too short. It should run into a shoulder that is well laid-back and sloping. A straight shoulder generally indicates that the animal is a bad mover, and also creates problems for the rider. A straight shoulder provides the rider with little support in front of his leg.

The chest should be deep and wide. This indicates stamina.

The back should be horizontal and well muscled. A short back is indicative of strength, but a long back allows the horse to cover more ground. Although body conformation is not



a common cause of lameness, certain characteristics can affect limb movement. The length of the back is such an example.

A horse with a back that is too long may develop a swing in its gait, and this can alter the movement of the limbs. Long-backed horses are prone to speedy-cutting and cross-firing.<sup>4</sup>

A horse with a back that is too short and with disproportionately long legs is prone to over-reaching, forging, and scalping.<sup>5</sup>

The loins should be wide, relatively short, and joined well to the pelvis. This allows the horse to transmit the entire driving force of the hindquarters. A horse that has a weak loin lacks endurance and a sturdy constitution.

The rump should carry a moderate slope, and should be well muscled. The tail should be set high. A tail that is set too low is generally indicative of weak hindquarters.

The thorax encloses the heart and lungs. It should be wide and deep to allow for maximum respiratory capacity and a well-developed cardiovascular system. The abdomen should be cylindrical and relatively small. Its size should be small

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<sup>4</sup>Speedy-cutting refers to any type of limb interference at a fast gait. Generally confined to pacers, cross-firing consists of the inside of the hind foot hitting the inside quarter of the diagonal forefoot.

<sup>5</sup>Over-reaching consists of the toe of the hind foot catching the forefoot on the same side, often catching the heel and pulling the shoe. Forging happens when the toe of the hind foot hits the sole area of the forefoot on the same side. When a horse is wearing shoes, forging is characterized by the sound of the front and hind shoes hitting. Scalping happens when the toe of the forefoot hits the dorsal surface of the metatarsal area of the hind limb on the same side.



enough, then, to prevent the intestines from exerting pressure on the diaphragm and hindering pulmonary efficiency.

### Conformation of the Limbs

The limbs should be well proportioned in relation to the body. Poor limb conformation can be considered a sign of weakness and predisposes the animal to lameness. When evaluating limb conformation, it is important to study the horse at rest as well as in motion. The horse should be put through its paces on a relatively hard track. A soft or grassy running surface can disguise faults otherwise readily apparent. The feet should be observed as they leave the ground, during flight, and as they land and bear weight.

#### The Forelimb<sup>6</sup>

Because the forelimbs bear some sixty-five percent of the horse's weight, they are more subject to injury from trauma and concussion than the hind limbs. The forelimbs are responsible for movement, support, and absorption of shock, but primarily serve to keep the horse erect so he is able to push forward from his hindquarters. When considering ideal conformation, one takes into account the length of the bone and the angulation between these bones. Ideal conformation of the forelimb puts no unnecessary strain on any of the limb's structures.

When observing anteriorly, both limbs should bear equal

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<sup>6</sup>Refer to plates 20 through 23 for anatomical reference.

amounts of weight, and the legs should be straight. If a line is dropped from the point of the shoulder, it should bisect the leg (see "A" of figure 3-1). The toes should face straight forward. The feet should be set apart the same distance as the limbs are at their point of origin in the chest. The carpal joints should not show any tendencies toward or away from each other. The cannon bone (the large metacarpal) should be centered under the carpus, and should show no lateral deviations.

When observing the limbs laterally, a sloping shoulder should be apparent. If a line is dropped from the tuber spinae, on the spine of the scapula, it should bisect the leg to the fetlock joint<sup>7</sup> and fall to a point just behind the heel. The carpus should not show tendencies anteriorly or posteriorly. The forearm should have well-developed musculature which serves to balance the limb. The area just beneath the carpus should not show a sudden indentation or cutting in (see figure 3-3). The slope of the hoof wall should be the same as the slope of the pastern.<sup>8</sup>

The angle of the scapula with the horse's body varies from 55 to 78 degrees. Between the scapula and the humerus is an angle varying from 85 to 100 degrees. Between the humerus and the radius at the elbow joint is an angle approximately 120

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<sup>7</sup>The fetlock joint is the joint between the large metacarpal bone and the first phalanx.

<sup>8</sup>The pastern is the part of the foot occupied by the first and second phalanxes.

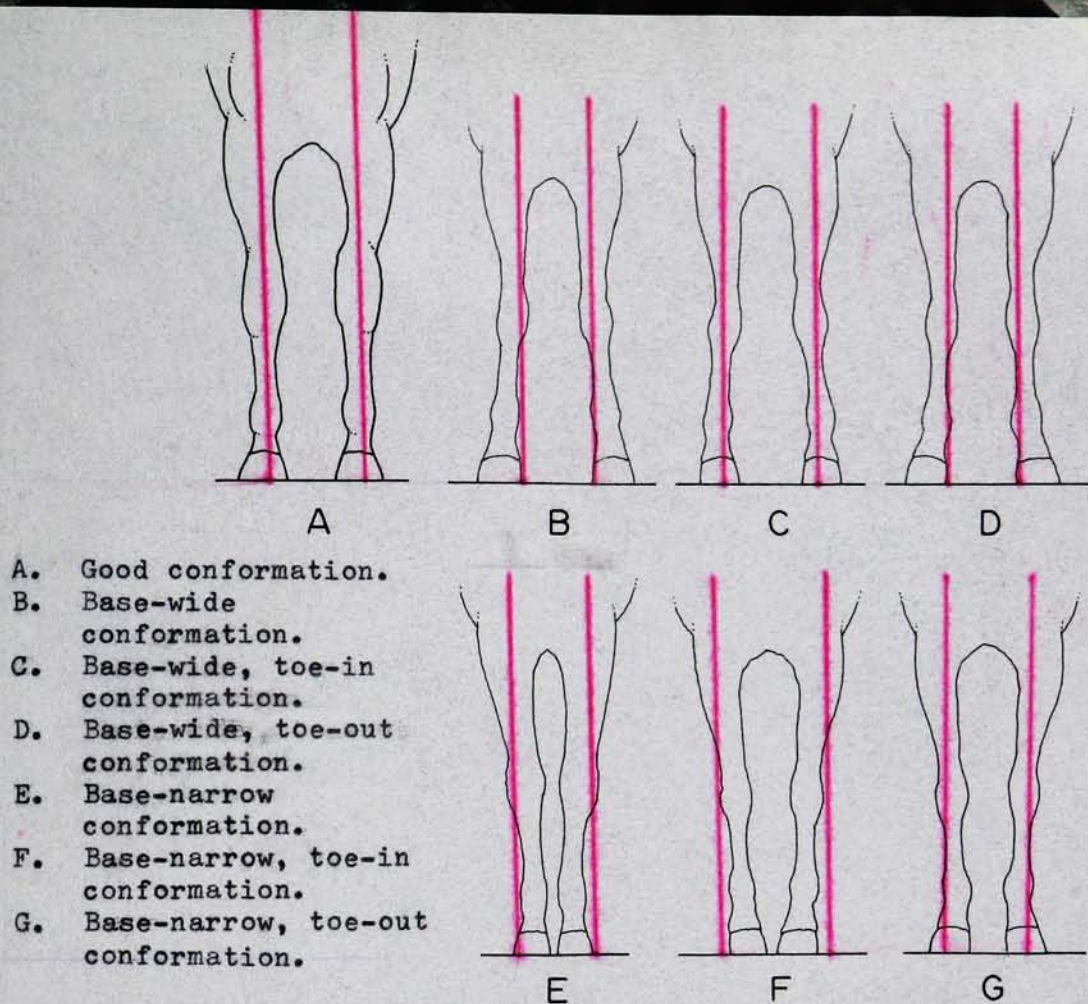


Figure 3-1.  
 Conformation of the thoracic limb, viewed anteriorly.

### CONFORMATION OF THE THORACIC LIMB

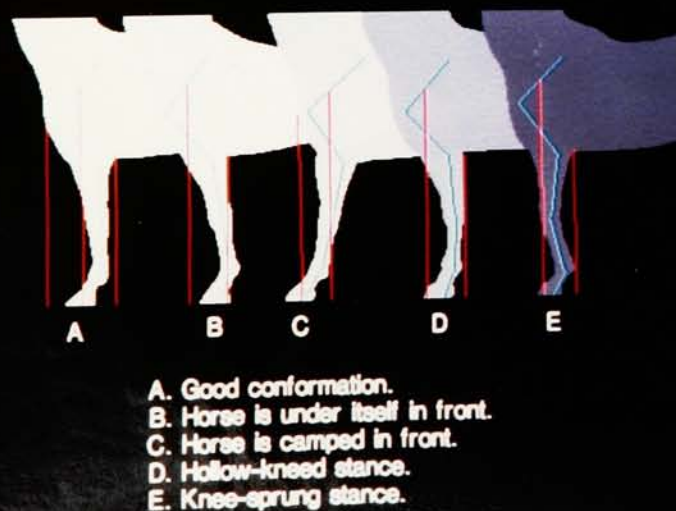


Figure 3-2  
 Conformation of the thoracic limb, viewed laterally.



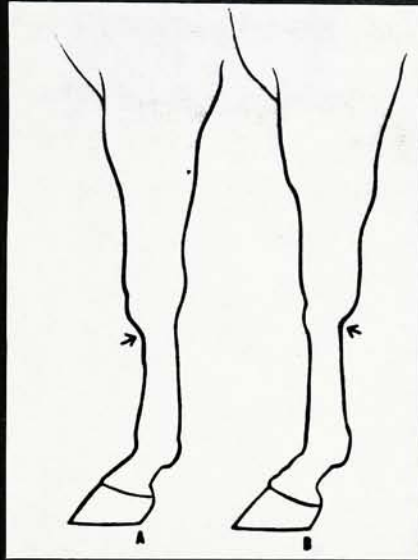


Figure 3-3.

Examples of poor conformation.

- A. Cut out under the knees, as indicated by arrow.
- B. Tied-in knees, as indicated by arrow.

Illustration is from Lameness in Horses, 3rd ed., by O. R. Adams, (Philadelphia: Lea & Febiger, 1974), p. 14.



to 138 degrees. Between the third or large metacarpal bone and the first phalanx is an angle of about 130 degrees. Between the ground surface of the foot and the anterior line of the hoof and pastern is an angle that should be approximately 45 degrees. These figures are not absolutes and will vary among the different breeds.

### Conformation of the Hind Limbs<sup>9</sup>

The hind limbs serve to propel the horse forward. Because they are less subject to trauma and concussion, lameness of the hind limbs is not as common as in the forelimbs. Conformation can influence conditions such as upward fixation of the patella, curb, and some forms of spavin.<sup>10</sup>

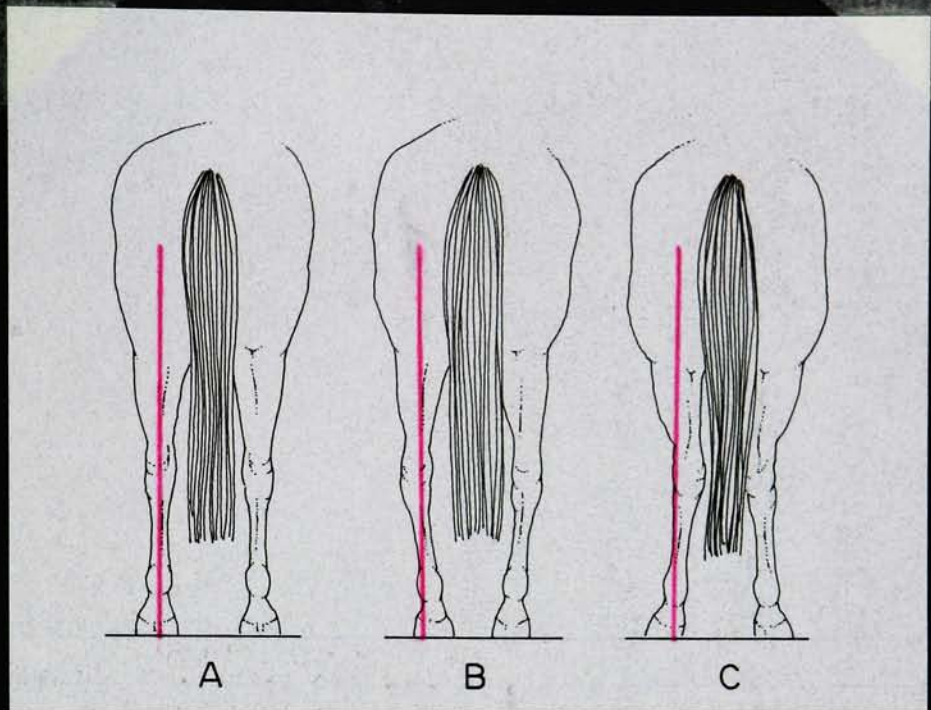
When viewed from behind, the limb should be well balanced. The hocks should be sturdy and large enough to sustain the animal's weight, but should be smooth. The inner thigh should be well muscled so as not to appear too thin. A line dropped from the point of the tuber ischii should divide the leg equally (see "A" of figure 3-4).

When viewed laterally, of course the limb should appear well balanced. It should be well muscled, and the muscles should taper gradually to the hock. The angle of the hock should not be too straight or too angular. If the angulation

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<sup>9</sup>Refer to plate 8 for anatomical reference.

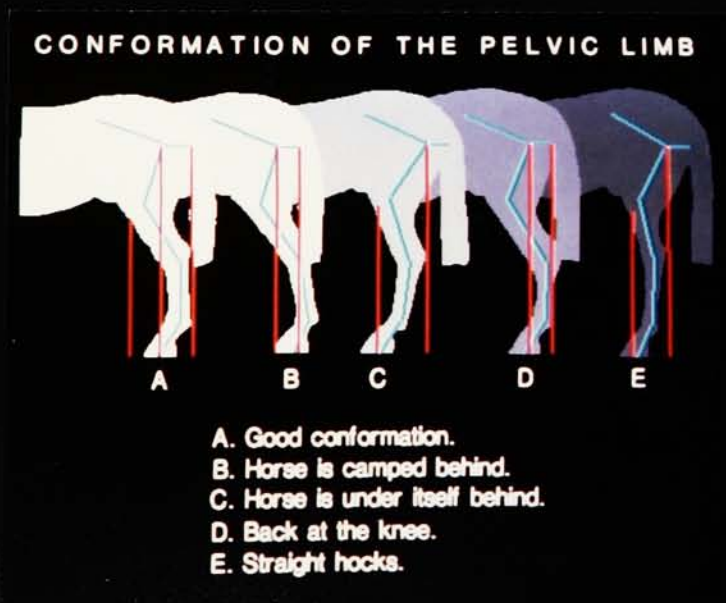
<sup>10</sup>Curb is the tearing of the plantar tarsal ligament and is accompanied by acute swelling and inflammation. Spavin is a joint disease usually affecting the proximal third metatarsal bone and the third and central tarsal bones.



