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The Turkmen (Akhal-Teke) horse's contribution to modern horse breeds development

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Abstract:

The Akhal-Teke, a historic horse breed originating in Central Asia, is renowned for its endurance, resilience, and unique physical characteristics, including its metallic coat. This thesis explores the breed's historical significance, genetic uniqueness, and its contributions to modern horse breeds, such as the Arabian, Thoroughbred, and Orlov Trotter. Genetic analyses reveal distinctive mitochondrial DNA markers and selective breeding practices that have preserved the Akhal-Teke's purity and unique traits over millennia. The breed's cultural importance is underscored by its role as a national symbol of Turkmenistan, while its genetic influence has shaped global breeding programs, enhancing stamina, agility, and versatility in equine sports.

Through comparative studies, the Akhal-Teke's unparalleled endurance and adaptability are positioned as foundational traits in the evolution of sport and endurance breeds. Modern breeding programs continue to leverage these traits, balancing preservation with performance improvement. This thesis concludes with a discussion on the Akhal-Teke's modern role in equestrian disciplines, its genetic value, and the critical need for preservation to safeguard its cultural and genetic legacy for future generations.

Absztrakt:

Az Akhal-Teke történelmi lófajta Közép-Ázsiából származik, híres állóképességéről, rugalmasságáról és egyedi fizikai jellemzőiről, beleértve a fémes csillogású szőrzetét. Ez a szakdolgozat a fajta történelmi jelentőségét, genetikai sajátosságát és a modern életünkben használt fajtákra, mint például az arab, a telivér és az orlov ügető való hatását tárja fel. A genetikai elemzések feltárták jellegzetes mitokondriális DNS-markereit, amiket a szelektív tenyésztési gyakorlat során évezredeken át sikeresen megőriztek a fajtatiszta akhal-tekében. A fajta kulturális jelentősége Türkmenisztán nemzeti szimbólumaként betöltött szerepe, míg genetikai jellegzetességeit a globálisan hasznosítják más fajták tenyésztési programjaiban, növelve ezen fajták állóképességét, mozgékonyságát és a sokoldalú hasznosíthatóságát a lósportban.

Leíró tanulmányok révén igazolást nyert az akhal-teke páratlan állóképessége és alkalmazkodóképessége, mint evolúciós eredmény. A fajta modern tenyésztési programjai rendszeresen alapoznak ezekre a tulajdonságokra, egyensúlyban tartva a hagyományos karakterek megőrzését a teljesítmény javításával.

Ez a dolgozat az Akhal-Teke modern lovas diszciplínákban betöltött szerepéről, genetikai értékéről, valamint a megőrzés kritikus szükségletéről zárul, amikkel megőrizhetjük kulturális és genetikai örökségét a jövő generációi számára.

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I. Introduction

The Akhal-Teke, or Turkmen horse, is among the oldest and most distinctive breeds in the world, native to the deserts of Central Asia, mainly in present-day Turkmenistan [1]. It enjoys a very rich history, which can be traced back as far as 500 BC, where it played a major vital role in the nomadic lifestyle. Over many thousands of years, the Akhal-Teke adapted not only to the most extreme climates but also to difficult terrain. This adaptation brought about an outstanding combination of endurance, agility, and loyalty that is unparalleled even now. Physically, the Akhal-Teke is built with a lean body, deep chest, and long legs that enable it to cover great distances with minimal fatigue. These physical features are complemented by a highly efficient metabolism adapted to the meager resources of its native desert environment [2]. In addition, this horse is also known worldwide for its sleek, metallic coat, with a feature so unique it earned this breed its nickname, "Golden Horse of the Desert"[3] (Figure 1).

Figure 1 : The Akhal-Teke, Golden Horse of the Desert

The Akhal-Teke has a privileged place in the history of horse breeding and up to now has taken up a great place in the attention of horse lovers and breeders. And deservedly so, because this horse is outstanding for very important genetic resources, put together with physical and behavioral features of the breed that make it valuable for the development of horse breeding. Some of these desirable qualities, including its endurance, toughness, and refined conformation,

have been selectively introduced into other breeds to enhance stamina and adaptability in challenging environments. Researchers have shown its influence in developing several modern horse breeds, such as that for the Thoroughbred. Its original genetic stock is linked to three founding sires, but one of them is believed to be related to Turkoman horses. This would therefore insinuate that Akhal-Teke is indeed part of the Thoroughbreds' genetic structure [4]. Akhal-Teke is also said to be closely related to the Arabian horse, with whom it shares some physical and genetic similarities [5]. Based on these shared characteristics, the Akhal-Teke may have played a significant role in the Arabian's evolutionary history, especially in terms of endurance traits vital for long-distance travel and survival in desert climates. Other horse breeds, such as the Trakehner, the Karabakh horse, the Budyonny horse or the Orlov Trotter have been influenced by the Turkmen horse. As such, generally, the Akahl-Teke is very interesting to ameliorate the endurance and performance of other breeds. The continued influences brought forth by the Akhal-Teke to the different breeding programs have returned to bring an increase of quality sport horses, endurance horses, and dressage horses to various parts of the world.

On the other hand, even if the Akhal-Teke has been and still is a very great genetic contributor to breeds used in sports, the preservation of the purity of its bloodline is also a big issue. Indeed, the antiquity of these horses' origins makes the Akhal-Teke one of the few horse breeds that have developed with minimal external genetic influence, thus preserving many of the original characteristics and allowing this breed to maintain a high degree of breed purity over millennial [4, 1]. Preserving the genetic heritage of the Akhal-Teke requires selective breeding programs. The Turkmenistan government and various Akhal-Teke associations globally maintain strict studbooks, recording pedigree data to track lineage and ensure only purebred Akhal-Teke horses are bred [3]. These studbooks are critical for upholding breed standards and identifying suitable mating pairs. The use of scientific methodologies, such as genetic monitoring and analysis of microsatellite loci and Single Nucleotide Polymorphism (SNP), genome sequencing, and the identification of molecular markers, are tools that can be used to help preserve the breed's unique characteristics while reducing risks of inbreeding and genetic drift [4, 1, 7]. These methods will ensure that future generations of Akhal-Teke horses retain their historical lineage and valuable characteristics, supporting both its cultural heritage and its potential for use in modern equestrian practices. We will begin our study of the history and peculiarities of the

Akhal-Teke breed by going through the development background of the breed in Central Asia and how desert environmental conditions shaped its physical, behavioral, and genetic characteristics.

Next, we will talk about the influence of the Akhal-Teke on modern horse breeds. This section will look at how Akhal-Teke influenced the breeding of other horse breeds, donating necessary features such as endurance, agility, and stamina. Emphasize some concrete breeds influenced by Akhal-Teke, such as the Arabian and the Thoroughbred. The above review shall then be followed by the comparison between Akhal-Teke with three other horse breeds: that of Arabian, Thoroughbred, and Orlov Trotter. It should consider all the differences in the physical conformation of temperament and endurance capabilities against each breed. This broadens the scope towards understanding how far Akhal-Teke contributed to establishing equines today. The final section of this paper will centre on the Akhal-Teke breed contemporary breeding and crossbreeding programs. Contemporary breeders will be discussed regarding the way they use this breed in the planning of future sport and performance horses. Such areas as preservation will be touched upon, together with problems in maintaining a pure breed, and the accompanying ethical issues in cross-breeding. The paper will conclude by looking into the future of the Akhal-Teke in the global equine landscape and this breed's continued contribution to further enhancing those qualities within today's horse breeds.

II. History, Origins, and Unique Characteristics of the Akhal-Teke Horse

1. Historical Background and Development in Central Asia

The Akhal-Teke horse is one of the most ancient and strikingly original horse breeds in the world. Its origin dates back more than 3,000 years to the deserts of Central Asia, particularly the territory of modern Turkmenistan [1,3,5]. This historical breeding region is located between the Caspian Sea and the Fergana Valley and is bounded by the Caspian Sea to the west, the Aral Sea to the north, and the Thian Shan and Pamir mountains to the east and southeast [8].

The ancestors of the Akhal-Teke are believed to have been domesticated by nomadic Turkoman tribes who roamed the steppes of Central Asia [5]. Even the breed's name has its roots in the breed's place of origin. The name "Akhal-Teke" comes from the Akhal Oasis, a region in southern Turkmenistan, home of the Tekke tribe, one of the Turkoman tribes that lived and bred these horses [3, 5, 9]. These tribes selectively bred the ancestor of the Akhal-Teke, most likely to be the Turkoman horse, to make them able to survive in harsh climate conditions with a minimum of resources [5]. These horses were mostly used for riding and war, known for their speed, endurance and metallic sheen [3,5]. Over time the Akhal-Teke became more than just an animal and were considered as a symbol of pride and a valuable asset for the Turkoman people.

The Akhal-Teke and its predecessors, the Turkoman horses, were highly prized by the Persian Empire (modern day Iran) especially during the Achaemenid period (550-330 BCE) [3,5,12]. Persian royalty and military leaders valued the Turkoman horses, using them for ceremonial events because of their elegant conformation and for enhancing the power of the Persian Empire's cavalry, providing a strategic advantage on the battlefield mostly because of their ability to cover long distances quickly. Persian rulers often received these horses as tributes or diplomatic gifts, further spreading their reputation and genetic influence across the region [5].

As trade flourished along the ancient Silk Road, word of this extraordinary horse traveled far beyond Central Asia, capturing the fascination of neighboring empires, like in the Arabian Peninsula, India, and the eastern Mediterranean for example. Among these was the Chinese Empire, who identified the Akhal-Teke as "Heavenly Horse" for its metallic trait and its unrealistic capacity in long distance endurance [10]. In ancient China they were called the Dayuan horse (or Ferghana horses) from the Ferghana Valley (modern Uzbekistan) [10, 11].

In the Western Han Dynasty, Emperor Wu of Han learned about these horses and wished to bring them to China to strengthen his military forces, as the "Heavenly Horses" were thought to be superior in long-distance endurance, potentially enhancing the effectiveness of his cavalry [11] (Figure 2). To obtain them, the Emperor sent envoys to the region of Dayuan. However the Dayuan rulers resisted the emperor's demands as these horses were already considered like a national treasure [10,11].

This event led to the Han–Dayuan war, approximately around 104-102 BCE, to obtain these Heavenly Horses. The Chinese forces eventually succeeded after a prolonged siege of the city of Ershi, and Emperor Wu secured more than 3000 Dayuan horses but from those horses only 1000 were able to survive the road to China [10]. These horses were then bred with Mongolian horses and other local breeds. It is essential to highlight the fact that from this event the productivity and military force in the Han Dynasty increased considerably [5,10,11].

Figure 2 : Flying Horse of Gansu, sculpture referring to celestial horses

This marked the beginning of the Akhal-Teke's historical influence in China, where it was revered not only as a superior warhorse but also as a symbol of prestige and cultural exchange along the Silk Road [10]. As years passed, Turkmenistan solidified its cultural identity, and the Akhal-Teke became increasingly central to Turkmen life. The Tribes continued to breed these horses selectively and the purity of the breed was reinforced by keeping them relatively isolated from outside influences even if these horses were prized in surrounding countries [3,5,9].