- A. Good conformation.
- B. Base narrow behind, often accompanied by bow legs.
- C. Cow hocks accompanied by base-wide conformation.

Figure 3-4.

Conformation of the pelvic limb, viewed from behind.



- A. Good conformation.
- B. Horse is camped behind.
- C. Horse is under itself behind.
- D. Back at the knee.
- E. Straight hocks.

Figure 3-5.

Conformation of the pelvic limb, viewed laterally.

is too severe, the animal is considered sickle-hocked. This conformation fault can cause bone spavin or curb. If the joint is not angled enough, bog spavin<sup>11</sup> and upward fixation of the patella can occur. If a line is dropped from the tuber ischii, it should touch the point of the hock. It should continue down the posterior aspect of the metatarsal area, and should contact the ground three or four inches behind the heel. If a line is dropped from the hip, it should bisect the foot (see "A" of figure 3-5).

I will not attempt a detailed discussion of the various conformation faults of the limbs, fore or hind. I leave that to the veterinary texts. I will mention; however, that conformation faults can cause a variety of problems relating to lameness, some of which I've mentioned briefly already. Some of these faults, dependent, of course, on their severity, are relatively minor, and others have more serious implications.

#### Conformation of the Foot<sup>12</sup>

Good conformation of the foot is necessary to all activities of the horse. Since poor foot conformation is indicative of poor limb conformation, a horse must have relatively good limb conformation to have good foot conformation.

The structure of the foot varies. However, the wall of

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<sup>11</sup>Bog spavin, a form of spavin, is characterized by the swelling of the tibiotarsal joint. The swelling is caused by increased amounts of synovial fluid.

<sup>12</sup>See figure 3-6 for anatomical reference.

the foot should be strong and thick enough to sustain the animal's weight without showing excessive wear. It should also be resistant to drying, and should be pliable with normal qualities of growth. The sole of the foot should be thick, and should shed normally. It should resist bruising. The bars should be well developed, and the frog should be strong and divide the sole evenly.

Foot axis and pastern axis are very important to good conformation of the foot. The pastern axis is an imaginary line passing through the center of the pastern. This imaginary line should divide the first and second phalanges into equal parts, as viewed from all sides. The foot axis is an imaginary line that follows the same angle of the pastern, when viewed from the side. When viewed from the front, the foot axis passes through the center of the toe of the hoof wall. The normal angle of the foot axis and pastern axis is approximately 47 degrees.

A level foot is another factor in good conformation of the foot. If a foot is level, the medial and lateral walls are of equal length. Horses may wear the foot unevenly. If the animal lands on the outside wall of the foot, the outside wall will wear low. And so it follows that an animal landing on the inside wall will have a low inside wall. A foot may be made level through corrective shoeing.

Poor conformation of the foot greatly influences the flight of the foot (see figure 3-7). Poor foot conformation and the resulting movement of the foot can cause increased



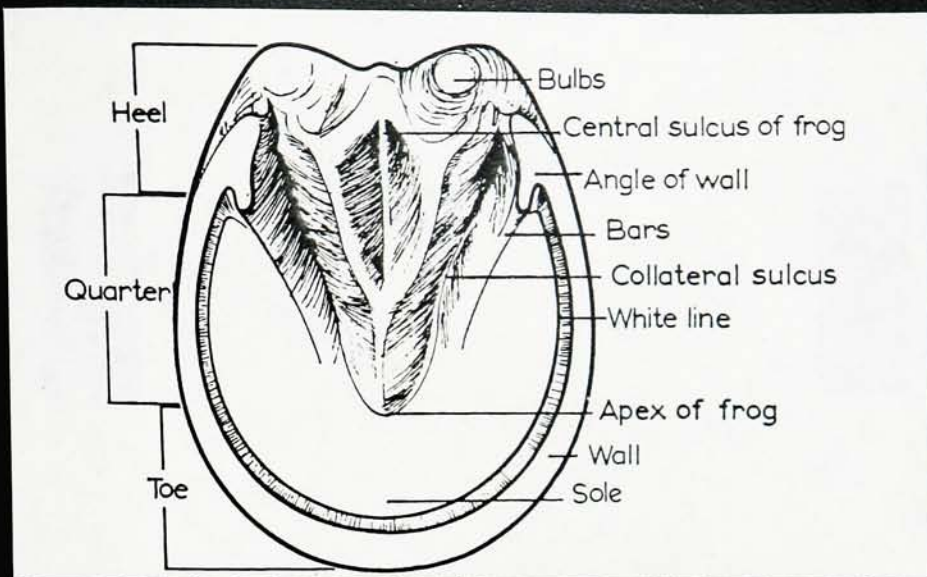


Figure 3-6.  
Structures of the foot.

Illustration is from: Lameness in Horses, 3rd ed., by O. R. Adams, (Philadelphia: Lea & Febiger, 1974), p. 26.

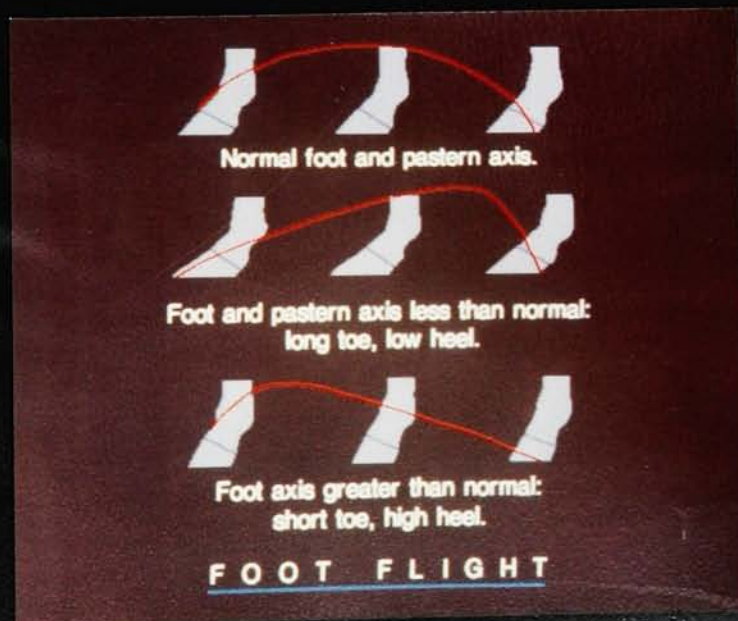


Figure 3-7.

trauma and concussion to the foot and its associated structures. This can result in numerous problems and is conducive to conditions such as ringbone;<sup>13</sup> strain on the muscles, tendons, and ligaments; navicular disease; and arthritis.

### The Drawing

When considering the drawing, I chose to base it on good conformation and the ideal measurements of the thoroughbred. As a point of departure, I used Ellenberger's diagram and accompanying charts establishing the measurements of various breeds.<sup>14</sup> Ellenberger's diagram shows a line drawing of a non-specific type of horse which serves as reference for the measurement tables of the different breeds. Concerning myself specifically with the thoroughbred, I completely reworked the drawing. My reference consisted of a previously done study (see "A" of plate 3) and several photographs. A key drawing accompanied by a table of measurement is shown in plate 6.

I chose to detail the principal drawing. One reason for doing this was to improve upon the clarity of detail. By omitting some of the lines indicating measurement in the principal drawing and including them in a detail, I was able to avoid possible clutter in the principal drawing. Also, because the details are also enlargements, it follows that they

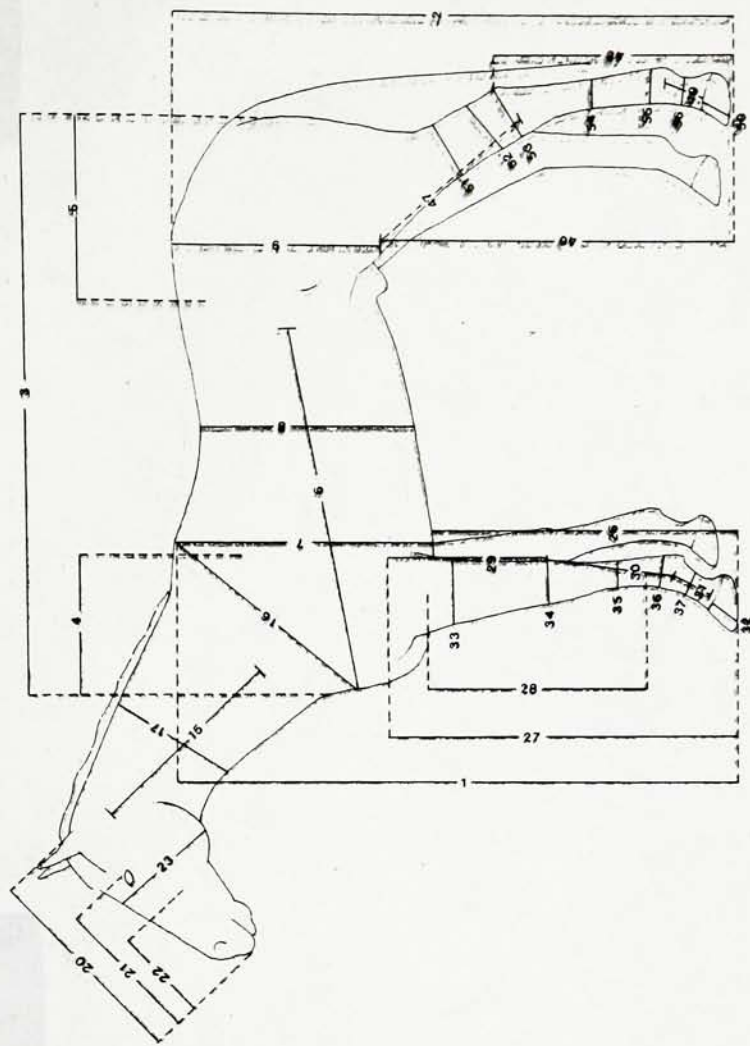
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<sup>13</sup>Ringbone is defined as new bone growth occurring on the first, second, or third phalanx.

<sup>14</sup>W. Ellenberger, H. Baum, and H. Dittrich, An Atlas of Animal Anatomy for Artists, Lewis S. Brown, ed., (New York: Dover Publications, Inc., 1956), pp. 34, 36-37.

1.	62 1/2	31.	5 1/8
2.	62 3/4	32.	4 1/8
3.	62 15/16	33.	6 11/16
4.	15 3/8	34.	4 1/4
5.	19 1/4	35.	2 13/16
6.	38 1/8	36.	3 9/16
7.	27 3/16	37.	2 3/8
8.	23 13/16	46.	40 1/2
9.	21 7/8	47.	20 1/2
15.	24 3/8	48.	25 9/16
16.	22 13/16	49.	4 3/4
17.	14	50.	4 3/4
20.	24 9/16	51.	6 1/2
21.	15 3/4	52.	5 11/16
22.	9 7/8	53.	5 7/8
23.	11	54.	3 9/16
26.	35 3/8	55.	3 3/4
27.	38 15/16	56.	2 9/16
28.	24 3/4		
29.	19 1/4		
30.	13 3/8		

Table of measurements in inches.



English thoroughbred stallion. Ten year old race horse.



read with more ease thereby adding to the clarity. I felt that simply enlarging portions of the drawings was not enough. It did not create enough interest. So, I decided to use the details to convey additional information. This added interest to the drawing as well as increasing its educational value. I chose to include skeletal anatomy thereby illustrating the underlying structure.<sup>15</sup> Skeletal anatomy is not shown in all of the details so that some variety exists. This makes the composition less monotonous.

The component parts of the drawing are as follows:

(1) principal drawing, (2) detail of the hind foot showing skeletal anatomy, (3) detail of the thoracic limb, (4) detail of the head showing skeletal anatomy, (5) accompanying text.

The accompanying text elaborates on the drawing. It reads as follows:

English and Irish breeders, indeed, consider that the Thoroughbred is a better made animal than the Arab, whose shoulders are too upright, giving him a short front, and whose hind legs are too bent in the shape of a sickle for their liking. They set great store by the shape of the hind leg, in particular the hocks, this is after all, the engine. Hocks which are hooked are liable to strain in the forms of curbs, spavins, and thoroughpins. They aim for a strong and muscular second thigh, a large bony hock, free from fleshiness, and they like the hind leg to drop straight down to the ground from the hock, with no forward curve, so that a straight plumbline [*sic*] can be dropped vertically from the tail to the ground which will touch the point of the hock and the fetlock joint. This is the type of hind leg which has proved to be the most durable in the hunting field.<sup>16</sup>

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<sup>15</sup>Plates 19 through 23 are studies for these drawings.

<sup>16</sup>Pamela MacGregor Morris and Nereo Lugli, eds., Horses of the World, (New York: A Division of Crown Publishers, 1973), p. 27.



In order to accurately depict the anatomical aspects, good reference was required. Drawings and photographs from books did not always show the views I needed, and the detail was not always sufficiently clear. I also made a troublesome discovery: there are conflicts in the drawings and the labelling of these drawings in various texts. It was in this way that I realized I could not take the accuracy of reference material for granted.

The problem of conflicts found in the labelling of drawings was relatively easy to remedy. These conflicts are primarily the result of antiquated terminology. I corrected these by consulting various current veterinary texts. A veterinarian was consulted when the texts were not sufficient.

The problem of accuracy and clarity of detail in reference drawings and photographs presented a more complex problem. I needed to be able to refer to actual skeletal structures. I was fortunate to have found and to be able to have photographed the necessary structures. I photographed specimens at the Museum of Comparative Zoology at Harvard University, the Rochester Museum and Science Center, and the New York State Veterinary College at Cornell University. The Harvard photographs were shot under less than ideal conditions, but I was able to improve conditions on my subsequent shootings. I photographed with Tungsten 160 film and utilized quartz lamps and a seamless background. Examples from these shootings appear in appendix A.