In the late 19th century, Russia expanded into Central Asia, including Turkmenistan. Russian officers, and most specifically the Russian General Kuropatkin, took a grand interest in the horses of the Turkomen tribes they fought [3,14,15]. It’s during that time that those horses will be officially renamed “Akhal-Teke”, after the Teke Tribe that lived close to the Akhal oasis [3,5]. Quickly the Akhal-Teke was incorporated into breeding programs and were crossbred with other breeds, including local breeds but also Arabian horses and even Thoroughbred, in order to

develop military and sport horses [15]. However, the Turkmen breeders were worried about these cross breeding efforts, concerned that the purity and unique characteristic of the breed would be lost, so the Russian Empire started to officially record the breeding lines [5,48]. In 1932 the studbook was closed and the first breed registry was printed in 1941 [3]. Despite its success in sports, the Akhal-Teke faced challenges in the later years of the Soviet Union. Then, between 1950-70 the breed almost disappeared when the USSR massey killed horses deemed no longer essential during these times of industrialization. By the 1970s, the Akhal-Teke was classified as rare, with only a few hundred purebred horses remaining [3, 16, 17]. With the dissolution of the Soviet Union in 1991, Turkmenistan gained independence, and the Akhal-Teke was immediately recognized as a national treasure. The new Turkmen government made the breed a symbol of national identity, incorporating it into the country's emblem and celebrating it in festivals [16,17,54]. In the newly independent Russia, horse breeders also recognized the importance of preserving the Akhal-Teke, which had become a cultural and historical symbol within the former Soviet Union [48].

Both Turkmenistan and Russia took steps toward reviving and protecting the Akhal-Teke in its unique heritage. International registries and associations, often led by Russian breeders, put effort to raise awareness about the breed and prevention of crossbreeding that would weaken the specific genetic traits characteristic of it. Russian breeders, along with those in Turkmenistan and other countries, committed to rigorous standards, ensuring the breed's purity and protecting its legacy [9,17,48]

The Akhal-Teke's influence continues in the global equestrian world, particularly in endurance sports and cross-country events, where its stamina, agility, and distinctive metallic sheen make it a favorite among enthusiasts. Modern breeding programs outside Turkmenistan, including in the United States and Europe, have helped raise awareness and appreciation for the breed, ensuring its legacy endures in both equestrian sports and cultural history [3,9,17].

2. Distinct Conformations, Physical and Behavioral Traits

Conformation traits

The Akhal-Teke is known for its distinctive and elegant appearance, which combines both grace and endurance. The breed's physical features set it apart from other horse breeds, giving it an unmistakable look that reflects its ancient heritage and adaptation to harsh desert conditions.

Size : It's a medium size horse, size depends on the gender. Male horses are usually around 1m60 where females are closer to 1m55. We can also have some individuals who can reach 1m70 [18].

Weight : Akhal Tekes are quite light horses with a weight around 425-465 kg [19, 20, 21]. The studbook identifies 3 types of morphology going from the smaller to heavier in case of sport horses.

Haircoat and skin : This breed is well known for its unique haircoat, indeed the metallic shine we can observe is one of the breed's signature traits. This extra shine seems to be due to the fine structure of the hair. The opaque core of the hair is narrower, or sometimes even absent in some cases, allowing the light to shine right through and produce the shimmering gleam [20, 21, 23, 26] (Figure 3). It is also important to note that this effect is reinforced by the very thin hair almost silk-like, this characteristic gives them some thermal advantages in hot desert climates [22]. The breed has sparse manes and tails with little forelock or leg feathering.

Figure 3 : Metallic shine of the haircoat - Akhal Teke

In terms of colors, the Akhal-Teke presents a wide range of haircoat colors, like : black, bay, gray, cream, chestnut, buckskin, perlino, palomino, cremello [18,19,20]. It can be common to find some white marks on the head and legs. A smokey pattern can also be seen, offering to the breed a wide variation of colors.

The skin of the breed is very thin, so much that superficial veins can be easily seen after effort [18, 21]. This characteristic reinforced the myth of “blood sweating horses” described in Ancient China. This phenomenon of blood sweating was most probably caused by Parafilaria Multipapillosa, a common parasite in the area where these horses were living [10,11]. This parasite damages the small blood vessels under the skin creating a reddish, bloody sweat during exercise or when the animals are under stress.

Head and neck : The head carriage is proud and noble. The head itself is finely chiseled with a narrow face. The profile is straight or slightly concave with prominent cheekbones and a refined muzzle. The ears set high up are fine and long. Akhal Teke eyes are large, almond-shaped and very expressive giving them a distinctive look and adding to its intelligent and alert expression. The neck is set high on the shoulder and is long and slender with an S-shape or a rounded curve [18, 19, 22].

Build and conformation : The Akhal-Teke has a lean, refined build with a long, slender body that is both athletic and streamlined. The musculature is flat and dense [19, 22]. The back is often long, with prominent, well-defined withers and broad loins, as is the croup with a tail set low. The shoulders are long and sloping. The Akhal-Teke’s chest is deep but narrow, allowing for expanded lung capacity essential for oxygen intake during prolonged exertion. However, its gastrointestinal tract is smaller, meaning it is less efficient in digesting large volumes of forage. The legs are long and thin with strong tendons and solid joints. The hooves are small with a very hard horn [18,19,20,25].

Physical characteristics

Movement and gait : These horses have alight, springy, and flowing gaits known as the "Akhal-Teke Glide". They move with an almost floating quality, which makes them a popular choice for disciplines like dressage and endurance riding. The gait is described as a four-beat, diagonal stepping [28]. The breed's unique trot is especially prized, capable of using either a four-beat or a two-beat gait, showing off its graceful, high-stepping action.

Muscle : The endurance and stamina of the Akhal-Teke can be explained by the specific physical features of this breed. For instance, taking as a background the studies of muscle composition, a high proportion of MyHC IIa and IIx isoforms accounts for speed and endurance [27]. This combination of fast-twitch and slow-twitch muscle fibers enables such a breed to sustain its physical activity and to make the animal very fit for long-distance travel and endurance sports.

Metabolism : Considering metabolism, Akhal-Teke is very efficient; it is bred to perform excellently in harsh conditions in Central Asia with limited provisioning of food and water. This metabolic efficiency allows the horse to utilize as little energy as possible and keep going for a lot longer without added calorie intake, which is of great value in disciplines requiring stamina [2].

Thermoregulation : The thermoregulatory attributes of the breed involve a semi-transparent, metallic coat that reflects sunlight and reduces heat absorption [20, 31]. Thin skin and a lack of subcutaneous fat contribute to heat dispersion in the Akhal-Teke and enable it to maintain a stable body temperature even in extreme desert climates. Together, these adaptations give evidence of the remarkable ability of the breed to sustain heavy loads and perform well under demanding conditions.

Just as its physical traits have made it a versatile breed, the Akhal-Teke's temperament has also been shaped by its heritage.

Temperamental traits

The Akhal-Teke is renowned for its bravery, devotion, intelligence, and sensitivity-skewed combination that emanates from its origin as a warhorse bred in the harsh desert environments of Central Asia [18, 20]. These qualities make the breed spirited but enduring, remarkable for resilience in hard conditions. Traditionally raised among nomadic tribes, the Akhal-Teke has developed a strong bond with humans, often forming a deep, almost exclusive attachment to a single rider, a quality that made it highly valued as a warhorse in ancient Central Asia. This is the "one-rider" bond that is so typical for this breed, as it thrives on close connection and is highly responsive to its handler's reactions [8, 20, 21].

The Akhal-Teke is a hot-blooded breed; therefore, it is spirited, energetic, and really smart to the extent of learning promptly. On the minus side of this breed are its sensitivity and sometimes stubbornness; this then makes it not an easy partner, especially for less-experienced riders. Thus, this breed needs constant but gentle handling and is best suited to experienced riders who understand its particular needs and temperament. Being an athletic horse and having that natural need for activity, the excess energy of the Akhal-Teke could turn into behavioral problems if not given regular exercises [24].

Though obedient and respectful under saddle, the Akhal-Teke are more tricky to handle when dismounted; thus, patience and calm handling will be necessary. Akhal-Teke horses are reserved at first but eventually warm up once trust is established. Overall, Akhal Teke horses are worthy partners: similarly loyal, hardworking, and dedicated partners who can match its extreme expectations with high devotion, coupled with mutual respect and understanding [21, 24].

3. Genetic Characteristics and Breed Purity

Akhal-Teke differs from others not only in physical and behavioral respects, but it has retained most of its genetic respect, having retained its structure unchanged for many centuries. This is due to a combination of geographic isolation in Central Asia and selective breeding that has preserved lineages. This is further demonstrated by the fact that modern genetics have identified a set of unique genetic features which are useful in illuminating its breed origins,

evolutionary lineages, and genetic distinctiveness [1,4, 32]. They also explain the nature of the breed, that is, its hardiness, endurance, and physical grace, among the hallmarks. Combined, such characteristics are instrumental in breeding the Akhal-Teke for its bloodline and maintaining the purity of the breed for its endurance and unique qualities.

Genetic investigations were carried out on Akhal-Teke horses, confirming that the breed possesses particular genetic markers setting it apart from other horse breeds. This is particularly true regarding its mitochondrial DNA and its SNP. The results obtained showed a peculiar mitochondrial DNA pattern for Akhal-Teke horses, specifically the G1 haplotype [4]. This haplotype, associated with lineage markers, joins the Akhal-Teke horses to a sameness of ancient Central Asian horses, possibly as early as the Han Dynasty in China [4, 11]. The marker, which has been retained for many centuries, infers a long history of selective breeding and scant genetic admixture, suggesting the maternal lines have conserved the Akhal-Teke Lineage [4, 34]. Further studies using SNPs data combined with mitochondrial DNA sequences support that there is significant genetic overlap between the Akhal-Teke and Middle Eastern breeds, indicating evidence for a Middle Eastern influence in the Akhal-Teke genetic tree rather than an exclusively Central Asian lineage. This thus puts into perspective not only the continuity of the G1 haplotype but also a stable maternal lineage with little genetic divergence from its ancestors, thus confirming its ancient origin as well as selective breeding [4].

Other than that, Akhal-Teke tends to have certain microsatellite loci which might be used while conducting its genetic diversity, lineage, and breed purity analyses [1]. Various studies of microsatellite loci conducted on Akhal-Teke in many countries such as Italy, Russia, and Turkmenistan have been characterized by high allelic diversity. This means that despite distance, these populations have managed to maintain a strong genetic background [1,6,31]. This genetic variation is not only crucial for the health, resilience, and adaptability of the breed but also from the point of view of preventing adverse effects due to inbreeding, such as congenital health problems or less fertility [1, 6].

From this perspective of genetic purity, the Akhal-Teke breed has been the subject of various studies concerned with its origin. One study, in fact, researched genetic variability of Akhal-Teke

populations in the Czech Republic, Russia, Estonia, and Switzerland and demonstrated that clear regional differences existed in allele frequencies and heterozygosity levels, reflecting the varying degree of genetic purity [31]. For instance, whereas the Russian Akhal-Teke population is characterized by rather high heterozygosity-most indicative of genetic health and diversity-the Czech population, for example, shows higher allelic variation due to possible crossbreeding and hinting at strict breeding practices in order to maintain Akhal-Teke lines pure [31]. But another Italian study by 17 microsatellite loci confirmed that the genetic diversity of the Italian Akhal-Teke population is very high, even though the size is extremely low, with low inbreeding coefficients and high heterozygosity [6].

These markers, such as HMS6 and HTG10 loci, are used routinely across Akhal-Teke breeding populations for line monitoring as well as maintaining genetic diversity. By selecting such markers, the breeders can monitor any decline in genetic health due to inbreeding and can conserve the breed's heritage and characteristics [6].

Despite these efforts, challenges still arise due to the relatively small population of Akhal-Teke horses, which can increase the chances of inbreeding and genetic drift over time. Secondly, smaller populations also make it more challenging to preserve genetic diversity, which is very important for preventing hereditary diseases. While the Akhal-Teke breed is said to generally be hardy, having developed over time to survive in extremely harsh environments, it is prone to specific genetic disorders such as Wobbler syndrome, hereditary cryptorchidism, and Naked Foal syndrome. For instance, Naked Foal Syndrome (NFS) is an inherited disorder seen in Akhal-Tekes, caused by a nonsense mutation in the ST14 gene. NFS is an autosomal recessive disorder causing hairlessness and skin abnormalities, which has been fatal in foals [26]. This condition exemplifies the health risk associated with inbreeding. Most particularly in isolated groups which have lower heterozygosity, increasing their vulnerability to inbreeding depression and genetic drift [6, 31]. To counteract this, microsatellite analyses, as has been done in Italy and Central Europe, have become an important tool in distinguishing levels of heterozygosity and in monitoring genetic variations between subpopulations, thus helping breeders make informed decisions in order to avoid excessive inbreeding.

To conclude this part, the genetic purity and health of the Akhal-Teke breed both rely on continuous scientific research and on attentive breeding management. Through the application of genetic tools, breeders can ensure that the Akhal-Teke maintains its ancient lineage and distinctive characteristics, thus preserving this unique breed for future generations.

III. Akhal-Teke's Influence on Modern Horse Breeds

1. Genetic Influence on Modern Breeds

The Akhal-Teke horse, with its distinctive genetic lineage and unique physical attributes, has contributed significantly to the genetic foundation and refinement of several modern horse breeds. Though it may not directly be the ancestor in every case, this breed holds a deep ancestral tie with many Oriental and Central Asian breeds. Its contribution can also be traced through common features shared, such as endurance, slender and graceful build, and a resilience particularly adapted to harsh climates. Akhal-Teke's contributions are demonstrated in a physical likeness, by shared genetic markers, and by impacts upon breeds as diverse as the Arabian and Thoroughbred, to Russian breeds such as the Don and the Orlov Trotter.

The Akhal-Teke and Arabian horse breeds both have histories in the extreme and taxing terrains of Central Asia and the Middle East, respectively, where selective breeding over many centuries achieved traits in resilience, endurance, and elegance—qualities much desired by nomadic groups and warrior societies. More recent genetic studies have established a more complex relationship between the two breeds than initially thought; rather than a single direction of influence, these breeds are more likely to share a common maternal lineage. Genomic studies, particularly mtDNA and Y-chromosome haplotype analyses, have stressed genetic similarities, such as the presence of shared haplotypes between the two breeds, suggesting a process of parallel evolution rather than a direct line of descent from Akhal-Teke to Arabian [4, 30, 32].

Maternal lineages identified by mtDNA analysis reveal that both breeds still harbor ancient haplotypes, including some shared with other equine populations of Central Asian and Middle Eastern origin [32, 33]. Such haplotypes not only demonstrate a common ancestry, but also underline exchanges in the region where the physical resilience and endurance traits in

Akhal-Teke horses were appreciatedassets. The legendary endurance of the Arabian, possibly supplemented by Akhal-Teke influence, is consistent with some of the physiological adaptations of the Akhal-Teke, notably its high percentage of Type I muscle fibers and very efficient thermoregulation systems for hot and cold extreme climates [4, 27, 32].

Genetic markers also explain the connection between these two breeds. Single nucleotide polymorphism studies have established that some markers associated with traits such as endurance, lean muscle development, and heat tolerance are common in the Akhal-Teke and Arabian horse breeds. For example, the G1 haplotype, shown to associate with enhanced aerobic metabolism, was found in the populations of Akhal-Teke horses and represents a genetic basis for this breed's legendary endurance in long-distance activities. Similarly, those markers are found in Arabian horses, renowned for endurance sports performance [4, 32, 34]. Those features are also found in Arabian horses, which evidences the critical initial contribution of Akhal-Teke genetics to their muscular strength and endurance capabilities [32].

In terms of physical and physiological changes, the Akhal-Teke's coat special metallic sheen, combined with its slim body build, adds greatly to heat resistance and promotes even more its age-old role of being a long-distance horse. These attributes were likely advantageous for early Arabian populations and helped shape the breed’s unique characteristics through selective breeding influenced by the Akhal-Teke. This historical relationship underlines the influence of Akhal-Teke genetics on the genetic structure of the Arabian horse, once again confirming its well-known characteristics of endurance and elegance—characteristics that still delineate this breed [4, 32, 33].

Consequently, although the Akhal-Teke and Arabian horse breeds developed in geographically and culturally disparate settings, genetic research brings forth their common ancestry that has been influenced by comparable environmental conditions and functional requirements. Indeed, this very longstanding genetic relationship has played a crucial role in establishing the distinctive characteristics of each breed and, therefore, influencing the evolution of contemporary equine breeds in which both the Akhal-Teke and the Arabian have left their stamp—characterized by traits of endurance, elegance, and adaptability [32, 33].

In Europe, the Akhal-Teke's impact extended far beyond its Central Asian roots as it contributed significantly to developing one of the world's most famous racing breeds, the Thoroughbred. Thoroughbreds were developed starting with the introduction of the Eastern stallions, Arabians, Barbs, and Turkoman horses, closely related to the Akhal-Teke, into native British mares in the 17th century [35, 36]. The founding stallions, including the Byerly Turk (1689), Darley Arabian (1713), and Godolphin Barb (1731), provided a genetic foundation for the ancestry of the Thoroughbred, producing an animal that synthesized features of power and stamina, features of great importance in competitive racing [36]. A number of additional Turkoman horses were imported into Britain, including the Darcy Yellow Turk and Darcy White Turk, which further contributed to the genetic diversity that would eventually characterize the athleticism of the Thoroughbred. Elegant and hardy, they exemplified the high esteem in which Eastern bloodstock was held in Britain, testified to by the fact that Oliver Cromwell purchased Darcy White Turk [37].

Nowadays, attention to the genetic aspect has unveiled a co-occurrence of mitochondrial DNA haplotypes in the Thoroughbred and Oriental bloodlines, which are evidence of an historic genetic inheritance from the Turkoman breeders. Specific mitochondrial haplotypes, such as Tb-oB1*, have been found in Thoroughbred lineages, which demonstrate heavy Eastern genetic contribution [32, 37]. Although direct evidence explicitly connecting specific haplotypes to the Akhal-Teke is still sparse, the study on Y-chromosome haplogroups by Wallner et al. (2017) revealed a majority of Eastern genetic contributions, which likely assimilate traits from both Arabian and Turkoman equine lineages [32]. These findings are evidence of the great contribution of Oriental stallions to building the performance gene reservoir of the Thoroughbred, depicting hundreds of years of genetic exchange across Central Asia and Europe driven by trade and war [34, 37].

More recent genetic studies on the myostatin MSTN gene, which affects muscle growth and speed, further explain the selective pressures that shaped the Thoroughbred's athletic profile. The MSTN C-allele, associated with sprinting ability, most likely arose through selection in Thoroughbreds, while the T-allele—associated with endurance—parallels the 'stamina' traits of the Oriental breeds, such as the Turkoman and Akhal-Teke [35]. This effect of the MSTN gene on muscle fibre composition suggests that East bloodlines have contributed genetic adaptations

not only for speed but also for endurance, reflecting qualities valued in Akhal-Teke horses [35, 37].

All these factors taken collectively underline the oblique contribution of the Akhal-Teke in determining the Thoroughbred through selective breeding modalities. This confluence united the endurance, speed, and elegance of Oriental steeds with native British stock to create a strain as refined for the rigors of competitive racing [36]. Such genetic exchange shows the indelible mark of Oriental steeds upon European breeding practices and, hence, a considerable effect on equestrian sports and worlds of breeding [35].

Interestingly, in Russia, in the late 19th century and up to the early 20th century, breeders were attempting to establish multi-purpose sport horses by crossing the Akhal-Teke with Thoroughbreds, hoping that the resultant breed would embody the endurance, toughness, and elegance of the Akhal-Teke combined with the outstanding speed of the Thoroughbred. This practice ceased in the 1930s when Soviet breeders realized the cultural and genetic importance of keeping the Akhal-Teke as a pure breed. The establishment of a closed studbook emphasized the importance of the breed's ancestry and provided retention of its unique features, ensuring its continuation. Even more so, Russia utilized an Akhal Teke to improve its own breed [38]. In fact, the Akhal-Teke played an important role in the improvement and development of local breeds, particularly the Don and Orlov Trotter [38, 42].

These Russian breeds, developed under demanding conditions for both military and agricultural work, were much improved by infusions of Akhal-Teke bloodlines, bringing resilience, refined physical structure, and stamina [38, 40, 42]. Don horses are traditionally bred on the Russian steppes and have been used mostly for extensive traveling in the course of military campaigns, where endurance and durability are the most sought-after qualities. The lean, refined build and increased endurance of the Akhal-Teke made it an ideal choice to introduce those traits into the Don horse to create a breed more capable of withstanding extended travels yet resilient to poor climates and terrains [40]. Similarly, the Orlov Trotter, created by Alexei Orlov during the 18th century, famous for its trotting speed and agility and for being versatile, benefited from improvements traceable to the genetic inputs made by the Akhal-Teke.

This conformation of the Akhal-Teke, with its refined head and neck carriage, gave the Orlov Trotter a touch of grace, adding to its athleticism and high suitability for competitive events and driving in carriages [41, 42]. Under this genetic influence of the Akhal-Teke, the Orlov Trotter was slowly molded into a breed embodying elegance and power—the very qualities that made horses esteemed in Russian horse culture [42]. Genetic research proves this influence of the Akhal-Teke on these breeds through the demonstration of common mitochondrial DNA markers and hinting at the convergence of traits toward endurance and adaptability.

The inclusion of Akhal-Teke bloodlines improved not only the physique and athleticism but also the genetic variability of Russian breeds, which helped to some extent reduce the issue of inbreeding among some native groups [39, 43]. In this respect, the great role of the Akhal-Teke is epitomized by the integration of genetic traits via selective breeding initiatives, being known not only as an original breed but also as a genetic reservoir for the improvement of other horse breeds in Russia [43, 44]. Such enhancements show a persistent role played by the Akhal-Teke in strengthening the durability and athletic ability of Russian horse breeds and hence confirming suitability for various practical uses and sport events for many generations [41, 42].

This concludes that the genetic legacy of the Akhal-Teke is far-reaching, influencing many breeds, from the graceful Arabian to the high-performing Thoroughbred and strong Russian breeds. Through careful breeding programs and genetic exchanges, the Akhal-Teke has shared characteristics of endurance, toughness, and specific physical traits through generations, thus helping to create these breeds into versatile and highly regarded bloodlines. This historical genetic exchange brings forth the very important role played by the Akhal-Teke in modern times in the development of various horse breeds, linking ancient ancestry with present-day performance standards.

Continuing on to the next section, the genetic factors will lead toward a reflection of how the Akhal-Teke made a major contribution to developing endurance and sport horse breeds because its inherent ability never ceases to spur improvements in performance capabilities among competitive equestrian sports.