Once the components of the drawing were chosen, and once

sufficient reference material had been obtained, I began planning the actual composition. I made numerous thumbnail sketches. Then, I chose the most pleasing composition and enlarged and refined it.

I then began executing the drawing. I masked each section as I worked. This served several purposes. It kept the drawing free from dirt and skin oils. I took the added precaution of wearing lintless gloves as I worked for this same reason. The mask also prevented a build-up of fixative on areas yet to be worked on.

An ink outline was laid first. Pencil was not used as it smears and "pollutes" the pastel colors. The pastel dust was applied next. First, a "wash" of pastel color was applied. The laying of darker tones followed. Fixative was used as required to keep the pigment from smearing and to aid in the building up of color. The rendering was completed with colored and graphite pencils. Next, I laid the lines indicating measurement. These were laid with either white or black ink--whichever best showed up on the particular color of ground. Because of the many layers of fixative (necessary to hold the pastel to the paper), the ink would not take readily to the paper. This was remedied by going over each line several times.

To finish the drawing, the lettering was executed. The first step was to determine the fit of the copy. By handwriting the copy first, I got a very good indication of how the space would accommodate the copy. As a practice run, I wrote out the

copy as it would appear on the drawing. Before executing the final lettering, it was necessary to warm up. Warming up enables me to develop a regular rhythm to the writing and aids in maintaining a consistent hand. Because the lettering was handwritten as opposed to computer-generated, the fit of the final lettering differed slightly from the fit of the practice lettering. This necessitated some spontaneous editing to avoid poor fit of the copy. Any errors were corrected by first removing them with an electric eraser, and then writing in the appropriate copy.

Framing was an important consideration to the character of the piece. The frame should enhance, not take away from the drawing. I felt that matting was not necessary as it added little to the piece. In fact, I felt that it detracted. So, I concerned myself only with a frame. I chose a simple metal section frame. The frame is sepia in color--the same color as the ink used for outlining and lettering. In this way, the color of the frame complements the drawing. It is also a very thin frame, and so does not overpower the drawing. It serves as a nice finishing touch to the piece. The same type of frame was used for the second panel in order to maintain a certain uniformity.

#### Panel II Aspects of Equine Motion and Motion Sequence

Working on Panel I enabled me to lay the groundwork for this second drawing. Decisions regarding character, basic format, and media had been made. And so as I approached this



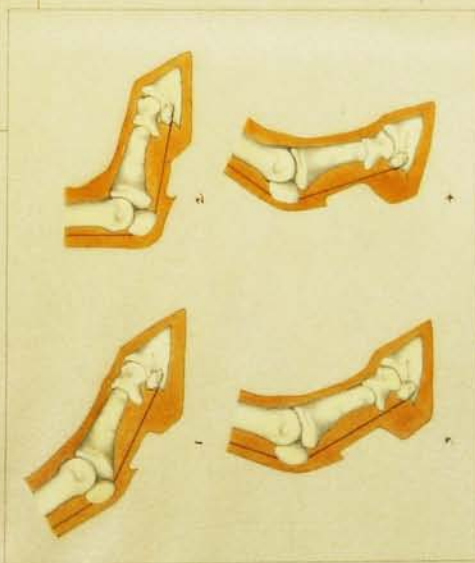
The lig of the foot is a complex construction of bone, ligament, & muscle. The foot must have the necessary strength to support the full weight of the body as groups of fibers make up these. The strength of the lig comes from the strength of the bone & from muscle at tendon. The phalanx play an important part and the ligament making up supporting the landing foot made up the foot apparatus after they apparatus tried to support the limb and the foot itself. through contraction, and to prevent excessive extension of the phalanx, system, or system pointed to a bit later where contraction occurred on the tips of the foot, contraction to the foot is produced by the animal's weight and by contraction of the muscle.



The movement of the front leg may be described under five stages: 1. The hoof travels over the ground, and the legs adjust to receive the impact of the body's weight. 2. The body moves forward, so that the hoof's center of gravity is just over the hoof at the instant it is lifted. 3. The hoof is lifted from the ground, and the leg is extended forward. 4. The hoof is extended forward, and the leg is extended forward. 5. The hoof is extended forward, and the leg is extended forward.

[illegible]

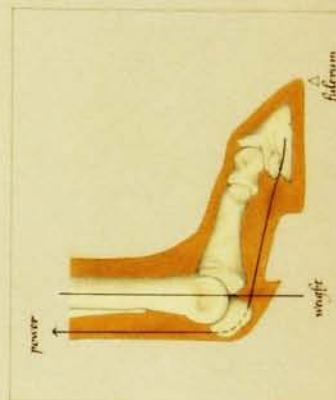
Now will contacts be given in the same level, with the top extended outward, however often a top movement is effected by an all-top step over by the body's tendency to avoid a under-tact condition the body will may contact the ground outside, but how the actual movement differs from the ideal and how it relates to the individual can be known can tell the individual's ability to make the same determination among either body whether the deviation is due to pain or to incorrect foot shape. If your position is incorrect during the ten to ten position how to correct it.



Twelve four-pointed movement of the digital knee<sup>3</sup> at the center.

[illegible]

the point where the lifting power is applied. The nearer the weight is to the fulcrum, the greater is the mechanical advantage of the lever and the less the power required. In the body, the power of a muscle is measured by the length of its fibres, and the weight of the bone to be moved. The weight of many distal bones is less than the maximum bone on the same bone. The power is applied at the end of the lever, which is at the back of the hand, and the weight is at the tip of the thumb. Thus, the farther the weight is from the fulcrum, the greater the effort required to move it. The weight of many proximal bones is more than the maximum bone on the same bone. The weight is applied at the tip of the bone, and the weight is at the back of the hand. Thus, the nearer the weight is to the fulcrum, the greater the effort required to move it.



But it's a hard old love.



piece, my main concern was with content: in this case, motion and the sequence of motion. To gain a better understanding of motion and all that it entails, I researched the physiology of movement. An overview follows.

### Physiology of the Forelimb

This discussion deals specifically with the canter and gallop because they best illustrate movement of the leg. However, it should be realized that the same movements and strains occur at all gaits. Yet, the degree of strain may vary. While this discussion is primarily concerned with the forelimbs, it should also be realized that the hind limbs go through the same movements in their turn.

In each stride, the leg of the horse undergoes two different kinds of strains: compression and concussion. Concussion occurs when the leg impacts the ground and bears weight. As the leg sustains weight and propels the horse forward and upward, compression is experienced.

The majority of injuries causing lameness occur in the front legs. Considering each front leg bears the greater amount of body weight at specific points in a stride, this is easily understood. The leading leg<sup>17</sup> is especially prone to injury. It bears the entire weight of the animal for a period of time longer than that of the nonleading leg, and it does so unassisted. And so, it follows that it is more subject to

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<sup>17</sup>At the canter and gallop, the forelimb that is the last to leave the ground before the period of suspension is considered to be the leading leg.

strain and injury.

Before breaking the canter down into the phases of movement, it should be understood from a more general standpoint. The canter is a restrained gallop, and it is a three-beat gait. With the right leg leading, the feet contact the ground as follows: (1) near-hind, (2) diagonal off-hind and near-fore together, (3) off-fore.<sup>18</sup> A short period of suspension follows.

### Phases of Movement

The movement of the front leg may be divided into five separate phases. They are as follows:

1. The hoof touches the ground, and the leg begins to receive the impact of the body's weight.
2. The body moves forward, so that the horse's center of gravity (that area below the withers [the point located at the base of the neck between the shoulder blades] and just behind the shoulder) is about to pass over the hoof; at this moment the fetlock usually reaches its lowest point.
3. The fetlock starts upward from its lowest point as the center of gravity moves ahead of the hoof. By straightening the digit, thus raising the fetlock, the leg pushes off the ground. The transition from the second phase to the end of the third is the most stressful period.
4. The hoof rises upon the toe, and the knee begins to relax as the hoof leaves the ground.
5. The leg moves through the air and straightens out in preparation for coming to the ground again.<sup>19</sup>

During the first phase, the horse's foot strikes the ground. It is a misconception that the leg extends and makes

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<sup>18</sup> "Near" refers to the left side of the horse; "off" refers to the right side.

<sup>19</sup> Leslie Emery, Jim Miller, and Nyles Van Hoosen, D.V.M., Horeseshoeing Theory and Hoof Care, (Philadelphia: Lea & Febiger, 1977), pp. 41-42.

contact with the ground during this extension. This is not true. The leg extends and then retracts. It is during the course of retracting the leg that the foot makes contact.<sup>20</sup> The rate at which the leg swings back directly influences how fast the horse moves. If the leg is pulled back at the same speed the horse's body is moving forward, the horse is travelling at near constant speed. In order for the horse to slow its speed, the speed of the backward swing of the leg is decreased. For the horse to quicken its pace, the speed of the backward swing of the leg is increased.

Concussion to the leg is greatest between the time the horse's leg first contacts the ground and begins to accept weight, and the time at which the leg accepts the full force of the weight. The leg is extended and the digit is relatively straight. The shock of the impact is absorbed by the shoulder, elbow, fetlock, and coffin joints.<sup>21</sup> The hoof also plays a part in the absorption of shock. As the body of the horse is carried forward, the leg experiences the maximum pressure of weight.

During the second phase, the horse is propelled forward by the contraction of the muscles of the posterior tendons of the forelimb, and also by the movements of the shoulder and elbow. The bending of joints acts to absorb shock. The coffin

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<sup>20</sup> See appendix D. The computer plot of the vertical acceleration of a horse's foot documents this.

<sup>21</sup> The coffin joint is the joint between the second phalanx and the third phalanx (also referred to as the coffin bone).



and fetlock joints reach maximum extension, and the flexor muscles begin to contract. The knee experiences increasing pressure as the weight of the animal moves over and ahead of it. The pressure on the knee continues to build through the third phase. Then, the leg breaks the hoof over at the toe. But before the hoof leaves the ground, the large deep flexor muscle exerts a strong pull on the hoof. This serves to lift the horse up and forward.

#### Differences Between the Front and Hind Limbs

Although the hind limbs undergo the same basic movements as the forelimbs, there are some differences. The hind legs function to lift and propel the body forward and upward. They are designed much like a spring and can extend with great force and then recoil again under the body. An important difference between the front and hind limbs is that the hind limbs carry weight but are not driven into the ground by the weight they carry. They are unlike the front legs in this respect as the front legs are driven into the ground. The front legs function primarily to bear weight as opposed to propelling it. The design of the front leg is less giving than that of the hind leg. Although it is not their primary function, the front legs also contribute to propulsion. Another difference between the limbs is the way in which they break over. Because the front leg travels a straight line through the air and contacts the ground squarely, it breaks over at the toe. However, the hind leg has a tendency to swing through the air, usually to the outside. The hoof will often

contact the ground sideways causing the foot to roll to one side. Also, the hind foot makes contact with the ground by gliding in smoothly as opposed to the more concussive impact of the front leg.

### The Mechanics of the Front Leg

The front leg is comprised of a series of levers and pulleys. A good example of this is the lever created by the large metacarpal bone and the digital bones during the third phase of movement. When the center of gravity passes over the hoof and the efforts of breakover are about to begin, this lever develops its form. The digital bones and the hoof form the actual lever. With the fulcrum<sup>22</sup> being the ground at the toe, the lever is from the fulcrum through the digital bones to the back of the sesamoids. This type of lever is classified as a second-class lever. The weight that is to be moved exists between the fulcrum and the point where the lifting force or power is applied. In the case of the horse, the deep digital flexor tendon is the principal lifting force. The weight is transmitted down the large metacarpal bone onto the fetlock. The back of the sesamoid bones are the end of the lever, and this is where the lifting force is applied. The time and effort required for the leg to reach breakover depend on the placement of the fulcrum, or toe. The more forward the placement of the toe, the more effort and time are required for the leg to reach breakover.

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<sup>22</sup>A fulcrum is the point on which a lever turns.

## The Drawing

All of the compositional elements used in Panel II stem from information uncovered in the course of my research. The elements are as follows: (1) four phases of the digital bones at the canter, (2) the digit as a second class-lever, (3) walk sequence, (4) buck sequence, (5) explanatory text.

There are three blocks of text that accompany various elements of the composition. The first one, somewhat general in nature, reads as follows:

The leg of the horse is a complex structure of bone, ligament, and muscles. The leg must have the necessary strength to support the full weight of the horse at speeds of forty miles per hour. The strength of the leg comes from the strength of the bone and the long muscles and tendons. The suspensory apparatus of the fetlock joint and the structures aiding in supporting the standing horse make up the stay apparatus. The stay apparatus serves to support the limb and fetlock, diminish concussion, and to prevent extensive extension of the fetlock, pastern, and coffin joints. In a fast gait, there is concussion exerted on the legs of the horse. Concussion to the foot is produced by the animal's weight and the counterpressure of the earth.

The two other blocks of text refer to specific elements of the composition. The text accompanying the illustration of the first four phases of movement of the digital bones at the canter follows closely the discussion on the physiology of the forelimb (pp. 61-64). It reads as follows:

The movement of the front leg may be divided into 5 phases. (1) The hoof touches the ground, and the leg begins to receive the impact of the body's weight. (2) The body moves forward, so that the horse's center of gravity--that area below the withers and just behind the shoulder--is about to pass over the hoof; at this moment the fetlock usually reaches its lowest point. (3) The fetlock starts upward from its lowest point as the center of gravity moves ahead of the hoof. By straightening the digit, thus raising the fetlock, the leg pushes off the ground. The transition from the second phase to the end of



the third is the most stressful period. (4) The hoof rises upon the toe, and the knee begins to relax as the hoof leaves the ground. (5) The leg moves through the air and straightens out in preparation for coming to the ground again. These five phases apply at any gait to both front legs, regardless of which leg is leading. The same movements are made by the hind legs in their turn. Understanding is essential here, because if the foot does not come to the ground properly or is not properly shaped, weight could be poorly distributed on it and uneven and excessive strains could result. Normally, the bearing surface of the hoof wall contacts the ground flat and level, with the leg extended outward. However, often a leg's movement is affected by an ill-shaped hoof or by the horse's attempt to avoid pain; under these conditions the hoof wall may contact the ground unevenly. Just how the actual movement differs from the ideal and how it relates to the individual's conformation can tell the knowledgeable observer much. He can often determine, among other things, whether the deviation is due to pain or to incorrect hoof shape. If the problem is incorrect shape, the deviation indicates how to correct it.<sup>23</sup>

The third block of text elaborates on the illustration of the digit as a second-class lever. It follows:

The front leg is an intricate series of levers and pulleys. The lever with which we are most concerned is that created by the cannon bone and the digital bones during the third phase of movement. This lever develops its working form at the beginning of the third phase. The form develops at the instant that the center of gravity passes over the foot and the efforts of breakover are about to begin. This lever is formed by the digital bones and the hoof. The fulcrum is the ground at the toe. The lever is from the fulcrum through the digital bones to the back of the sesamoid bones. A physicist calls this a second-class lever; the weight to be moved is between the fulcrum and the point where the lifting (power) is applied. The closer the weight is to the fulcrum, the greater the mechanical advantage of the lever and the less is the power required. In the horse, the power is applied primarily by the deep digital flexor tendon. The weight is transmitted down the cannon bone onto the fetlock. The power is applied at the end of the lever, which is at the back of the sesamoids. Thus, the farther the toe is from an imaginary perpendicular line through the fetlock joint when the horse is at rest with the

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<sup>23</sup>Adapted from Horseshoeing Theory and Hoof Care by Leslie Emery, Jim Miller, and Nyles Van Hoosen, D.V.M., (Philadelphia: Lea & Febiger, 1977), pp. 41-44.

weight evenly distributed, the farther the fulcrum is from the weight, and greater is the effort needed to operate the lever.<sup>24</sup>

I chose to include two illustrations showing the sequences of particular gaits. The plates of Muybridge, my photographs of the horse in motion, and various book illustrations served as reference. I chose first to deal with the walk. I felt that a simple approach was in order, and so rendered the walk in line with subtle shading. Had I chosen to render it in color, I feel that it would create tension--giving the eye too much to look at. By keeping the illustration in line, I feel it creates a pleasing variation of texture and complements the composition. The second sequence shows a bucking horse. For this illustration, it was necessary to depart from the pastel dust technique. A subtle transition of tone from the beginning of the sequence to the end was required. I feel that this is best accomplished through the use of transparent color. Pastels not being transparent enough, I turned to watercolors applied with an airbrush. In this way, I was able to achieve the desired tonal gradations. Additional rendering was done in both graphite and colored pencils.

The method of arriving at a final layout was the same as the method used in the first drawing. Similar execution of technique, with the exception of the airbrushed illustration of the bucking horse, was used also.

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<sup>24</sup> Adapted from Horseshoeing Theory and Hoof Care by Leslie Emery, Jim Miller, and Nyles Van Hoosen, D.V.M., (Philadelphia: Lea & Febiger, 1977), pp. 61-63.

#### IV. CONCLUSION

The study of gait analysis is an active and flourishing field. It has many applications that reach far beyond what one might expect. The information uncovered through the study of the horse and how it moves contributes to the knowledge of animal locomotion in general. Underlying principles of movement are relevant to many different organisms. Present day technology allows us to expand our understanding of how both animal and man move. We can monitor respiration, analyze muscles for glycogen<sup>1</sup> depletion, and perform biopsies to determine the degree of involvement of individual muscle fibers. Knowledge of how muscles function is essential to understanding any kind of muscular or orthopedic problem. It helps us understand athletic training and how to effectively utilize athletic ability. It contributes also to the understanding of rehabilitation and the building of artificial limbs.

Understanding this has enabled me to gain a greater awareness of what being a scientific artist involves. In the course of pursuing my thesis work, I came to recognize myself in the role of both scientist and artist. In addition to this, I was made aware of the importance of research. As a scien-

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<sup>1</sup>A polysaccharide, the chief carbohydrate storage material in animals, formed by and largely stored in the liver and to a lesser extent in the muscles; it is depolymerized to glucose and liberated as needed.



tific artist, it is not only a responsibility to oneself that inspires thorough research, but also a responsibility to one's art and one's audience.

I learned that one should not take the accuracy of published information for granted. While involved in research, I encountered several inaccuracies. I checked the material against other publications, against my own research, and consulted professionals when it was called for. I notified the publishers of these inaccuracies. In this way, I have contributed to the educational value of my own work as well as improving upon the accuracy of published information.

I feel that I have been successful in my work. I have produced material that is of aesthetic and educational value to both the scientific and artistic communities.

And although I have been thorough in my work, I have only scratched the surface. The groundwork has been laid for future pieces which I intend to pursue. More importantly, an attitude has been established which I hope remains prevalent throughout my career. I continuously strive to approach life and career with energy, enthusiasm, and sensitivity--living life responsibly and living it from the heart.

APPENDIX A

THOMAS EAKINS:  
An Overview of His Studies in Anatomy

By

Karen Ackoff  
January 1982

On May 1st, 1984, when Thomas Eakins presented his paper, "The Differential Action of Certain Muscles Passing More Than One Joint," to an audience at the Academy of Natural Sciences Proceedings of Philadelphia, an overlapping of interests was apparent. Firstly, his topic of animal locomotion is and has been of interest to both the artist and the anatomist. Secondly, the analytic character of Eakins's working methods put into play the ideals of his scientific colleagues.

In 1878, Edweard Muybridge published the first photographs of the horse in motion. These studies attracted the attention of scientists and artists in Europe and America. Muybridge felt that scientists found his studies to be animated zoology and artists found them to be motion stopped.

Eakins's interest in anatomical studies began, or perhaps was encouraged, by Rosa Bonheur, an animal painter with whom he spent three years in Paris. She made an impression on Eakins with her dissections of the horse which she used as reference for her paintings. Once he returned to Philadelphia, Eakins began his own horse dissections--doing both drawings and skeletal studies in plaster relief. This led to his eventual teaching of horse anatomy, with an emphasis on function, at the Pennsylvania Academy of the Fine Arts. Although, he was later dismissed after he undraped a male model to a class of men and women.



Eakins experimented in many directions. His interest in Edweard Muybridge's motion studies was so recognized that he was asked to serve as a member of the supervisory commission when Muybridge was invited to further his studies at the University of Pennsylvania. Other members of the commission were university scientists and Academy of Natural Sciences Proceedings members.

The challenge of tradition marked Eakins's work. He worked using many types of observations. This was especially apparent in his work on the Fairman Rogers's four-in-hand.<sup>1</sup> Fairman Rogers was an ANSP member,<sup>2</sup> avid horseman, and owner of the first four-in-hand coach in Philadelphia. Muybridge's photographic studies caught his attention and so he commissioned Thomas Eakins to paint his coach in action--the Muybridge photographs serving as reference for the positions of the horses' legs. Aside from the Muybridge studies, observations were made without the camera. Landscape studies were done from life. The horses were modelled in wax, serving as reference for preparatory sketches.

Although Eakins's use of photographs in his work was scorned by other painters, he remained headstrong and purposeful throughout his endeavors. Few painters would admit to using photographic reference for their work. It was thought to be beneath their dignity. This attitude might have been par-

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<sup>1</sup>A vehicle drawn by four horses and driven by one person.

<sup>2</sup>The Academy of Natural Sciences Proceedings of Philadelphia.

tially attributed to the fact that at that time there was a rivalry between the painter and the photographer--photography having replaced the portrait. Painters were forced to pursue other directions in their work and so, turned to impressionism, post-impressionism, etc. Yet, Eakins remained faithful to this approach.

Eakins's presentation of his paper was preceded by twenty-five years of study in the field of anatomy. He undertook the research for his paper because of an incompatibility he found between what authorities had written and his own observations. Muscles are classified as flexors and extensors

and were thought to rest and work alternately. This simple classification was found to be unsatisfactory when applied to muscles passing more than one joint--flexing one joint while extending another.

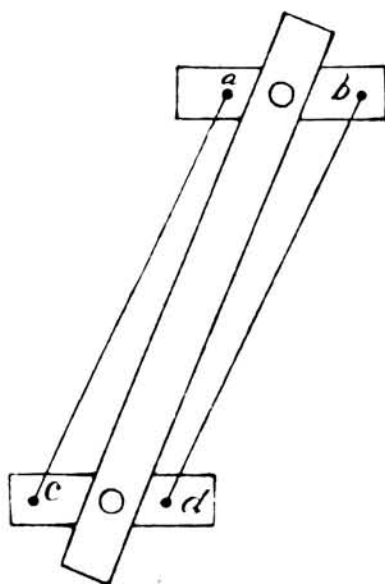


FIGURE A-1

Eakins set about constructing a model of the entire limb to help him consider leverage and the tendons extending from the muscles. Pine board was cut to outline the bones; the pieces pivoted together. Catgut served as tendons and ligaments; rubber bands as muscles. See figure A-1.<sup>3</sup> This

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<sup>3</sup>Drawing is from Thomas Eakins's article "The Differential Action of Muscles Passing More Than One Joint," The Proceedings

helped Eakins to establish two important principles. The collapse of the leg was prevented, when the hoof was set firmly on the ground, by the leverage of the tendons passing those joints. The tightening of the rubber bands represented the action of the principal muscles. When these rubber bands were released, the upper part of the limb would spring forward.

To further these findings, Eakins denuded a horse's leg of all muscle fiber and found no tendency for the leg to collapse. An increase of weight on the limb, in fact, produced an increase in its resistance to collapse. This was explained with photographs at the presentation of his paper to the Academy of Natural Sciences Proceedings.

To illustrate the muscle and tendon action in a simple way, Eakins constructed another model (figure A-2).<sup>4</sup> If two strings, inextensible, were looped from "a" to "c" and from "b" to "d," the upper horizontal piece was held up and sustained weight. If the strings were replaced with rubber bands

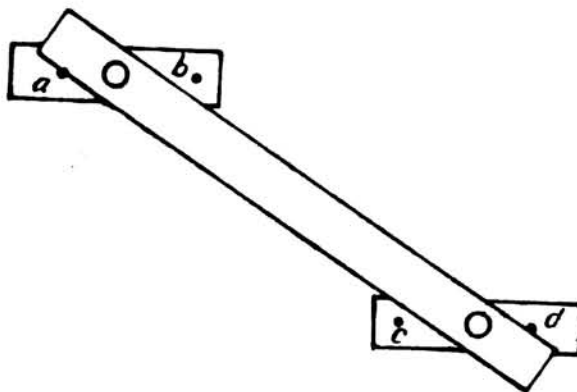


FIGURE A-2

and, therefore, could be stretched, the upper horizontal piece

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of the Academy of Natural Sciences of Philadelphia, (1894):  
p. 173.

<sup>4</sup>Drawing is from Thomas Eakins's article "The Differential Action of Muscles Passing More Than One Joint," p. 174.



sprang forward very far and very quickly compared to the actual shortening of the rubbers. As Eakins pointed out, they only approximated the movement of the leg as a pivot and did not represent the motion accurately because articular surfaces are not circular (as in the model). The axes of bones moving in constraint, one against the other, did not stay in the same plane. Eakins found the axes described to have warped surfaces.

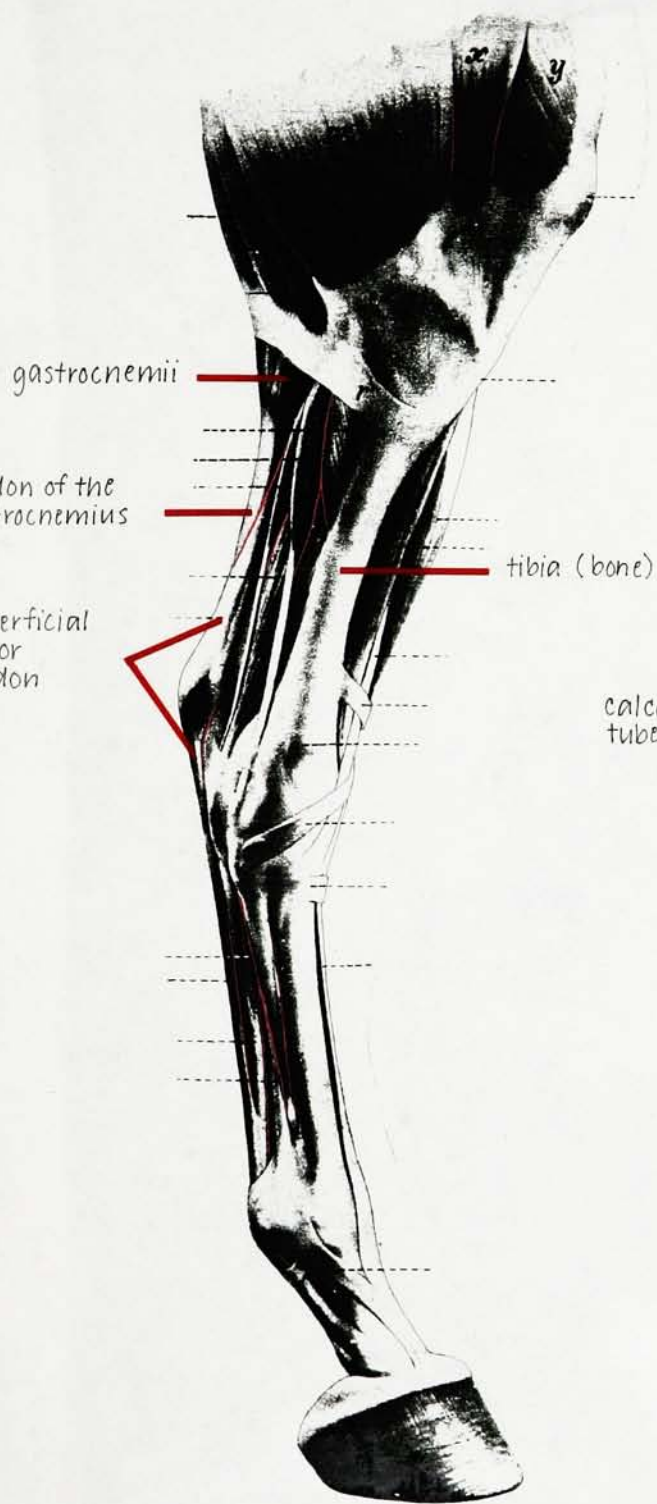
To properly investigate the action of a muscle, Eakins believed it necessary to consider it with reference to the levers to which it was attached as well as its relation to the entire movement of the animal. When this was taken into consideration, it was evident that numerous muscles previously categorized as antagonistic were actually two parts of the same muscle. The gastrocnemius was cited as an example.