2. Role in the Development of Endurance and Sport Breeds

The Akhal-Teke's impact on contemporary endurance and sport breeds is fundamentally based on its exceptional stamina, agility, and resilience—characteristics that have been carefully inherited to develop high-performance horses adapted for complex disciplines. The Akhal-Teke is renowned for its capacity to cover great distances with minimal tiredness, and its genetic contributions have been instrumental in developing breeds that excel in endurance sports, including cross-country races and competitive endurance racing [46].

Physiological Adaptations

The Akhal-Teke horses exhibit special physiological features that lend them the reputation of endurance athletes. Their efficient metabolic rate, adapted to survive in arid and extreme climate conditions, supports prolonged energy release and quick recovery, both essential in endurance sports. Muscle composition studies have shown a high proportion of endurance-oriented muscle fibers in Akhal-Teke horses, developed over centuries of selective breeding in the challenging desert conditions. These muscle fibers, particularly the Myosin Heavy Chain (MyHC), permit Akhal-Tekes and their descendants to maintain steady, prolonged activity [27]. These traits have been instrumental in the development of sport breeds like the Anglo-Teke, the Budyonny, and the Karabakh horse. [44, 50, 52].

Usage in Sport Disciplines

In order to fully understand the implication of the Akhal-Teke in the development of modern sport breeds, it is important to highlight the different categories in equestrian sports where the Akhal-Teke shines.

Akhal-Tekes are recognized for their aptitude in equestrian sport for their lean physique, athleticism, and fluid gaits, making them well-suited for dressage (Figure 4). They perform transitions elegantly and precisely, qualities that are very much prized in competitive dressage [18, 19].

With strong hindquarters, fast reflexes, and an excellent power-to-weight ratio, they are able to negotiate complicated courses with remarkable agility in show jumping [19, 27]. They do not

have that sheer explosive power that some heavier breeds possess, but their determination, good connection with riders, and agility contribute much to better performance in technical challenges.

The breed does very well in eventing as well, performing well in all three phases: dressage, cross-country, and show jumping [9] (Figure 4). Their stamina supports the demands of long cross-country runs, while their precision and athleticism suit the technical aspects of dressage and jumping. And obviously, in endurance racing, Akhal-Tekes are distinguished competitors because of the ability to keep a constant speed over long distances and to recover quickly between stages (Figure 4). Their incredible resilience and energy efficiency mean they are able to dominate global endurance competitions, showing strength and versatility they can be relied on to display [9, 19].

Figure 4 : Akhal teke in different equestrian sports : Jumping event (top left), Dressage show (top right) Eventing (bottom left) and Race (bottom right)

Crossbreeding Programs

Breeders have been able to take advantage of the endurance attributes of the Akhal-Teke through targeted crossbreeding programs in order to enhance the athletic potential of modern sport horses. For example, various crossbreeding efforts have combined the endurance of Akhal-Teke horses with the speed of Thoroughbreds, resulting in versatile horses which excel at eventing, show jumping, and cross-country racing [49]. The Anglo-Teke, Anglo-Arabian, and Shagya Arabian are representative breeds which reflect the endurance and adaptability derived from the Akhal-Teke [47, 51, 58].

Consciously chosen features like the Akhal-Teke respiratory efficient system, lean musculature, and energy-efficient features which allow for smooth movement over long distances [47, 52]. In endurance racing, most Akhal-Teke crosses participate in various international competitions and appear resistant during the stages, quickly recovering between them.

Impact on Competitive Disciplines

The Akhal-Teke's features, particularly endurance and agility, have left an indelible mark on competitive disciplines. For example, in endurance racing, Akhal-Teke crosses-especially when combined with other high-stamina breeds like the Arabian-perform exceptionally well in long, hard rides across difficult terrains, showing resilience and quick recovery times [48, 49]. Breeds such as the Karabakh horse and Budyonny reflect this influence, inheriting the Akhal-Teke's stamina and endurance capabilities [45, 53].

In disciplines like jumping and dressage, Akhal-Teke blood adds flexibility, elasticity of muscles, and a lighter build. These features promote more fluid, accurate movements that allow hybrids to be competitive in those disciplines which place a premium on agility and technical proficiency. Horses like the Anglo-Teke and Anglo-Arabian are especially known for their smooth gaits, which confer style and efficiency on competitive performances [48, 49].

Competitive endurance events continue to highlight theAkhal-Teke's long-lasting effects on today's athletic horses. With an even disposition and offering the rider partnership, these Sport horses carry Akhal-Teke blood through their breeding; Anglo-Arabian, Budyonny, and Shagya Arabian are regarded with respect for this balance in both mental and physical endurance,

respectively. An amalgamation that makes the Akhal-Teke a very peculiar foundational breed when it comes to sports in terms of endurance [53].

In summary, the Akhal-Teke has contributed significantly to the development of modern sport and endurance breeds. Its unique physiological and temperamental characteristics, such as stamina, adaptability, fast recovery, and connection with riders, continue to influence contemporary equestrian disciplines. Only by crossing the Akhal-Teke with other high-performance breeds have breeders been able to produce horses capable of meeting the heavy demands of competitive endurance and eventing, thus securing a place for this horse in equestrian history [48].

3. Cultural and Economic Influence of the Akhal-Teke in the Horse Breeding Industry

The Akhal-Teke horse occupies a special place in the world of cultural heritage and in the international breeding industry. In Turkmenistan, this breed represents something more than just a breed; it is a national symbol and an integral element of the country's identity [54]. Its impact on breeding practice, equestrian sports, and the economy stretches far beyond its original geographical region, posing an impact on a global scale [55].

In Turkmenistan, the Akhal-Teke horse is highly considered as a symbol of endurance, beauty, and strength. It is regarded as a national treasure and is ranked highly within the cultural heritage of the Turkmen. The government has invested heavily in the preservation and popularization of this breed, further solidifying its importance in the national image. The Akhal-Teke horse has an honored place on the national coat of arms and currency of Turkmenistan, symbolizing cultural heritage and pride of the Turkmen people [54]. Turkmenistan annually celebrates a national holiday called Turkmen Horse Day in honor of the Akhal-Teke breed (Figure 5). The celebration of the breed occurs on the last Sunday of April, during that period parades, and ceremonial honors conferred upon breeders can be seen [54, 55]. This annual event brings out the deeper meaning of the breed for the Turkmen people, as a symbol of cultural preservation and national pride.

Figure 5 : Performance of an Akhal Teke during Turkmen Horse Day

It has further influence in the art and folklore of Turkmenistan. The horse often appears on tapestries, in paintings, and in sculptures, more often than not, it symbolizes loyalty, nobility, and courage [55] (Figure 6). In traditional weddings and other major ceremonies, the Akhal-Teke is a symbol of prosperity and status, binding the Turkmen people with their ancestral past.

This has contributed to the preservation of the Akhal-Teke in its purest form because breeding practices have been strictly adhered to with the view of keeping the breed pure and upholding its esteemed qualities [54, 55].

Figure 6 : Emblem of Turkmenistan with the Akhal Teke in the center and Turkmen horses statue

The cultural adoration for the Akhal-Teke has had a strong influence on breeding practices, not just in Central Asia but around the world. The Akhal-Teke is therefore valued for endurance, agility, and a temperament that sets it apart and has made it a desirable component in most breeding programs aimed at improving other equine breeds. Indeed, the Akhal-Teke has been used in Central Asia, for hundreds of years, in the improvement of local horse breeds, particularly in Kazakhstan and Uzbekistan, for acquiring endurance and strength, useful in riding long distances and surviving rigorous environmental conditions [56]. The athletic build and gracious movement of the Akhal-Teke have made it influential in sport horse breeding programs in Europe; examples of such crosses include the Trakehner, Anglo-Arabian, and Budyonny, where the Akhal-Teke's traits enhance performance in the disciplines of eventing, endurance racing, and dressage [57].

Breeding programs throughout the world have utilized Akhal-Teke blood to develop performance-oriented breeds, merging a mix of speed, stamina, and strength. One of the important examples is the Anglo-Teke, a cross between Akhal-Teke and Thoroughbred, known for combining the speed of the Thoroughbred with the stamina typical for Akhal-Teke [58]. This crossbreed has obtained popularity in the competitive equestrian disciplines, eventing, where it shows the best performance due to its well-proportioned conformation and athletic ability. Similarly, crossbreeding efforts with Arabian horses have produced Teke-Arabian crosses that are particularly well-suited for endurance racing and desert competitions. Combining the Akhal-Teke's ability to withstand extreme climates with the legendary stamina of the Arabian has produced a crossbreed that is ideal for long-distance endurance racing in regions like the Middle East [58]. In Europe, more specifically in Germany and the Netherlands, the genes of the Akhal-Teke have been used in Warmblood breeding programs. This form of hybridization combines the aspect of increasing the athletic performance, stamina, and mental focus of a Warmblood horse in performing activities such as dressage and show jumping. Their graceful body and strong hindquarters make them desirable for activities requiring fluid motion and balance, thus allowing breeders to produce Warmbloods that could perform well in events that demand stamina along with strong structural soundness [48]. The influence of the Akhal-Teke breed is mainly felt in competitive endurance where its attributes are highly appreciated. Hybrid horses with Akhal-Teke parentage have shown high resistance to heat and increased metabolic

efficiency, enabling them to be more successful in long-distance races [59]. Akhal-Teke crossbreeds have excelled in the United States in endurance events such as the Tevis Cup, where their stamina, decreased fatigue levels, and fast recovery give these horses a clear competitive advantage. These crossbreeds, with their combination of Arabian and Thoroughbred ancestry, are in high demand among competitive riders for their endurance and ability to sustain high speeds over long distances [59].

Economically, the Akhal-Teke is one of the most valuable horse breeds on the world market, pure and in crossbreeds. It is the most important breed in Turkmenistan, and export is strictly regulated by the government to preserve the purity and prestige of this breed. High-quality Akhal-Teke horses receive premium prices internationally, with documented lineages and strong records of performance garnering hundreds of thousands of dollars [60]. To some extent, because of the breed's rarity and unique qualities, the Akhal-Teke is considered a status symbol, desirable to buyers who believe these horses are assets in their own right.

The higher demand increases the breed's market value, more so to collectors and competitive riders from countries like Russia, the United States, and other parts of Europe. Crossbreeds with Akhal-Teke ancestry are valued similarly, especially where endurance racing is a highly popular sport. For example, in the Middle East, Akhal-Teke crosses are greatly appreciated for their ability to work well under high temperatures and cover very long distances, thus being suitable for endurance racing. Among others, the Anglo-Teke and Teke-Arabian crosses find the highest demand at the market. These crossbreds acquire the best features from the parent breeds and become even more versatile for equestrian disciplines [58].

With the heightened profile of the Akhal-Teke, the International Association of Akhal-Teke Breeders (MAAK) and numerous other organizations play a vital role in controlling breeding practices and preserving the unique features of the Akhal-Teke. Such breeders' associations apply genetic markers and pedigree analysis for making informed breeding decisions to maintain a balance between the preservation of integrity and the benefits of crossbreeding [48]. By promoting responsible breeding practices, these organizations help sustain the breed’s legacy while allowing its unique qualities to enhance other equine lines

IV. Comparative Analysis of the Akhal-Teke and Other Major Horse Breeds

The Akhal-Teke is famous for its specific features of conformation, behavior, and endurance, which make this breed a perfect object for comparison with other influential breeds. Such a comparative study is presented below, based on three major breeds: the Arabian, a desert breed; the Thoroughbred, an international standard of speed and agility; and the Orlov Trotter, a breed that is known for its endurance and grace in harness. These breeds have been selected according to their historical value, their general use in equestrian sports, and their peculiar characteristics. The aim of this analysis will be to establish how the distinctive features of the Akhal-Teke compare to these breeds, underlining the differences in physical conformation, temperament, endurance, and their respective roles in modern equestrian disciplines.