The gastrocnemius (refer to plate 8)<sup>5</sup> is a short muscle with its origin above the knee and is inserted into the calcaneal tuber. In standard anatomies of that time, this muscle was said to be the flexor of the knee joint, flexor of the leg on the thigh, and the extensor of the ankle joint. The muscle, as flexor of the knee, would then be antagonistic to the great triceps of the thigh. Yet, Eakins found that the great extensor cruris, as it pulled on the patella and straightened the knee, moved the origin of the gastrocnemius con-

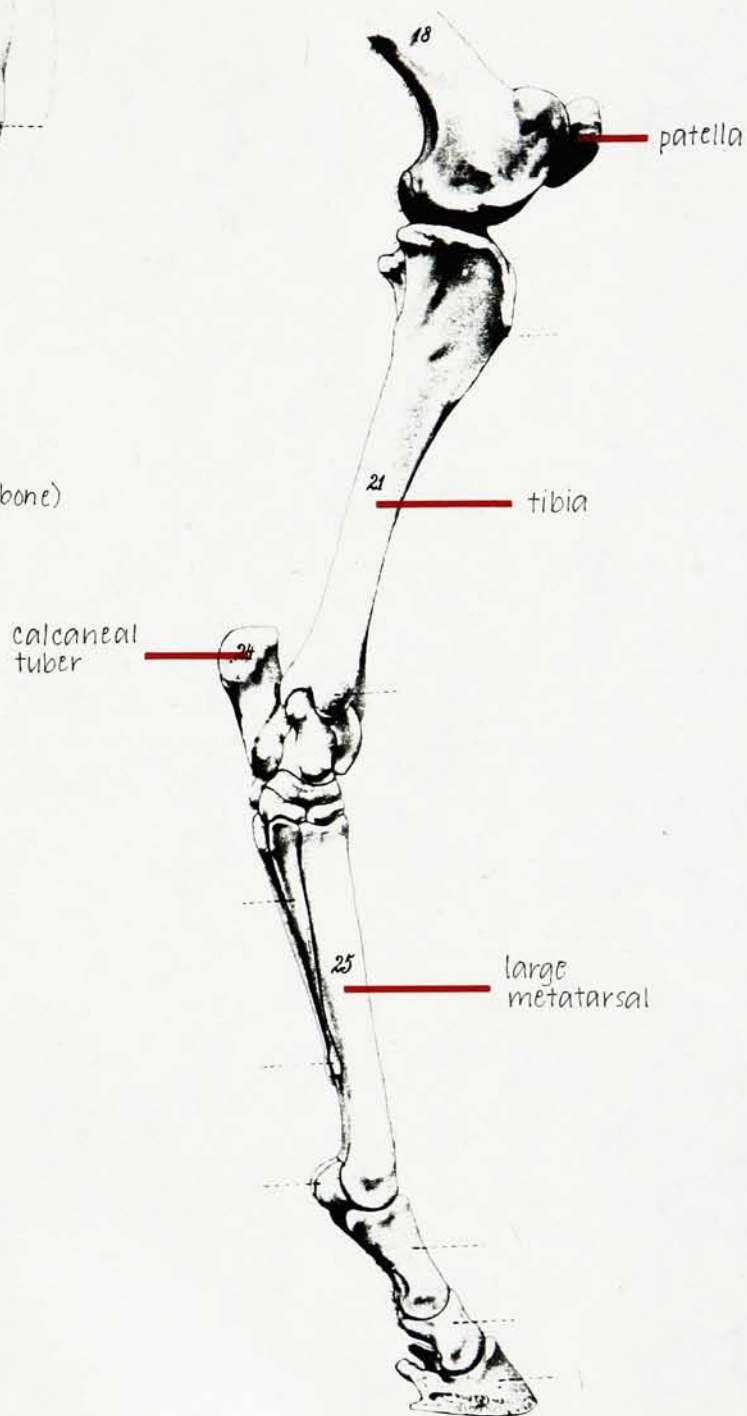
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<sup>5</sup>Drawing is from An Atlas of Animal Anatomy by W. Ellenberger, H. Dittrich, and H. Baum; Lewis S. Brown, ed., (New York: Dover Publications, Inc., 1949), pp. 22-23.

Muscles and bones of the pelvic limb.  
Medial view.



Muscles.



Bones.

tinuously forward. The gastrocnemius pulled on the calcaneal tuber and contracted itself at the same time and drew forward the calcaneal tuber faster than the origin moved forward and acted during this entire process. Eakins proved this point by cutting away all the muscles except the gastrocnemius in the dissected horse. The gastrocnemius was contracted and drew forward the calcaneal tuber, but it extended, not flexed, the knee. The fibers of the gastrocnemius are short, so that if the origin of the muscle were not moved forward, the muscle would reach its limit of contraction before the movement was completed. Thus, the gastrocnemius was found to be auxiliary to the triceps, not antagonistic.

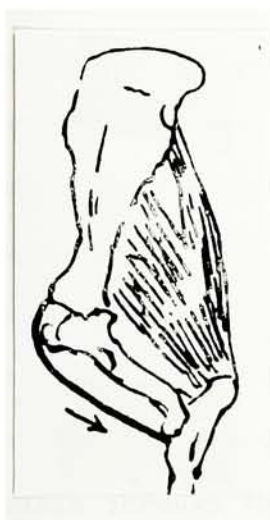


FIGURE A-3

Eakins furthered his exploration of this discovery by looking at the tendinous portion of the flexor metatarsi--the tendon running up the tibia. This tendon possesses greater leverage on the upper portion of the knee joint than on the lower ankle joint which it also passes. But this muscle also has reverse leverage. At the knee, it has a shorter leverage than at the ankle joint. And so, it raises the calcaneal tuber as it contracts and pulls

down the flexor metatarsi tendon. See the arrow in figure A-3.<sup>6</sup> Taking into consideration the differential action of the

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<sup>6</sup>Drawing is from Thomas Eakins's article "The Differential Action of Muscles Passing More Than One Joint," p. 177.



gastrocnemius muscle, the triceps can be looked upon as the auxiliary of the gastrocnemius in extending the knee joint.

Eakins cited another example of differential muscle action: the biceps in the arm of the horse. In the arm of the horse, the biceps are in front of the bone; the triceps behind. The biceps flexor radialis surrounds the tendon drawn in heavy black line in figure A-4.<sup>7</sup> (For anatomical reference, see plates 9 and 10.)<sup>8</sup> The biceps flexor radialis takes a greater leverage above at the shoulder, and



FIGURE A-4

a shorter one on the radius below. The long head of the triceps arises from the axillary border of the scapula and is inserted into the olecranon. The olecranon affords the triceps greater leverage below, rather than above, as it is set far back and above the elbow joint. The triceps and biceps form a circuit of strain during the act of progression. The biceps act to extend the scapula on the humerus. The extensor of the scapula pulls through the triceps on the olecranon giving the biceps a longer leverage on the radius than on its own tendon and gives it in front of the elbow. Thus, the biceps extend the scapula

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<sup>7</sup> Drawing is from Thomas Eakins's article "The Differential Action of Muscles Passing More Than One Joint," p. 179.

<sup>8</sup> Drawings are from An Atlas of Animal Anatomy by W. Ellenberger, H. Dittrich, and H. Baum; pp. 19-22.

Muscles and bones of the thoracic limb.  
Medial view.

flexor  
carpi  
radialis

extensor  
carpi  
ulnaris

extensor  
carpi  
radialis

olecranon

ulna

radius

accessory  
carpal

carpal bones

metacarpal II

metacarpal III

proximal  
sesamoid

proximal phalanx

middle phalanx

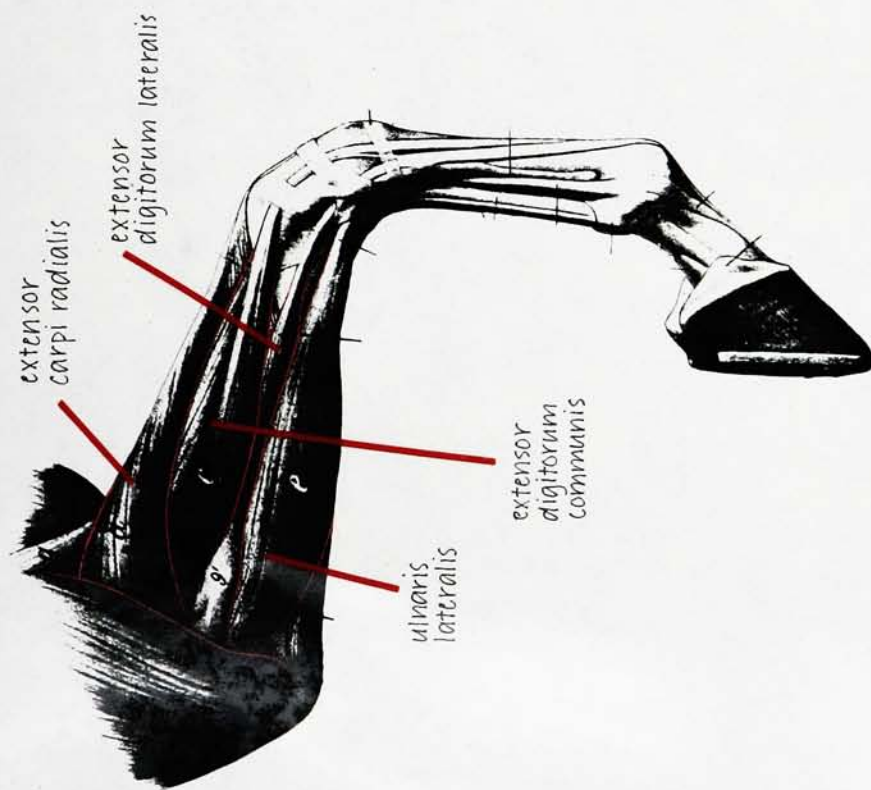
distal  
sesamoid

distal phalanx

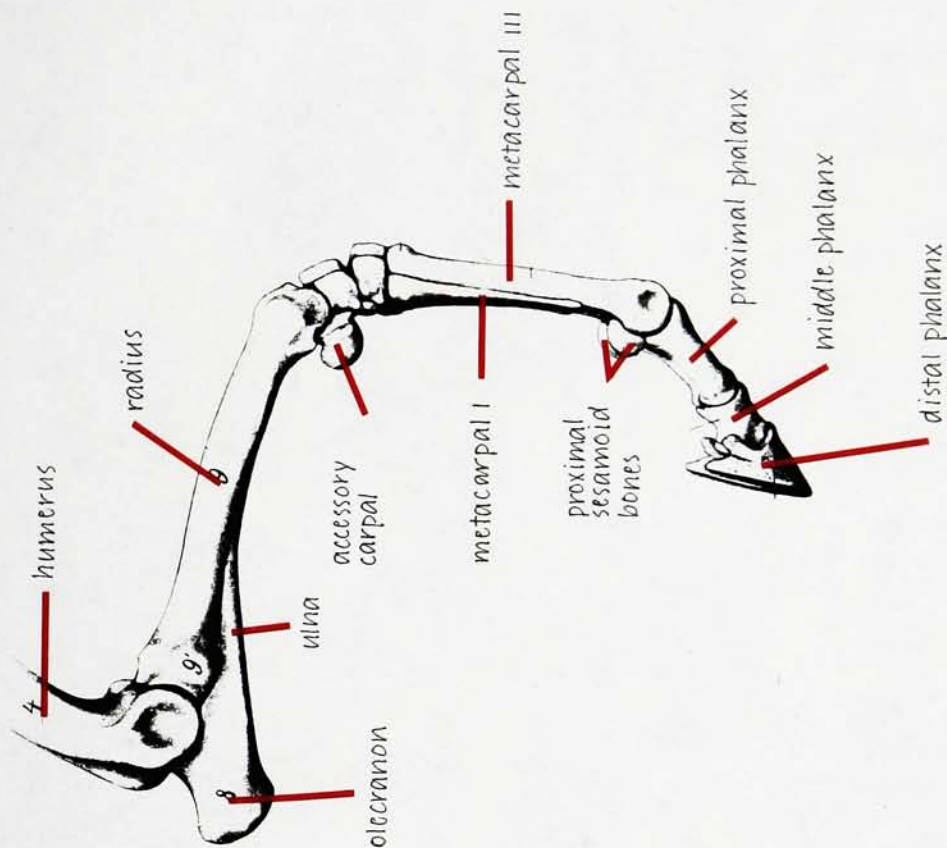
Bones.

Muscles.

Muscles and bones of the thoracic limb.  
Lateral view.



Muscles.



Bones.



and also extend, not flex, the radius.

Upon understanding differential muscle action, Eakins found it less difficult to connect other muscles with the principal movement of the animal. Eakins closed his paper with the following statement:

On the lines of the mighty and simple strains dominating the movement, and felt intuitively and studied out by him, the master artist groups, with full intention, his muscular forms. No detail contradicts. His men and animals live. Such is the work of three or four modern artists. Such was the work of many an old Greek sculptor.<sup>9</sup>

Harrison Allen, a member of the Muybridge commission, helped Eakins prepare his paper for publication. Allen provided explanatory notes that helped bridge the gap between Eakins's vocabulary and the vocabulary of the anatomist.

Eakins's paper was received well by his fellow ANSP members, and they acknowledged the compatibility of his work with that of scientific knowledge: the preoccupation with analysis being the underlying tie. This separated Eakins from his contemporaries, and is to some extent thought to be the result of his temperament. There is a connection between Eakins, ANSP members, and their search beneath the surface--no matter what the subject of their studies. Eakins, along with many members of ANSP, got his education at Philadelphia Central High School. Central High was established in 1838 on the principle that scientific knowledge and a proper attitude best equipped the citizens of a democracy for an effec-

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<sup>9</sup>Thomas Eakins, "The Differential Action of Muscles Passing More Than One Joint," p. 180.

tive life.

In a time span of forty years, Eakins asked more than two hundred people to sit for his studies and paintings, and included in this were several ANSP members. Yet curiously enough, he never painted an official portrait. The reason for this was Eakins's search for the fundamental principle in the human appearance--similar to his search for the principles behind the movement of the locomotor muscles of the horse. His portraits did not flatter, and they were not realistic in the sense that Eakins preferred to paint his sitters as they might appear in ten years. In the human appearance, he found movement of intellect and spirit through time. He tried to capture a person's experience and responses to that experience, believing that to be a part of what defines a face.

Although Eakins used photography to aid him in his studies of anatomy, the majority of his photographic work had no connection with his painting. Yet sometimes, his photographs did serve as a frame on which he painted. They were primarily used as reference for parts of paintings as well as to evoke inspiration.

Eakins painted with a concern for value, not color. The black and white photograph might have appealed to him as a way to instantly record and analyze these values.

In conclusion, Eakins's anatomical studies seemed to be an extension of his character: his desire to analyze and to probe beneath the surface, whether it be a portrait

painting or a motion study. Motion fascinated him--physical motion and motion of spirit. He set out to capture both. And he did.



## BIBLIOGRAPHY

1. Eakins, Thomas, "The Differential Action of Muscles Passing More Than One Joint." The Proceedings of the Academy of Natural Sciences of Philadelphia, 1894, pp. 172-180.
2. Ellenberger, W.; Dittrich, H.; and Baum, H. An Atlas of Animal Anatomy. Lewis S. Brown, ed. New York: Dover Publications, Inc., 1956.
3. Encyclopedia Britannica, 1966 ed. S.v. "Thomas Eakins."
4. Gray, Henry. Anatomy, Descriptive and Surgical. Revised 15th English ed. New York: Bounty Books, 1927.
5. \_\_\_\_\_. Anatomy of the Human Body. 29th American ed. Philadelphia: Lea & Febiger, 1973.
6. Hendricks, Gordon. The Photographs of Thomas Eakins. New York: Grossman Publishers, 1972.
7. \_\_\_\_\_. Thomas Eakins: His Photographic Works. Philadelphia: Pennsylvania Academy of the Fine Arts, 1969.
8. Johns, Elizabeth. "'I, A Painter:' Thomas Eakins at the Academy of Natural Sciences," Frontiers 3 (1981-1982): 43-51.

## APPENDIX B

### THE REVERSAL PROCESS

# REVERSAL PROCESSING STEPS for black and white slides

Use standard agitation.

All temperatures should be 70 degrees F.

- |   |                    |
|---|--------------------|
| 1. First developer  | 7-9 min.           |
| 2. Water rinse (constant running)   | 8 normal<br>2 min. |
| 3. Bleach   | 3 min.             |
| 4. Clearing bath  | 2 min.             |
| 5. Rinse  | 30 sec.            |
| 6. Wetting agent (photo flo)  | 30 sec.            |
| 7. Re-exposure: hold film 12 to 14 inches<br>from 100 watt bulb for 30 sec. each<br>side. NO WATER DROPS! |                    |
| 8. Second developer (D-72 straight)   | 2 min.             |
| 9. Rinse  | 30 sec.            |
| 10. Fixer   | 5 min.             |
| 11. Hypo clear  | 2 min.             |
| 12. Wash  | 5 min.             |
| 13. Wetting agent   | 30 sec.            |
| 14. Dry   | 30 min. ?          |

Use Panatomic-X film at 100-125 ASA

As an option, you can tone the image by adding a 12% solution of Rapid Selenium Toner to the Hypo Clearing Agent.

Hypo Clear with toner:

Working Solution:	Hypo eliminator	1.0 liter
	Kodak Rapid	20-60 ml.
	Selenium Toner	



## APPENDIX C

REFERENCE MATERIAL:  
A COLLECTION OF PHOTOGRAPHIC  
PLATES OF SKELETAL ANATOMY, SURGERY,  
AND MOTION STUDIES



Horse, Right thoracic  
limb, palmar view



Horse, Right thoracic  
limb, cranial view



Horse, Right thoracic  
limb, lateral view



Horse, Right thoracic  
limb, medial view

Right thoracic limb.



Horse, Right pelvic  
limb, plantar view



Horse, Right pelvic limb,  
Dorsal view



Horse, Right pelvic limb,  
lateral view



Horse, Right pelvic limb,  
medial view

Right pelvic limb.



• Right carpus



• Right carpus

Right carpus.



Horse skull  
ventral view



Horse skull  
right view



Horse skull  
left view



Horse skull  
dorsal view

The skull.



- 1-3. Preparation of the horse for surgery.
4. Exposure of the third metacarpal bone.
5. Subcutaneous closure.
6. Skin closure.

Plate 13.

cranial-medial approach to the cranial-medial aspect of the third metacarpal bone.





• walk GG12



• walk GG13



• walk GG14



• walk GG15



• walk GG16



• walk GG17



• walk GG18



• walk GG19



• walk GG20



• walk GG21



• walk GG22

Plate 14.

Motion study: Bradford walking.



• Trot || 6



• Trot || 7



• Trot || 8



• Trot || 9



• Trot || 10



• Trot || 11



• Trot || 12

Plate 15.  
Motion study: Bradford trotting.

• canter PP1



• canter PP2



• canter PP3



• canter PP4



• canter PP5



• canter PP6



• canter PP7

Plate 16.  
Motion study: Bradford cantering.





• BUCK AA1



• BUCK AA2



• BUCK AA3



• BUCK AA4



• BUCK AA5



• BUCK AA6



• BUCK AA7



• BUCK AA8

Plate 17.  
Motion study: Bradford bucking.





Gallop AA3



Gallop AA4



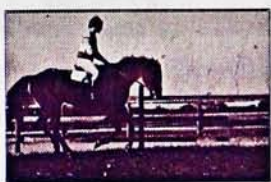
Gallop AA5



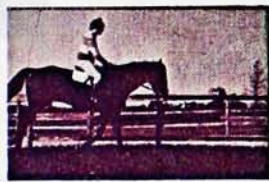
Gallop AA6



Gallop CC2



Gallop CC3



Gallop CC4



Gallop CC5

Plate 18.

Motion study: Bradford galloping.

APPENDIX D

NOTES  
from an interview with  
PROFESSOR GEORGE PRATT

1 FEBRUARY 1984

National Institute of Health (NIH) grant:  
Funding for work with humans

To measure bone strength:

1. X-rays
2. Photon densitometry

Measure amount of opacity to x-rays, in a sense, a measure of density. Does not give direct picture of elastic properties of bone, capacity to sustain loads.

Can you determine the strength of bone non-invasively?

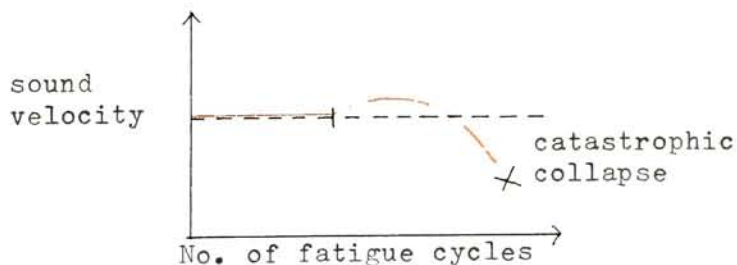
YES. By measuring the velocity of ultrasound through bone. The stiffer the bone, the faster the sound.

PAPER CLIP THEORY: (Bone) builds up damage, gets weaker.

#### BOSTON MARATHON STUDIES

- \* Measured bone strength in 140 runners before, 102 after. A decrease in ultrasound velocity was expected, BUT an increase was found.
- \* Nature has some sort of mechanism for strengthening bone under stress.
  - \* Mechanism is not understood. Trying to gain understanding.
  - \* Look at in vitro bone and measure sound velocity.

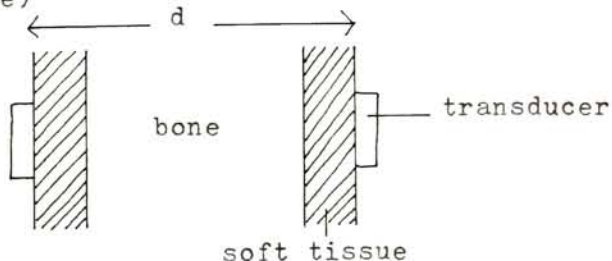
#### IDEAL EXPERIMENT



Velocity of sound as a function of number of fatigue cycles.

Before eventual decrease in velocity and fracture, is a preliminary increase in velocity of sound. This is not understood.

- \* In LIVING TISSUE (with soft tissue on either side of bone)

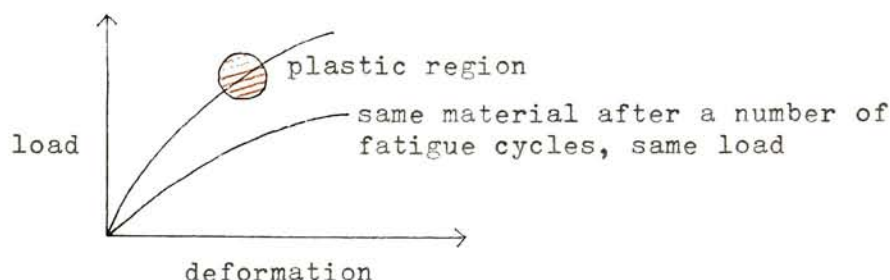


Must measure distance and time between transducers

$$\frac{d}{t} = \text{velocity effective}$$

Must be on guard for soft tissue changes

ELASTIC MODULUS: Velocity of sound gives direct look at elastic modulus, property of bone (measures slope of deformation curve).



If I load something, I deform it. In the beginning there is a linear relationship which says if I increase the load, I increase the deformation. Reach the plastic region and the curve bends over (plastically deforming the material: micro-damage).

#### BONE

Velocity of sound uncovers:

- \* More active tissue than suspected
- \* Changes are larger and faster than suspected
- \* Changes in mechanical properties over time scale are more rapid than expected
- \* Trying to unravel mystery
  - \* Anticipate injury
  - \* Monitor healing

Measured bone strength in various populations:

1. Boston marathon
  2. Army recruits
  3. Harvard track team
  4. Group of women at Mass. General Hospital
  5. Sedentary populations
- \* Harvard track team member in training:  
Measured velocity of sound through tibia (shin bone). At 80 days, terrific drop in velocity of sound (16% drop), individual stopped training due to acute distress for 3 weeks, velocity of sound recovers.  
THIS IS TYPICAL.
  - \* Boston Marathon:  
Found increases in velocity of sound. Looked at velocity of sound in women as a function of their age (26 women). Measured velocity of sound across patella. Slight increase with age.



- \* Sedentary women:  
Significantly decreased with age as early as age 30.
- \* Sedentary men show flat curve, slight increase in marathoners.

BONE problems are particularly acute in women. Post-menopausal women subject to osteoporosis. (Men also subject, but in no way to the same extent.) Changes in women take place earlier than one might have suspected.

EXAMPLE: Army recruits at Fort Jackson

25% women end up in hospital with stress fractures, only 4% men

Something is going on in the bones of women, at all ages in life, which is not the same as what is going on in the bones of men.

STRENGTH - complicated definition, is not as simple as a matter of density.

#### ULTRASONIC DETERMINATION OF BONE STRENGTH

- \* New technique for looking at bone, one sees things one does not see with x-rays.

Continuing to study animals, particularly racehorses, and finding similar things as before, i.e., will monitor an animal in training, everything proceeds normally until sudden drop in velocity of sound. Animal is sore. If he's rested, he can recover. If he's not rested, is in greater risk of actually breaking a bone.

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GROUND RESILIENCY - elastic properties of surface animal or person runs on.

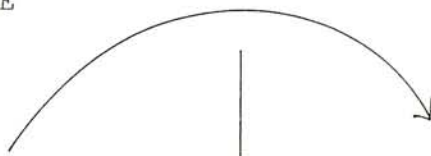
- \* Much work has been done, particularly at Harvard, on the biomechanics of running. Interested in interaction of the spring of the running surface with the runner. Key is to match these two springs in such a way so that the track rebounds to the impact of the runner's leg and completes its rebound just as the leg leaves the ground.
  1. SLOW TRACK with a slow rebound (like running on fluffy pillows). As you run, your foot depresses or deforms the track. Track wants to spring back, but your foot may have left track surface before the rebound is complete. Left footprint in the track, left elastic energy in racing surface and did not recover it.
  2. HARD TRACK is also to some extent slow. Will deform under your weight and will rebound very quickly, and will complete its rebound before your foot has left the ground. Track starts to recompress. So again you leave energy behind in track, and do not extract it.

FOLKLORE: hard track is a fast track. It is

faster than a soft track, but not optimal.

3. TUNED TRACK - optimal surface. Deform the track and it completes its rebound just as your foot leaves the ground.

#### JUMPING HORSE



##### TAKE-OFF:

Absorb a minimum amount of energy from horse's spring

##### FENCE

##### LANDING:

Absorb impact energy. Forget about elastic efficiency or getting the most energy back out of track. Concentrate on absorbing energy of impact.

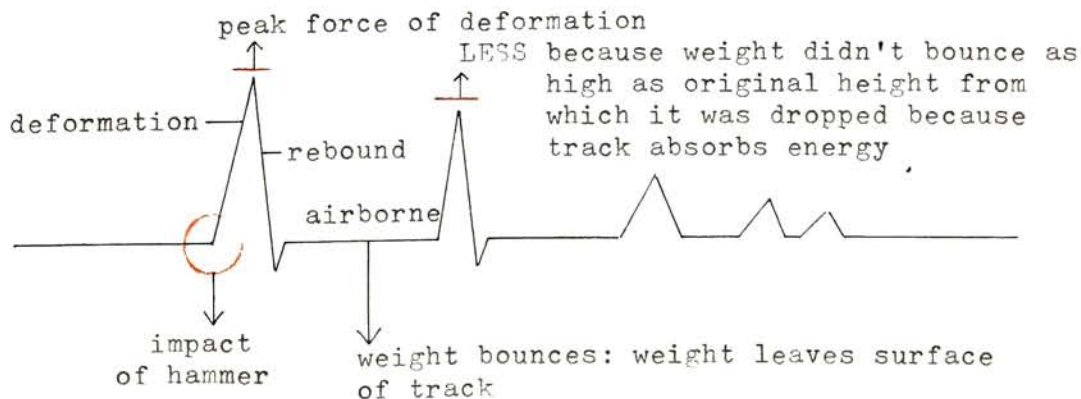
Opportunity to make better, more uniform surfaces to jump off and to land on that can take a lot of traffic (as in eventing). Finger Lakes Track - wood chip training track. Durable surface, less sensitive to heavy traffic. Excellent surface for parts of event course.