1. Comparison with the Arabian Horse

The Akhal-Teke and Arabian horse breeds have been influenced by their arid desert environments to exhibit exceptional endurance and resilience. Their distinct physical traits and temperamental differences, however, underline how each breed adapted to survive in different conditions and to excel in specific equestrian functions.

a) Physical Traits and Adaptations

Both breeds share a base of desert-related adaptations, but their conformation belies different evolutionary routes. . The Akhal-Teke stands taller, on average, 1.55 to 1.60 meters, with a lean, elongated body built for long-distance travel at ultra-low energy costs. Its narrow chest, high withers, and slightly sloping croup help to reduce energy consumption; together, these features have turned the animal into a real icon of sustained endurance [19, 32]. In contrast, the Arabian, which stands between 1.45 and 1.55 meters, has a compact and refined body with a shorter back and high tail carriage. Such a build enhances agility and balance, which allows the Arabian to excel in shorter endurance races across different terrains [33, 62]. The metallic coat of an Akhal-Teke is made by semi-transparent hair and thin skin that reflects sunlight, helping in thermoregulation during extreme heat [20].

However, this adaptation allows for poor insulation in colder climates. The Arabian breed, with its thick and glossy coat, offers better protection over a range of climatic conditions, yet it loses some of the heat-dissipation advantages of the Akhal-Teke [22, 32, 61]. Both breeds prioritize pulmonary capacity over gastrointestinal efficiency since their deep chests allow more efficient oxygen absorption while exercising. However, the Akhal-Teke's slenderer thorax is built for longer distances, while the Arabian's deeper thorax offers a compromise between stability and respiratory function [33, 45]. For desert survival in breathing and visibility, Arabian horses have developed typical features such as a dished face, big nostrils, and eyes set wide apart [19,61]. Their arched neck is less long than that of the Akhal-Teke but still generous for balance and agility in dynamic or uneven terrains [33,43].

Figure 7 : Arabian horse (left) and Akhal Teke (right)

Both breeds have developed musculature specifically adapted to enhance their endurance capacities. The Akhal-Teke has flat, dense muscles containing a lot of slow-twitch fibers, which contribute to sustained energy output over extended distances. Its sloping shoulders and upright pasterns, as stated, also provide a fluid energy-efficient gait [20, 32]. The Arabian is built with rounder, stronger muscles and a higher proportion of fast-twitch fibers, thus possessing agility and explosive power, excelling in disciplines where quick bursts of speed are required. Its flatter shoulder angles and shorter pastern are in favor of powerful movement over the Akhal-Teke smoother, gliding stride [28, 43, 61] (Figure 7).

b) Temperament

The histories of the Akhal-Teke and Arabian have given way to their temperaments and the priorities of breeding. The Akhal-Teke is said to be independent and loyal, often forming a very strong bond with just one rider and sometimes even an exclusive relationship in respect to that rider. That therefore makes it an ideal partner for an experienced equestrian where focus and responsiveness are needed, as in endurance racing [20, 19]. This sensitivity and independence can make the Akhal-Teke more difficult for less experienced handlers [21, 32].

Conversely, the Arabian breed is known for being friendly and energetic; thus, it becomes easier to handle and ride by horsemen of different riding experiences. The friendly nature of the Arabian breed along with its intelligence and versatility allows it to thrive in animated environments and within a range of equestrian activities [33, 45].

While both breeds display loyalty and intelligence, the greater level of affability of the Arabian allows for adaptability, while the quieter nature of the Akhal-Teke appeals to those seeking a driven, intensely bonded relationship [62, 20].

c) Uses and Effectiveness in Sport

Akhal-Teke and Arabian breeds have carved out peculiar niches in the equestrian world, using their unique physiological and psychological makeups to dominate certain disciplines while showcasing some of the best athletic attributes, no doubt linked to their shared desert ancestry.

The Akhal-Teke is famous for its fantastic feats in ultra-long-distance endurance events like 100-mile races [57, 59]. The Akhal-Teke's lean body, athletic makeup of slow-twitch fiber, and efficient energy production may promote superior performance under extreme conditions when endurance and heat resistance become major factors [32, 19]. Its smooth flowing gait allows for minimal fatigue while sprawling across vast expanses with unparalleled efficiency. Equally, its grace and precision have earned it recognition in the art of dressage, where fluid movement and sharp responsiveness are paramount [20, 21]. The limited prevalence of the Akhal-Teke in various equestrian disciplines can be attributed to its rarity and the emphasis on selective

breeding [33, 62]. Conversely, the Arabian horse demonstrates versatility as a competitor, thriving in a wider array of equestrian pursuits.

The horse's agility, quick recovery, and athletic build enable it to be placed ahead in mid-distance endurance events, desert racing, and competitive trail riding [45, 61]. The Arabian's compact form and fast-twitch muscle structure allow it to have strong, agile movements, competing successfully over shorter distances, more dynamic endurance events, and varied terrains [32, 33] (Figure 8). Besides its overwhelming stamina, the Arabian horse has acquired substantial popularity in showmanship, flat racing, and other recreational activities, which have consolidated its position as a multi-purpose breed [43, 61]. Its ability to adapt and gentle temperament make it suitable for riders of all levels, and this has contributed much to its popularity worldwide [20, 62]. On athletic performance, the Akhal-Teke is superior because of its intensive specialization.

Its slow-twitch muscle fibers and streamlined body make it an ideal long-distance competitor, particularly in harsh climates. The ability of the breed to sustain energy and recover fast under pressure underscores its athletic endurance and suitability for ultra-long-distance events [32, 33]. Meanwhile, the Arabian's athleticism shines through its versatility. While it may not match the Akhal-Teke in very long-distance races, its agility, endurance, and more generalised muscular structure give it success in disciplines requiring rapid acceleration, fast turns, and the ability to adapt in diverse environments [61, 43].

Figure 8 : Arabian horses performing during a race

Taken together, these breeds represent two synergistic models of equine athleticism. The Akhal-Teke is the embodiment of precision with a focus on endurance, excelling in the longest and toughest competitions, while the Arabian represents a more robust blend of speed, agility,

and versatility, performing exceptionally in almost all equestrian disciplines. Such traits not only highlight each breed's athletic preeminence but also bolster their prevailing legacies in equestrian sports around the world [62, 32, 33].

d) Shared traits and Genetic influence

Despite their divergence, the Akhal-Teke and Arabian breeds find a deep connection with the maternal lineages that formed the basis of these horses and the parallel adaptations of those horses to extreme environmental challenges. Both breeds demonstrate very good endurance, elegance, and adaptability important for their survival in harsh conditions in Central Asia and the Middle East. These features were further accentuated through selective breeding in their respective regions, reflecting a long involvement in nomadic and warrior societies [32, 33]. The distinct physiological features of the Akhal-Teke-efficient thermoregulation and lean muscle structure-likely augment similar trait development in the Arabian and underscore the powerful influence of shared environmental pressures and selective breeding.

2. Comparison with the Thoroughbred Horse

a) Physical Traits and Adaptations

Thoroughbred is famous for its power and speed, yielded by centuries of selection for competitive racing. Its height at withers is 1.55–1.70 meters, and a typical weight is in the range of 450–600 kg, hence bigger and heavier than Akhal-Teke [63]. This size difference underlines that Thoroughbred is specialized for explosive athleticism in contrast with Akhal-Teke breed specialization for endurance [19, 35].

Its well-balanced and symmetrical frame includes a broad chest, muscular hindquarters, and long, sloping shoulders, each optimized for propulsion and oxygen delivery at high velocities in flat racing and steeplechase events [36]. Its chest cavity prioritizes lung capacity over gastrointestinal development, enhancing its ability to sustain rapid oxygen intake during sprints. While the Akhal-Teke sacrifices gastro-intestinal space to increase lung volume, its narrower thorax and longer body length underline long oxygen circulation for endurance instead of a speed [20, 37].

The differences in musculature also contribute to these specializations. The Thoroughbred has a higher proportion of fast-twitch fibers, allowing for rapid acceleration and forceful strides. Its ideally sloped hocks and long pasterns provide flexibility and elasticity, which are very important in competitions related to speed [19, 36]. In contrast, the Akhal-Teke has a flatter and more compact musculature and is composed mainly of slow-twitch fibers, which is in favor of energy conservation during long-extended exercises but lacks the burst of power seen in the Thoroughbred [21, 35] (Figure 9).

Figure 9 : Thoroughbred horse (left) and Akhal Teke (right)

Coat and skin adaptations reflect their environmental functions. The glossy, short coat and moderately thick skin of the Thoroughbred allow for general climate adaptability, well suited to temperate regions where flat racing is most common [20, 36]. This is in contrast to the semi-transparent, metallic coat of the Akhal-Teke, which allows for superior thermoregulation in extreme heat yet less insulation in colder climates [21, 19].

b) Temperament

Temperaments of Akhal-Teke and Thoroughbred horses clearly reflect the different historic roles and requirements of breeding. Thoroughbreds, developed for speed and competitive racing, are spirited, high-energy, and intensely driven. This-fiery and competitive nature combined with intelligence renders them excellent performers on a racetrack but also more challenging to handle, especially for less experienced riders [36, 37]. Thoroughbreds excel in

structured training regimes, where professional trainers can manage their energy and keep their focus during races [63].

In contrast, the Akhal-Teke, bred for survival and endurance and close relationships with its people, is intelligent, sensitive, and independent [19, 21]. Whilst generally calmer than the Thoroughbred, the Akhal-Teke's reactive nature means it requires a patient and confident handling approach.

In other words, while both breeds prove to be intelligent and task-oriented, their temperamental traits are more directly related to their functions: the passion and drive of the Thoroughbred make it well-suited to high-speed racing scenarios, while the Akhal-Teke's steady nerves and stamina make them particularly successful at endurance events and long, challenging journeys [20, 21].

c) Uses and Effectiveness in Sport

The Akhal-Teke and the Thoroughbred represent two very different paradigms of athletic ability, each excelling in quite different equestrian pursuits due to their respective specializations and selection goals.

The Thoroughbred was bred for speed, combining powerful hindquarters, a broad chest, and a high proportion of fast-twitch muscle fibers to dominate flat racing and steeplechase events [36]. Its build provides explosive acceleration for short bursts of high-intensity performance in sprinting and mid-distance races—less suited to very long distances, where the Akhal-Teke excels [36, 63]. In the discipline of dressage, each breed showcases distinct advantages. The Akhal-Teke exhibits flexible and elastic movements alongside a graceful physique, rendering it especially notable in precision-oriented activities, where its seamless gaits, including the "Akhal-Teke glide," highlight aspects of fluidity and balance [20, 21, 28]. Conversely, the Thoroughbred, despite being less innately graceful, offsets this with its athletic capabilities and quick responsiveness, excelling in intricate routines that necessitate both strength and concentration [36, 63]. In show jumping, however, the Thoroughbred has a unique advantage in being able to navigate complex courses with both speed and precision [36]. With their characteristic and efficient trot, combined with their lean, muscular body, the Akhal-Teke is also a formidable competitor in show jumping events [19, 20].