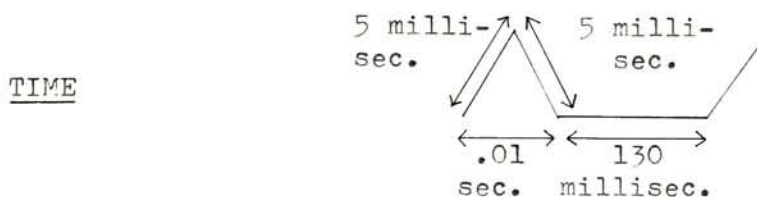
#### TRACK TESTING

1. Trying to develop instrumentation that is more accurate, gives a more complete picture of what a drop looks like.
  2. Extract more information out of a drop which will tell amount of energy absorbed in an impact.
  3. How much of the track surface participates in the impact?
  4. How hard the track is, i.e., peak forces of impact.
- \* Essentially all the engineering parameters that characterize a racing surface.

#### DROP-HAMMER TEST:

Drop a hammer on track which hits a ring which sits on track. Hammer drives ring into cushion. Force transducers are on ring (strain gauges measuring force) - transmitted via cable to tape recorder.



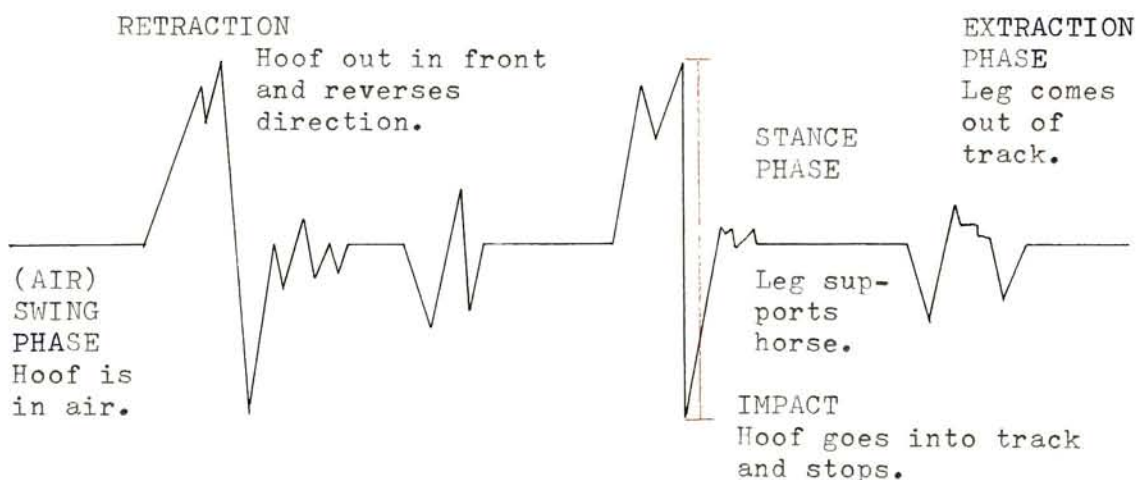


This gives us a detailed picture of mechanical properties of the track. Job is to relate that to mechanical properties of horse's leg and attempt to achieve a tuned track condition in this way (as done at Harvard with human runners).

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VERTICAL ACCELEROMETER on hoof of horse - gives us details of the hoof as it goes into the track.

### Left Foreleg



Force of impact will vary depending on lead.

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Filming of horses with high speed films.

EXPERIMENTS have been done on cats where they surgically transected the brain stem from the forepart of the brain (producing vegetative state - breathing, heart beating, no other activity or control of locomotion). Can electrically stimulate brain stem and put cat on treadmill and put through walk, trot, canter, gallop. Information of how to walk CANNOT be coming from brain. One concludes there must be a gait program resident in spine (nerve centers in spine that control gait).

HENCE: Great runners are born, not made. Can you photograph a young horse (with a high speed camera) and say it has the gait of a champion? To some extent, this has been successful. Have been very active in this. Although, must realize gait is not everything.

OTHER ASPECTS: cardiovascular and respiratory systems, other aspects as to what makes a champion.

Great animals do not run in an inefficient way.



## APPENDIX E

### ANATOMICAL STUDIES

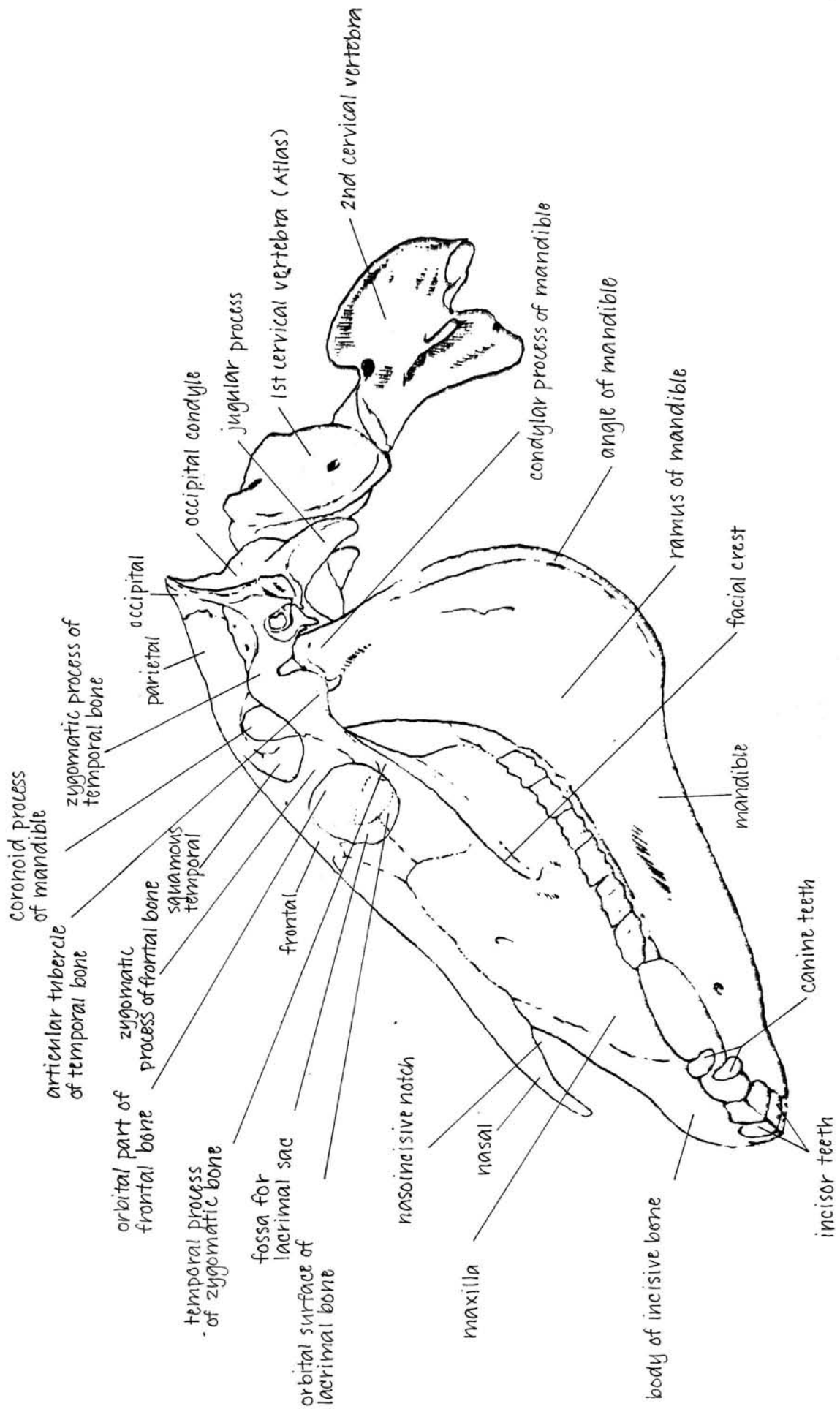


Plate 19. Skull, lateral view.

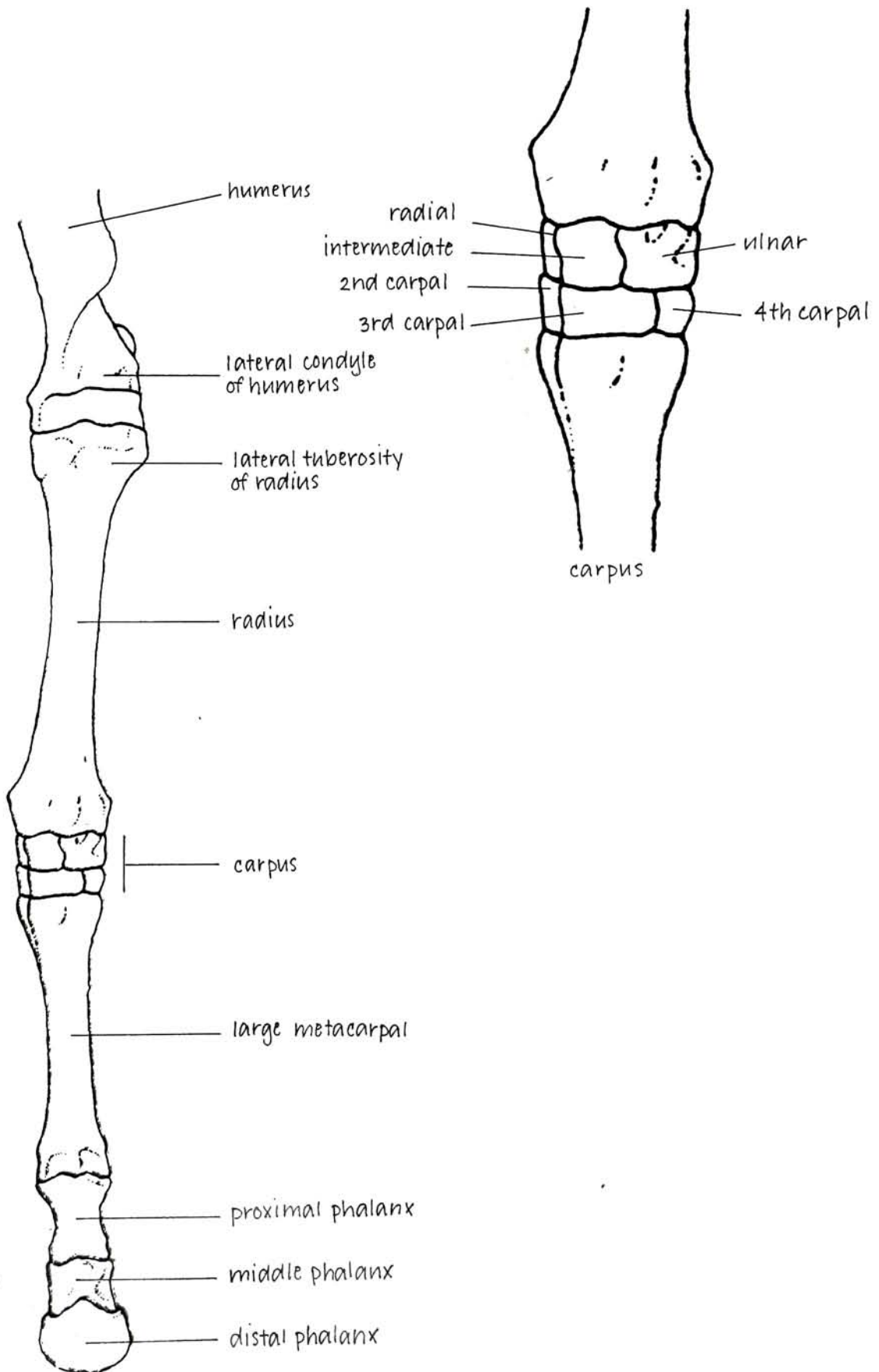


Plate 20. Bones of the left thoracic limb, cranial view.

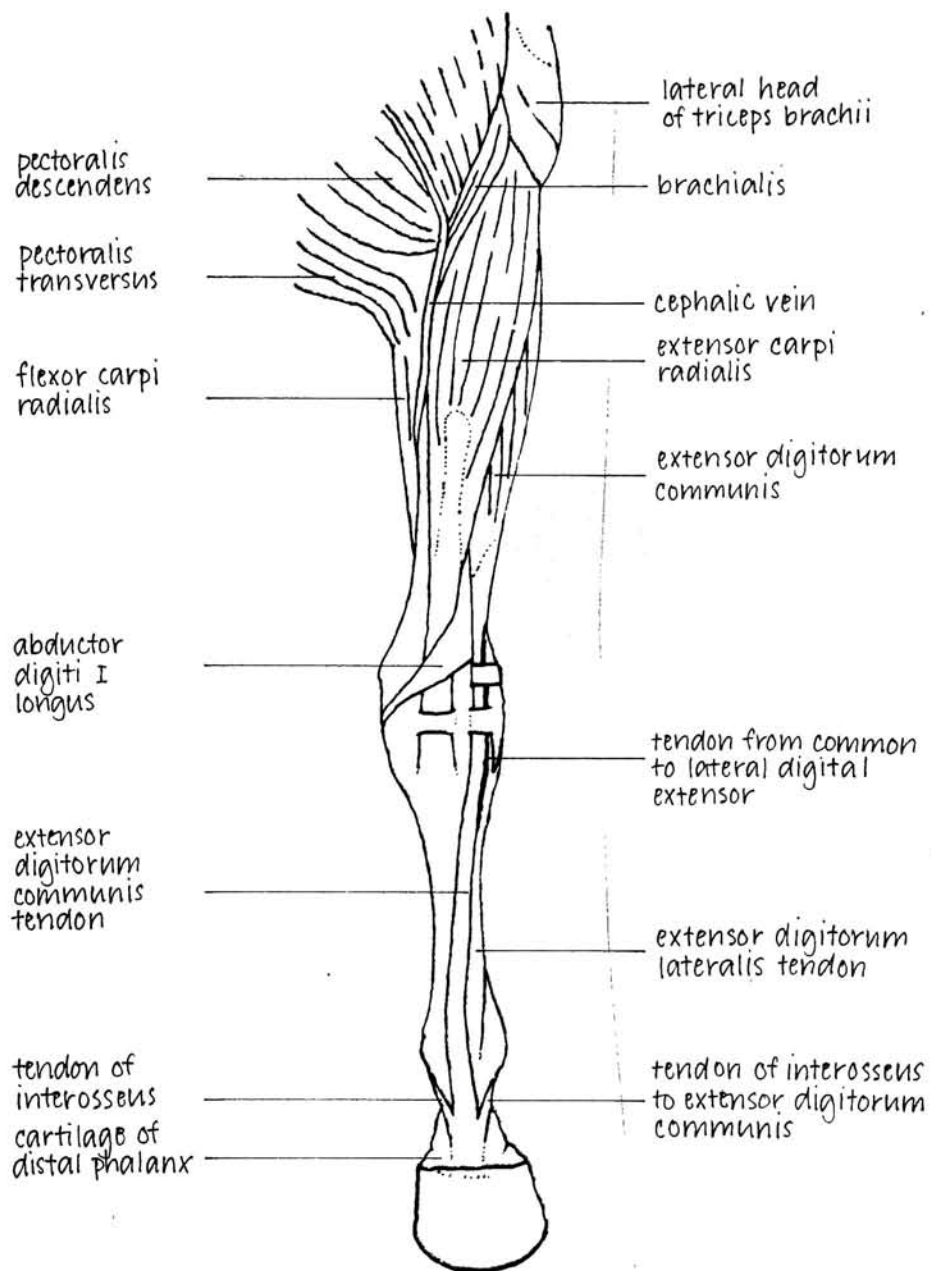


Plate 21. Muscles of left thoracic limb, cranial view.