Its stamina and responsiveness make the Akhal-Teke particularly well-suited to precision events, such as roping and cutting, within Western disciplines. The Thoroughbred is better suited to speed events, such as barrel racing and polo, where it is superior to most horses because of its rapid acceleration and agility [35, 36, 63].

Racing remains a defining point of distinction between the two breeds. The Thoroughbred, accepted as the international standard for flat racing, is unrivaled in its ability to generate tremendous power over short distances, thus defining its fame on the racecourse [36, 37] (Figure 10). However, it should be reminded that the Akhal-Teke took part in laying the genetic foundations of the Thoroughbred in its early days of development. This influence has contributed much to the development of Thoroughbred's speed, refinement, and adaptability, although the two breeds excel in different fields [37, 43].

Figure 10 : Thoroughbred racing

In overview , the Akhal-Teke and Thoroughbred represent a complementary set of advantages: the former excels in sprint and mid-distance races owing to its explosive power, while the latter dominates the long-distance and jumping events because of its efficient body constitution and excellent stamina. Both of these horse breeds emphasize the richness in equestrian excellence and special adaptations that horses can develop to satisfy different requirements [19, 21, 36].

d) Shared traits and Genetic influence

The two breeds show high resilience and endurance, although in different ways. The speed and strength of the Thoroughbred are augmented by its cardiovascular and muscular effectiveness, while the Akhal-Teke is characterized by its ability to save energy and have long-lasting stamina [27, 35, 36].

Genetically, the Akhal-Teke, as mentioned previously, has contributed to the development of the Thoroughbred, specifically in terms of furthering its articulation and versatility. The historical crossbreeding introduced the elements of stamina and elegance, which have been linked to the modern-day Thoroughbred's athletic versatility. These genetic contributions underline the interrelation of horse breeding and shared heritage between the breeds [32, 35].

In a nutshell, the Thoroughbred and the Akhal-Teke represent associated equine strengths, with the former absolutely dominant in speed-oriented sports, and the latter in endurance and precision-oriented events—diversity within equestrian specialization.

3. Comparison with the Orlov Trotter

a) Physical Traits and Adaptations

These two breeds, the Orlov Trotter and the Akhal-Teke, represent very distinct anatomical adaptations that speak to differences in breeding purpose and environmental pressures but share endurance and hardness. The Orlov Trotter is symmetrical and well put together, with a convex and massive structure compared to the other breed, standing between 1.60 and 1.70 meters in height and weighing 450–550 kg, while the Akhal-Teke is slender and much longer-legged [64].

The Orlov Trotter has a well-proportioned head with a straight profile and broad nostrils to increase airflow during sustained trotting. The neck is long, slightly arched, and set high on the shoulders to provide power and stability during harness work. In comparison, the Akhal-Teke has

a head that is finely chiseled with a slight convexity of profile and a high-set neck to emphasize flexibility and stride efficiency [41, 64].

Both breeds reveal a developed respiratory system for improved pulmonary efficiency at the cost of reduced gastrointestinal space. However, both have builds indicating different endurance strategies: The chest is broader and deeper with the Orlov Trotter, increasing lung capacity for sustained trotting and medium-distance events. Its frame is wider and weight higher, however, which would better serve the efficiency of ultra-long distances—predominantly the domain of the Akhal-Teke [64].

The Orlov Trotter has longer, more muscular legs with well-developed tendons and broad joints, which are better suited for stamina in harness racing but less elastic than the refined, slender legs of the Akhal-Teke [18, 41]. These differences come out in their gaits: the extended, rhythmic trot of the Orlov Trotter is just perfect for harness racing, while the fluid, elastic stride of the Akhal-Teke speaks of speed and elegance [28, 41, 42].

Figure 11: Orlov Trotter (left) and Akhal Teke (right)

Coat and skin adaptations underline their environmental specializations. In a way, the dense glossy coat and thicker skin of the Orlov Trotter protect against the harsh Russian winters,

guaranteed that the breed would do well in colder climates, unlike Akhal-Teke with a thin, silky coat fine-tuned for heat dissipation in its desert environment [22, 41, 63] (Figure 11).

b) Temperament

Temperamentally, therefore, the Akhal-Teke and the Orlov Trotter represent different roles and breeding purposes each was developed for and have divergent strengths adapted to different equestrian activities.

The Orlov Trotter is highly valued for its quiet, tractable, and friendly nature, hence very versatile. It is even-tempered, docile, hence it is easy to approach by a wide range of handlers, including less experienced riders [64].

Known to be a strong-willed breed with a good work ethic, the Orlov Trotter does well in performing tasks that require reliability and concentration—harness racing, farm work, etc [41, 64]. Very social, this breed is quite approachable and gets on very well with its handlers if the environment is stable and trustworthy. Also, Orlov Trotter is forgiving, therefore allowing small mistakes in handling or training, which renders it a perfect choice for any person looking for a sturdy and flexible partner [64]. On the other hand, the Akhal-Teke is much more delicate and spirited – not being a riding horse for the beginning riderer due to its being over–sensitive and independent. While both breeds are intelligent and highly trainable, the Orlov Trotter's cooperative and steady demeanor suits it for tasks requiring teamwork, routine, and prolonged effort under harness. Meanwhile, the Akhal-Teke's independent and sensitive personality aligns with disciplines that demand resilience, adaptability, and endurance, making it a partner for riders seeking a more dynamic and focused equestrian experience [20, 21, 23].

c) Usage and Performance in Sports

Akhal-Teke and Orlov Trotter differ in their usage and sports performance due to their unique selective breedings and features. The most well-known specialty of the Orlov Trotter is harness racing and its participation in the traditional troika. The troika, a three-horse carriage configuration where the central horse trots and the outer horses canter, highlights the Orlov's stamina, elegance, and ability to maintain a steady, rhythmic trot over extended distances [41]

(Figure 12) . Its powerful gait and endurance make it the breed of choice for this visually stunning and culturally significant sport.

Figure 12 : Troika with Orlov Trotter

In addition to harness racing, the Orlov Trotter is highly valued in recreational carriage driving, competitive driving events, and even agricultural work, where its strength and calm demeanor shine. Its ability to sustain high-speed trotting under load has made it a staple in carriage competitions throughout Europe and Russia [38, 64]. By comparison, the lighter build and energy-efficient gait of the Akhal-Teke are less suited for harness work but excel in endurance-focused disciplines, dressage, and eventing [18, 19]. These are categories where the strong build of the Orlov Trotter limits its agility and elasticity [42].

Both breeds have also shown versatility in equestrian tourism and trail riding, though the Orlov Trotter is better suited to cold climates and structured activities, while the Akhal-Teke is superior over challenging terrains and long, unstructured journeys [40, 64].

d) Shared Traits and Genetic Influence

Despite the differences, Akhal-Teke and Orlov Trotter share their origin in endurance and hardness. As mentioned earlier, historically the Akhal-Teke has contributed to the breeding and fine-tuning process of the Orlov Trotter breed. Its early selective breeding included Akhal-Teke

bloodlines to infuse the Orlov breed with stamina, style, and versatility. This cross resulted in developing the present Orlov Trotter into a multi-discipline breed good for harness racing, yet retaining the stamina and athleticism from Akhal-Teke [41, 42].

In summary, the Akhal-Teke and Orlov Trotter represent complementary strengths in the equestrian world and highlight the diversity of equine athleticism and the remarkable adaptability of horses to meet human needs across vastly different environments and historical contexts [38, 40].

Summary of Comparative Characteristics :

The following table highlights the key similarities and differences among the Akhal-Teke, Arabian, Thoroughbred, and Orlov Trotter (Table 1).

Table 1 : Comparative analysis of the Akhal Teke with Arabian horse, Thoroughbred and Orlov Trotter

Breed	Heights (m)	Build	Temperament	Sport specialization
Akhal-Teke	1.55–1.60	Lean, refined	Sensitive, loyal	Endurance, dressage, eventing
Arabian horse	1.45–1.55	Compact, arched	Spirited, sociable	Endurance, desert racing
Thoroughbred	1.55–1.70	Muscular, powerful	Fiery, competitive	Flat racing, steeplechase
Orlov Trotter	1.60–1.70	Robust, strong	Calm, cooperative	Harness racing, carriage driving

The Akhal-Teke's unique traits set it apart from other breeds, making it highly versatile and well-suited for endurance and performance sports. While the Arabian shares its desert adaptations, the Thoroughbred competes in speed-centric disciplines, and the Orlov Trotter thrives in harness events, the Akhal-Teke's combination of stamina, elegance, and loyalty ensures its place as a distinctive and valuable breed in the equestrian world.

V. Modern Breeding Programs Influenced by the Akhal-Teke

1. Crossbreeding Programs and Genetic Studies

The Akhal-Teke horse has been a cornerstone of crossbreeding programs around the world to improve endurance, agility, and temperament in modern horse breeds [65]. Many of its physiological characteristics, such as effective metabolism, lean musculature, and refined conformation, render it unique in the creation of high-performance horses. While the preceding sections addressed how these attributes inform the sport and endurance disciplines, the following addresses the genetic and methodological underpinnings in crossbreeding efforts.

This is to make sure the importance of the Akhal-Teke in such breeding programs, through extensive genetic research, as explained previously. Mitochondrial DNA, such as G1, associated with efficient energy metabolism and endurance, are highly sought after in breeding programs for long-distance performance horses [2, 4]. Notably, besides the Single Nucleotide Polymorphism associated with muscle composition and thermoregulation —an important factor in equine performance under extreme conditions [2]. These findings prove the Akhal-Teke's present-day relevance to modern breeding programs.

Breeders worldwide have been using planned crossbreeding programs to introduce Akhal-Teke blood into other breeds, producing offspring that combine the distinguishing features of the Akhal-Teke with the strengths of other breeds [3, 48, 58]. For instance, the Anglo-Teke, a crossbred mixed with the endurance and hardiness of the Akhal-Teke and the Thoroughbred's speed and athleticism, epitomizes genetic combination through selective breeding. While previous chapters outlined the success of the Anglo-Teke in endurance riding and dressage, it is important to note here that it is the product of directed breeding programs. The Teke-Arabian similarly combines the endurance of the Akhal-Teke with the climate tolerance and athletic diversification of the Arabian, again evidencing the directed exploitation of genetic resources to achieve both ecological and performance goals [56, 58, 65].

In Russia, the Akhal-Teke has been instrumental in the development of the Budyonny horse, a breed originally designed for military purposes and later modified for use in sport and general-purpose riding. The cross-breeding of Akhal-Teke with Don and Thoroughbred has

provided the Budyonny with stamina and refinement, retaining much of the gene pool from the Akhal-Teke [38]. Similarly, in the United States, the Nez Perce horse is another example of the versatility provided by Akhal-Teke genetics, crossed with the Appaloosa to produce a breed well-suited for endurance and recreational riding [59, 65].

Success in these programs depends critically on careful breeding and genetic monitoring. Breeders have selectively introduced characteristics, such as the efficient respiratory system and lean musculature of the Akhal-Teke, into hybrid breeds in order to optimize performance in endurance and other demanding activities [48]. Still, finding the right balance is not easy; overuse of Akhal-Teke bloodlines in crossbreeding risks diluting the breed's unique characteristics [1, 6, 48]. These risks are mitigated by organizations such as the International Association of Akhal-Teke Breeders (MAAK), which focus on ethical breeding practices, strict studbook management, and the application of genetic monitoring tools that can safeguard the breed's legacy [3, 48].

Earlier discussions clearly placed the Akhal-Teke in an instrumental role in shaping modern equestrian disciplines; however, cross-breeding programs also show its wider importance as a genetic resource. These initiatives go beyond specific disciplines and outline how the physiological and behavioral traits of the Akhal-Teke are purposively combined within larger breeding strategies to improve the functionality of modern performance horses. This again proves the success of such breeds as the Anglo-Teke, Teke-Arabian, and Budyonny, which strategical use of Akhal-Teke genetics underlies the foundation for versatility and adaptability across a wide range of equestrian needs [56, 65, 66].

With the increasing use of Akhal-Teke bloodlines in crossbreeding programs, questions have been raised regarding the preservation of the unique lineage of the breed. While hybrids out of Akhal-Teke continue to perform at the top level, a parallel attempt is being made to save the original breed and maintain its integrity [1, 55]. That means a delicate balance must be struck between using exceptional Akhal-Teke genetics for hybrid vigor and ensuring that the actual lineage itself remains sound [66]. The next section will discuss such conservation efforts, elaborating on a few programs directed toward conserving the legacy of the Akhal-Teke, while still encouraging good results from crossbreeding.

2. Preservation of the Breed

Akhal-Teke is one of the oldest and most unique breeds of horses that is highly threatened by modern conservation. With a low population size across the world, the breed is at the edge of losing genetic variability, which could further lead to an increase in the incidence of hereditary diseases and become less tolerant to environmental variations [6, 26, 31]. Its increasing use in crossbreeding schemes put even more pressure on its purebred traces, so it presents a very delicate balance between conservation and genetic exploitation [48].

Modern preservation efforts are based on the genetic knowledge presented in the previous chapters of this thesis. Tools such as mitochondrial DNA analysis, which identified the G1 haplotype associated with endurance and metabolic efficiency, and SNP studies are now being applied in the management of the breed's genetic health and monitoring [4]. Those genetic markers not only unveil the Akhal-Teke's very special lineage but also guide decisions concerning breeding to avoid inbreeding and to preserve the very characteristics that define this breed [6].

To preserve the breed, the Akhal-Teke, international bodies and governments of nations have come up with strategic programs. The International Association of Akhal-Teke Breeders, MAAK, has very strict studbook standards; the book only registers horses that conform to rigid genetic and physical requirements as purebred [48]. This allows the preservation of the line of the breed while at the same time reducing risks associated with genetic drift. It has now become commonplace for breeders to use molecular tools, such as microsatellite loci analysis, in monitoring genetic variation and any loss of heterozygosity, allowing informed decisions to be made on pairing and selection [1, 6, 31].

In Turkmenistan, the Akhal-Teke is feted as a national emblem and enjoyably subsidized by the state. Programs emphasize the preservation of the purity of the breed through state-run breeding farms and public awareness campaigns [53, 54, 55]. The annual Turkmen Horse Day is a colorful cultural event that underlines the historical importance of this breed in becoming a bedrock of Turkmen heritage [65]. Such efforts underline the cultural value of this breed while fomenting international awareness.

Outside of Turkmenistan, the breed is maintained by breeders and researchers in Russia, Europe, and North America. Collaborations between breeding associations and scientific institutions have led to the establishment of specialized Akhal-Teke breeding farms [3, 17, 48]. These programs actively seek out genetic diversity while maintaining the physical and behavioral characteristics that define the breed [31]. They, at the same time, balance the demands made by crossbreeding programs against the need for maintaining the purity of the population of purebreds intact [48].

Increased use in crossbreeding programs, however, presents a unique challenge to the Akhal-Teke—notably in the creation of the Anglo-Teke and Budyonny. In a sense, while hybrids have expanded its influence and versatility, they bring up concerns about dilution of its distinctive traits [56, 58, 59]. That is a challenge organizations like MAAK take up through encouraging breeding practices that are ethical and ensure that no hybridization takes place at the expense of the identity of the Akhal-Teke [48]. Preservation-oriented breeding programs ensure that the breed remains a genetic resource for crossbreeding while maintaining its status as a purebred entity.

In conclusion, the preservation of the Akhal-Teke must be based on a multi-strategic operation in scientific research and public cultural promotion, including international cooperation. Such efforts hope to ensure that future generations continue the legacy of the Akhal-Teke through modern approaches in genetic identification and promotion of public appreciation for this breed. The Akhal-Teke inspires as a cultural icon and a genetic treasure to underline the importance of horse breed conservation at the time when the world is changing very fast [6,7, 54, 65].

In all, preservation of the Akhal-Teke is a dynamic and ongoing process that amalgamates traditional practices with modern science. By applying genetic monitoring, international cooperation, and cultural advocacy, horse breeders and local, national, and international organizations are working to ensure the survival of this most ancient and exceptional breed. Such efforts would not only protect the legacy of the Akhal-Teke but also emphasize its very important role in enriching global equestrian diversity.

VI. Discussion: The Future of the Akhal-Teke in Global Horse Breeding

The Akhal-Teke horse is a remarkable testament of the wisdom of ancient breeding practices and the enduring relevance of its unique features in modern equestrian activities. This study has brought to light the double role of Akhal-Teke horses as a critical source for the genetic basis of modern breeds and a rare, precious pure-blood lineage. However, its future lies in successfully maneuvering through the thin line that exists between preservation and innovation, where both its genetic potential and historical legacy could be secured.

The Akhal-Teke has been fixed as a genetic resource, through further utilization of its characteristics in crossbreeding programs, giving rise to crucial concerns about sustainability [1, 48]. While programs like those producing the Anglo-Teke and Budyonny have proved the breed's ability to take in performance and increase diversity, such success underlines that this is an overexploitation risk. These hybrids excel in endurance and sports disciplines, but the process of selectively channeling the Akhal-Teke's genetic advantages into hybrids has to be carried out with due care to avoid dilution of the purebred population [48, 65].

The concern then opens wider ethical and strategic questions on equine breeding. The small number of Akhal-Teke is an inherent weakness, not only to genetic drift but also to the loss of defining characteristics through careless crossbreeding or poor breeding practices [1, 6, 31]. Tools and methodologies applied to the study and preservation of the bloodlines of the Akhal-Teke, including advanced genetic analyses, have to be further developed in order to cope with such risks [1, 4]. Preservation, however, cannot lean solely on technological solutions. This should also involve a concerted effort at breeding, researching, and connecting stakeholders across regions in a unified manner to develop strategies that prioritize genetic diversity and health [48, 54].

Of greatest importance, however, is that the Akhal-Teke breeding stock holds even greater meaning for its national symbolism and cultural icon, especially for Turkmenistan—a past inextricably entwined with national identity [55]. This culture connects humanely with a compelling narrative that can drive global advocacy and interest in the breed. The story of the Akhal-Teke is one of resilience, elegance, and history—one that should be leveraged to engage

broader audiences, not only within the equestrian community but in cultural and educational contexts [54, 65]. Aligning conservation with the story of this breed makes them much more noticeable and strengthens support for preservation.

Looking forward, the Akhal-Teke represents a case study in the challenges and opportunities of equine conservation in the 21st century. But the interplay between preservation and innovation goes far beyond this single breed. For example, unique adaptations of the Akhal-Teke to extreme climates might show a way toward breeding horses more attuned to a changing world. All these traits make it somewhat of a potential model for sustainability within equine practices, combining tradition with modern needs [56, 65]. In the end, it is the journey of the Akhal-Teke from ancient steppes to modern breeding programs that reflects the possibilities and perils of equine development. Its future lies in the hands of those who can best navigate through the complexities in preserving them, ensuring that their legacy as a genetic treasure, cultural emblem, and equestrian icon endures [33, 65] (Figure 13). While the challenges are enormous, the rewards of preservation of this exceptional breed are beyond measure, not only to the equestrian world but, more widely, to the appreciation of the function which history, culture, and science play in shaping our relation with nature.

Figure 13 : The Soviet Union Stamp in 1988 with an Akhal Teke

VII. Summary

The Akhal-Teke horse represents a remarkable chapter in equine history, combining unique physiological and genetic traits with an enduring cultural legacy. This thesis has explored the breed's origins in Central Asia, its survival through centuries of selective breeding, and its contributions to the development of modern horse breeds. By tracing its genetic distinctiveness, such as the G1 haplotype and unique mitochondrial DNA patterns, the study has highlighted the Akhal-Teke's unparalleled endurance, agility, and adaptability, which have shaped equestrian practices for generations.

While the Akhal-Teke's past is steeped in history, its future depends on the careful preservation of its unique lineage and the ethical application of its genetic legacy. All efforts to maintain genetic diversity and reduce risks associated with small population sizes are important for the safeguarding of this breed. At the same time, its role in enhancing other breeds through responsible crossbreeding shows its ongoing relevance in the equine world.

With the ever-changing equestrian sports and breeding, the Akhal-Teke's contribution addresses the importance of unique breed conservation not only in practical values but also in a cultural and historical sense. The Akhal-Teke will be able to continue being a long-lasting symbol of excellence and resilience by honoring its heritage and seeking innovative ways to integrate its strengths into modern equine practices. It is not a story of mere survival but one of thriving against the odds, which is, in itself, a fitting metaphor for the remarkable bond between man and horse.

IX. References

1. A V Ustyantseva et al. Genetic characterization of Akhal-Teke horse subpopulations using 17 microsatellite loci. 2019 IOP Conf. Ser.: Earth Environ. Sci. 341 01. 2019 IOP Conf. Ser.: Earth Environ. Sci. 341 012070. DOI 10.1088/1755-1315/341/1/012070
2. Tóth B, Auth A, Rompos L, Bakos Z. Effect of feed deprivation on selected parameters of lipid mobilisation and hepatic function in healthy Akhal Teke horses. Equine Vet J. 2018 Jan;50(1):98-103. doi: 10.1111/evj.12730. Epub 2017 Sep 1. PMID: 28776730.
3. The Akhal-Teke Foundation, public charity for education and preservation of the Akhal Teke – www.akhaltekefoundation.org
4. Kang Z, Shi J, Liu T, Zhang Y, Zhang Q, Liu Z, Wang J, Cheng S. Genome-wide single-nucleotide polymorphism data and mitochondrial hypervariable region 1 nucleotide sequence reveal the origin of the Akhal-Teke horse. Anim Biosci. 2023 Oct;36(10):1499-1507. doi: 10.5713/ab.23.0044. Epub 2023 May 4. PMID: 37170508; PMCID: PMC10475378.
5. Carole Ferret, « À chacun son cheval ! Identités nationales et races équines en ex-URSS (à partir des exemples turkmène, kirghize et iakoute) », Cahiers d'Asie centrale [En ligne], 19-20 | 2011, mis en ligne le 01 janvier 2012, consulté le 01 mai 2019. URL : http://journals.openedition.org/asiecentrale/1508
6. Cozzi MC, Strillacci MG, Valiati P, Rogliano E, Bagnato A, Longeri M. Genetic variability of Akhal-Teke horses bred in Italy. PeerJ. 2018 Sep 6;6:e4889. doi: 10.7717/peerj.4889. PMID: 30202639; PMCID: PMC6129384.
7. Akhal Stud – www.akhalstud.hu
8. Alfonso Casani, The Akhal-Teke horse, the jewel of Turkmenistan 2022,- www.medomed.org
9. Akhal-Teke Association of America – akhal-teke.org
10. Jessica Eile-Keith, The introduction of the Heavenly horse in China - www.karakumstud.com
11. Zhu, S.; Zhang, N.; Zhang, J.; Shao, X.; Guo, Y.; Cai, D. Ancient Mitochondrial Genomes Provide New Clues in the History of the Akhal-Teke Horse in China. Genes 2024, 15, 790.