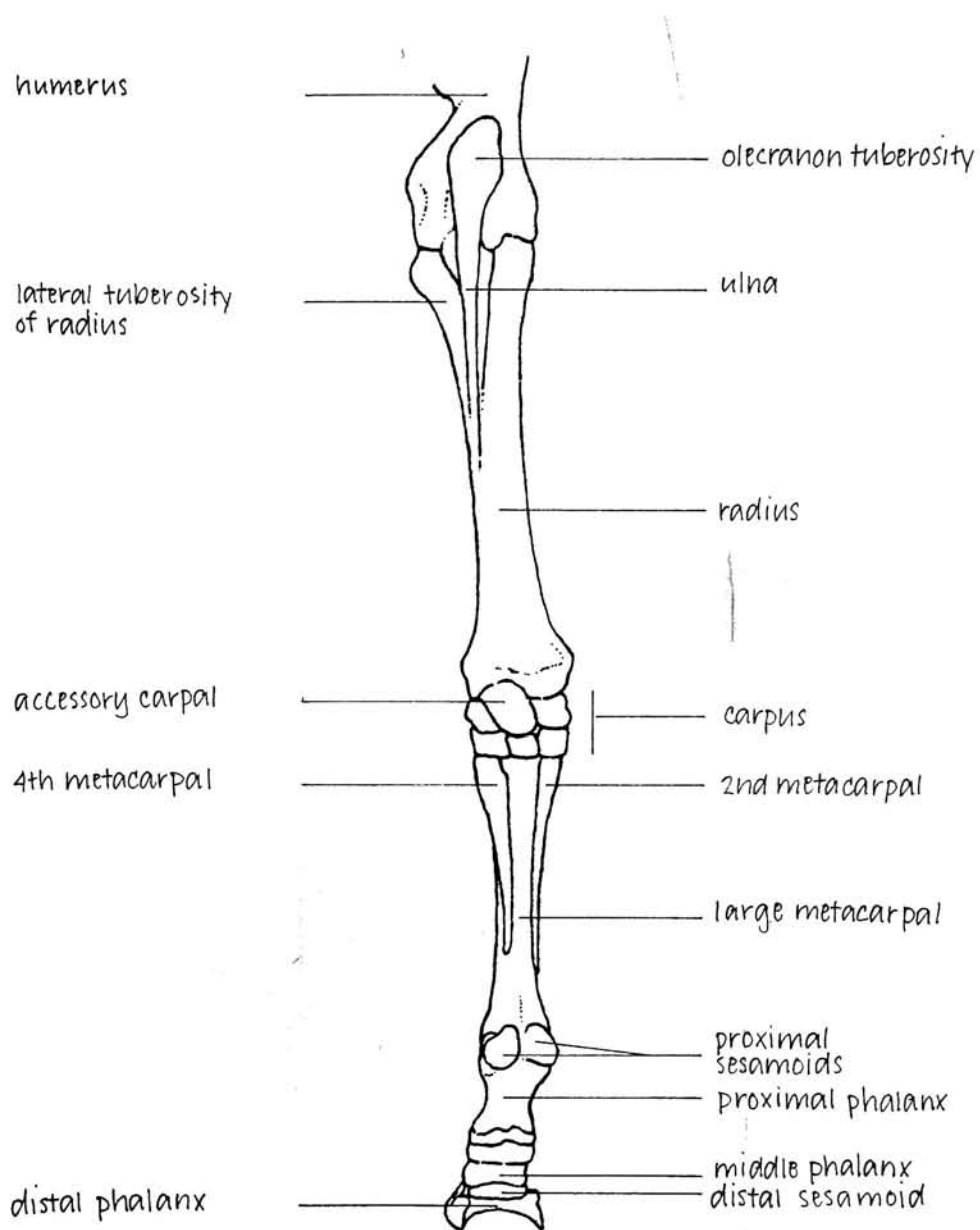


Plate 22. Bones of the left thoracic limb, palmar view.

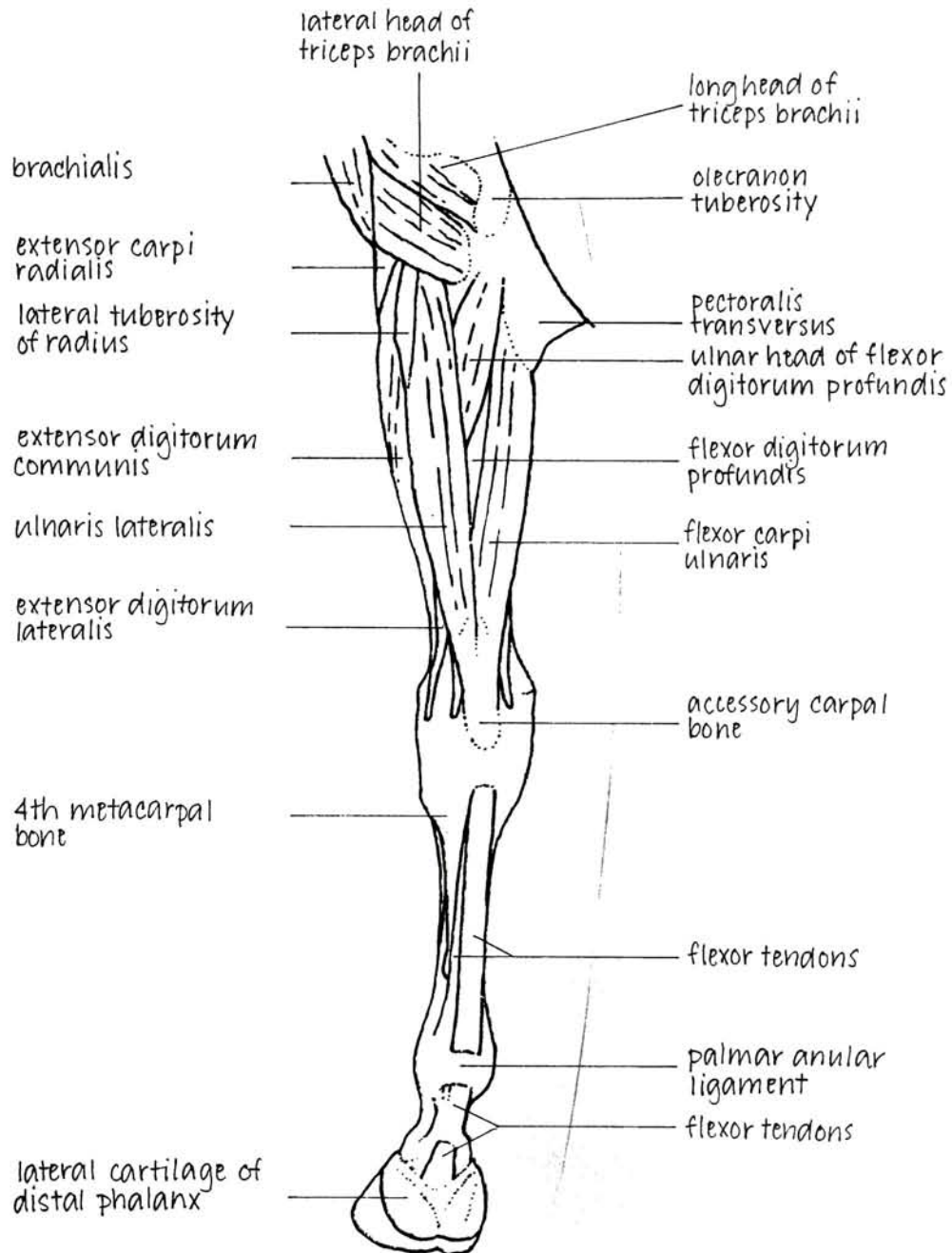


Plate 23. Muscles of the left thoracic limb, palmar view.

## SOURCES CONSULTED

Art Reference

1. Da Vinci, Leonardo. The Drawings of Leonardo da Vinci. Introduction and notes by A. E. Popham. New York: Reynal & Hitchcock, 1945.
2. \_\_\_\_\_. The Notebooks of Leonardo da Vinci. 2 vols. Arranged, rendered into English, and introduced by Edward MacCurdy. New York: Reynal & Hitchcock, n.d.
3. Eakins, Thomas. "The Differential Action of Muscles Passing More Than One Joint." Proceedings of the Academy of Natural Sciences of Philadelphia, 1894, pp. 172-180.
4. Encyclopedia Britannica, 1966 ed. S.v. "Thomas Eakins."
5. Encyclopedia Britannica, 1966 ed. S.v. "Leonardo da Vinci."
6. Encyclopedia Britannica, 1966 ed. S.v. "Edward Muybridge."
7. Hendricks, Gordon. The Photographs of Thomas Eakins. New York: Grossman Publishers, 1972.
8. \_\_\_\_\_. Thomas Eakins: His Photographic Works. Philadelphia: Pennsylvania Academy of the Fine Arts, 1969.
9. Johns, Elizabeth. "'I, A Painter:' Thomas Eakins at the Academy of Natural Sciences." Frontiers 3 (1981-1982):43-51.
10. Livingstone-Learmonth, David. The Horse in Art. London: The Studio Publications, 1958.
11. Muybridge, Edward. Animals in Motion. Edited by Lewis S. Brown. New York: Dover Publications, Inc., 1957.
12. Payne, Robert. Leonardo. New York: Doubleday & Company, Inc., 1978.
13. Svaren, Jacqueline. Written Letters. New York: Taplinger Publishing Company, 1975.

14. Tannenbaum, Samuel A. The Handwriting of the Renaissance. Introduction by Ashley H. Thorndike. New York: Frederick Ungar Publishing Co., 1958.

#### Equine Reference

1. Edwards, Elwyn Hartley, ed. Encyclopedia of the Horse. London: Octopus Books Limited, 1977.
2. Luard, Lowes D. The Anatomy and Action of the Horse. Woodstock, Vermont: The Countryman Press, n.d.
3. MacGregor-Morris, Pamela, ed. The Book of the Horse. Foreword by Lucinda Prior-Palmer. New York: Exeter Books, 1979.
4. MacGregor-Morris, Pamela, and Lugli, Nereo, eds. Horses of the World. New York: A Division of Crown Publishers, Inc., 1973.
5. Osborne, Walter D., and Johnson, Patricia H. The Treasury of Horses. New York: Golden Press, 1966.

#### Medical Reference

1. Adams, O. R. Lameness in Horses. 3rd ed. Philadelphia: Lea & Febiger, 1974.
2. Ellenberger, W.; Dittrich, H.; and Baum, H. An Atlas of Animal Anatomy. Edited by Lewis S. Brown. New York: Dover Publications, Inc., 1956.
3. Emery, Leslie; Miller, Jim; and Van Hoosen, Nyles. Horseshoeing Theory and Hoof Care. Philadelphia: Lea & Febiger, 1977.
4. Gray, Henry. Anatomy, Descriptive and Surgical. Revised 15th English ed. New York: Bounty Books, 1927.
5. \_\_\_\_\_. Anatomy of the Human Body. 29th American ed. Philadelphia: Lea & Febiger, 1973.
6. Milne, Dennis W., and Turner, A. Simon. An Atlas of Surgical Approaches to the Bones of the Horse. Philadelphia: W. B. Saunders Company, 1979.
7. Rooney, James R. Biomechanics of Lameness in Horses. Baltimore: Williams & Wilkins Company, 1969; reprint ed., Malabar, Florida: Robert E. Kreiger Publishing Company, 1969.



8. \_\_\_\_\_. The Lamé Horse: Causes, Symptoms, and Treatment.  
South Brunswick: A. S. Barnes and Company, 1974.
9. Sisson, Septimus; Grossman, James Daniels; and Getty, Robert. The Anatomy of Domestic Animals. 5th ed. Vol. 1. Editorial coordination and completion by Cynthia Ellenport Rosenbaum, N. G. Ghoshal, and Daniel Hillmann. Philadelphia: W. B. Saunders Company, 1975.
10. Turner, A. Simon, and McIlwraith, C. Wayne. Techniques in Large Animal Surgery. Philadelphia: Lea & Febiger, 1982.

#### Television Reference

1. CBC. "Science Magazine." Show 5, 1977. "Animal Locomotion."
2. CBC. "Science Magazine." Show 5, 1977. "Gait Study."
3. CBC. "Science Magazine." Show 5, 1977. "Orthopedic Engineering."
4. PBS. "NOVA," No. 1014. "A Magic Way of Going: The Story of Thoroughbreds."