12. Akhal-Teke Horse Origin & History: In-Depth Guide – www.horsenameideas.com
13. Stud farm of Akhal-Teke – www.akhal.net
14. Patricia Salem, Discover the Exotic Akhal-Teke, 2019 – www.fei.org
15. A. N. Kosharov, E. M. Pern et G. A. Rozhdestvenskaya, « Horses », dans Animal Genetic Resources of the USSR. Animal Production and Health Paper Publ., Rome, FAO, 1989
16. Jean-Louis Gouraud, L'Asie centrale, centre du monde (du cheval), Paris, Belin, octobre 2005
17. European association of Akhal-Teke – akhaltekehorses.com
18. Akhal-Téké – www.classequine.com
19. Akhal-Teke – www.woopets.fr
20. Caroline Cochran, BSc, Akhal Teke Horse Breed Guide: Characteristics, Health & Nutrition, 2023 – madbarn.com
21. Audrey Dulieux, Akhal-Teké : tout savoir sur cette race de chevaux venue d'Asie, 2024 – www.passeportsante.net
22. AKHAL-TEKE – livestockconservancy.org
23. Katherine Blocksdorf , Akhal-Teke Horse: Breed , 2024– www.thesprucepets.com
24. Akhal-Teke Breed , 2012– www.allabouthorses.com
25. Akhal Teke France Association – akhal-teke.fr
26. Anina Bauer, Theresa Hiemesch, Vidhya Jagannathan, Markus Neuditschko, Iris Bachmann, Stefan Rieder, Sofia Mikko, M Cecilia Penedo, Nadja Tarasova, Martina Vitková, Nicolò Sirtori, Paola Roccabianca, Tosso Leeb, Monika M Welle, A Nonsense Variant in the ST14 Gene in Akhal-Teke Horses with Naked Foal Syndrome, G3 Genes|Genomes|Genetics, Volume 7, Issue 4, 1 April 2017, Pages 1315–1321
27. Leisson K, Alev K, Kaasik P, Jaakma Ü, Seene T. Myosin heavy chain pattern in the Akhal-Teke horses. Animal. 2011 Apr;5(5):658-62. doi: 10.1017/S1751731110002375. PMID: 22439988.
28. Molly Nicodemus, Molly Friend, Jeannette Beranger, PSXV-13 Relationship between Velocity and Temporal Variables in the Akhal-Teke Glide, Journal of Animal Science, Volume 100, Issue Supplement_3, October 2022, Pages 293–294, https://doi.org/10.1093/jas/skac247.533

29. Elevage Akhal Teke Stud France – www.akhal-teke.biz
30. Orlando L. Ancient Genomes Reveal Unexpected Horse Domestication and Management Dynamics. Bioessays. 2020 Jan;42(1):e1900164. doi: 10.1002/bies.201900164. Epub 2019 Dec 6. PMID: 31808562.
31. Jiskrová, I.; Vrtková, I.; Prausová, M., Genetic Diversity of Populations of Akhal-Teke Horses from the Czech Republic, Russia, Estonia and Switzerland. Acta Univ. Agric. Silvic. Mendel. Brun. 2016, 64 (2), 461-6.
32. Cosgrove EJ, Sadeghi R, Schlamp F, Holl HM, Moradi-Shahrbabak M, Miraei-Ashtiani SR, Abdalla S, Shykind B, Troedsson M, Stefaniuk-Szmukier M, Prabhu A, Bucca S, Bugno-Poniewierska M, Wallner B, Malek J, Miller DC, Clark AG, Antczak DF, Brooks SA. Genome Diversity and the Origin of the Arabian Horse. Sci Rep. 2020 Jun 16;10(1):9702. doi: 10.1038/s41598-020-66232-1. PMID: 32546689; PMCID: PMC7298027.
33. Remer, V., Bozlak, E., Felkel, S., Radovic, L., Rigler, D., Grilz-Seger, G., ... & Wallner, B. (2022). Y-Chromosomal insights into breeding history and sire line genealogies of Arabian horses. Genes, 13(2), 229.
34. Cieslak M, Pruvost M, Benecke N, Hofreiter M, Morales A, et al. (2010) Origin and History of Mitochondrial DNA Lineages in Domestic Horses. PLoS ONE 5(12): e15311. doi:10.1371/journal.pone.0015311
35. McGivney BA, Han H, Corduff LR, Katz LM, Tozaki T, MacHugh DE, Hill EW. Genomic inbreeding trends, influential sire lines and selection in the global Thoroughbred horse population. Sci Rep. 2020 Jan 16;10(1):466. doi: 10.1038/s41598-019-57389-5. PMID: 31949252; PMCID: PMC6965197.
36. Bower, M., McGivney, B., Campana, M. et al. The genetic origin and history of speed in the Thoroughbred racehorse. Nat Commun 3, 643 (2012).
37. Cunningham EP, Dooley JJ, Splan RK, Bradley DG. Microsatellite diversity, pedigree relatedness and the contributions of founder lineages to thoroughbred horses. Anim Genet. 2001 Dec;32(6):360-4. doi: 10.1046/j.1365-2052.2001.00785.x. PMID: 11736806.

38. Atroshchenko, M.; Dementieva, N.; Shcherbakov, Y.; Nikolaeva, O.; Azovtseva, A.; Ryabova, A.; Nikitkina, E.; Makhmutova, O.; Datsyshin, A.; Zakharov, V.; et al. The Genetic Diversity of Horse Native Breeds in Russia. Genes 2023, 14, 2148. https://doi.org/10.3390/ genes14122148
39. Der Sarkissian C, Ermini L, Schubert M, Yang MA, Librado P, Fumagalli M, Jónsson H, Bar-Gal GK, Albrechtsen A, Vieira FG, Petersen B, Ginolhac A, Seguin-Orlando A, Magnussen K, Fages A, Gamba C, Lorente-Galdos B, Polani S, Steiner C, Neuditschko M, Jagannathan V, Feh C, Greenblatt CL, Ludwig A, Abramson NI, Zimmermann W, Schafberg R, Tikhonov A, Sicheritz-Ponten T, Willerslev E, Marques-Bonet T, Ryder OA, McCue M, Rieder S, Leeb T, Slatkin M, Orlando L. Evolutionary Genomics and Conservation of the Endangered Przewalski's Horse. Curr Biol. 2015 Oct 5;25(19):2577-83. doi: 10.1016/j.cub.2015.08.032. Epub 2015 Sep 24. PMID: 26412128; PMCID: PMC5104162.
40. Кононова Л.В.. "ГЕНЕАЛОГО-ЗООТЕХНИЧЕСКАЯ ХАРАКТЕРИСТИКА ПЛЕМЕННОГО ЯДРА ЛОШАДЕЙ АХАЛТЕКИНСКОЙ ПОРОДЫ СТАВРОПОЛЬСКОГО КРАЯ" Аграрный вестник Урала, no. 9 (212), 2021, pp. 44-52.
41. Olga Petri (2023) Between Purity and Pragmatism: The Politics of Purebred Breeding and Racing of the Orlov Trotter in Imperial Russia, 1880–1915, The International Journal of the History of Sport, 40:12, 1140-1160, DOI: 10.1080/09523367.2023.2291440
42. L V Kalinkova et al, The influence of crossbreeding on genetic structure of the Orlov Trotter breed, 2019 IOP Conf. Ser.: Earth Environ. Sci. 341 012064
43. Kovalevskaya V.B. Ancestors of the Oriental Horse in Eurasia: Origin and Distribution. Archaeology, Ethnology & Anthropology of Eurasia. 2020;48(1):129-139.
44. Cieslak, M., et al. (2010). "The Origins of Horse Domestication." *Science*, 329(5998), 1482-1485. doi:10.1126/science.1189404
45. Ansour, A., & Cothran, E. G. (2013). "Microsatellite Analysis of Genetic Diversity and Population Structure of Arabian Horse Populations." *Journal of Heredity*, 104(3), 386-398. doi:10.1093/jhered/est022
46. Bower, M. A., et al. (2013). "The Genetic Legacy of Ancient Horses." *PLOS ONE*, 8(9), e67775. doi:10.1371/journal.pone.0067775

47. Hendricks, B. L. (2007). *International Encyclopedia of Horse Breeds*. Norman: University of Oklahoma Press.
48. The International Association of Akhal-Teke Horses (MAAK). "Crossbreeding Reports." – maakcenter.org
49. FEI Archives. "Equestrian Competition Records." – data.fei.org
50. Orlando, L., et al. (2013). "Revisiting the Evolutionary History of Domesticated Horses." *Science*, 336(6081), 1503-1507. doi:10.1126/science.1217134
51. Ricard A, Bruns E, Cunningham EP 2000. Genetics of performance traits. The Genetics of the Horse AT Bowling, A Ruvinsky 411–38 Wallingford, UK: CAB Int.
52. K. Leisson, Ü. Jaakma, T. Seene, Adaptation of Equine Locomotor Muscle Fiber Types to Endurance and Intensive High Speed Training, Journal of Equine Veterinary Science, Volume 28, Issue 7, 2008, Pages 395-401, ISSN 0737-0806, https://doi.org/10.1016/j.jevs.2008.05.007.
53. World Arabian Horse Organization (WAHO). "Publications on Akhal-Teke Influences." – www.waho.org
54. Development of scientific, educational, cultural and sports infrastructure and international relations of the Akhal-Teke horse breeding – turkmenistan.gov
55. Embassy of Turkmenistan in the United States. "Turkmen Horse Day and National Celebrations." – usa.tmembassy.gov.tm/en
56. Alexander Klimuk, The pure bred Akhal-Teke horse and it's influence on other pure bred breeds, 1998 – karakumstud.com
57. Bonnie L. Hendricks, International Encyclopedia of Horse Breeds, University of Oklahoma Press, 2007
58. Lewin, L. (2004). The influence of Turkmen horses on the modern world. International Journal of Equestrian Studies, 12(3), 45-58.
59. Rousseau, É. (2017). Horses of the World. Royaume-Uni: Princeton University Press.
60. Beth Mallory, Akhal Teke Horse: Care, Cost & History (2024) – horseonly.com
61. What are the characteristics of the arabian horse – equspaddock.com
62. Akhal Teke vs Arabian horse : Comprehensive comparison guide – horsenameideas.com
63. Akhal Teke vs Thoroughbred Horse : in-depth comparison guide – horsenameideas.com

64. Caroline Cochran, Orlov Trotter Breed Guide - Characteristics, Health & Nutrition, 2023 – Madbarn.com
65. Adèle Vaupré, Race L'akhal-téké, la polyvalence au-delà des apparences, 2023 - www.chevalmag.com
66. Bibby, Miriam. "Preview of Horse Breeds and Human Society." Horse Breeds and Human Society, 2019. doi:10.4324/9780429024009.