THE TARPAN AND ITS RELATIONSHIP WITH WILD AND DOMESTIC HORSES.[1]

SO much progress has been made during recent years in working out the origin and history of domesticated horses that the time has now come when inquiries may be profitably pursued along certain definite lines.

In the first place (assuming that horses have had a multiple origin), inquiries should be instituted with the view of ascertaining so far as possible the characteristics of the post-Glacial species and varieties which have taken part in forming the present domestic races and breeds; in the next place, inquiries should be instituted with the view of ascertaining to which of the lower Pleistocene species the more immediate ancestors of the living horses are most intimately related; and, in the third place, an attempt should be made to determine from which of the ancestral forms the various domesticated breeds have inherited their more striking characters, *i.e.* to ascertain to which ancestral types the Shire, Clydesdale, Percheron, and other heavy breeds, the Barb, Arab, thoroughbred, Kattiawar, and other slender-limbed breeds, are indebted for their chief peculiarities.

In this paper I shall not attempt to show that either Prejvalsky's horse, the Celtic pony, or the Libyan variety recently described by Prof. Ridgeway[2] is genetically related to pre-Glacial species, or entitled to be regarded as an ancestor of one or more domestic breeds.

Sufficient data for a discussion of this kind is not yet available. I propose now, by way of clearing the ground for the investigations mentioned above, to inquire whether the Tarpan (long regarded as the wild progenitor of the common horse of Europe) deserves a place amongst the ancestors of living races and breeds.

The first account of the Tarpan[3] we owe to Gmelin, who came across a troop near Bobrowsk during his journey through Russia between 1733 and 1743. He describes them as mouse-coloured, with a short, crisp mane; the tail always shorter than in domestic horses, sometimes full, sometimes only furnished with short hair; the legs dark from the knees and hocks to the hoofs; and the head thick, with the ears sometimes long, sometimes short.

Since this description appeared, some Continental naturalists have regarded the Tarpan as a true wild species; others, like Dr. Nehring, considered it the last survivor of the ancient prehistoric horses of Europe modified by an infusion of domestic blood; while not a few agreed with Pallas that the Tarpan herds might very well be the offspring of escaped domestic horses.

English naturalists have, as a rule, adopted the view of Pallas.

Notwithstanding all that has been written on the subject since Gmelin's time, hippologists agree with Salensky that the relationship of the Tarpan with wild and domestic horses has not yet been cleared up.

During the nineteenth century very little was done towards determining the systematic position of the Tarpan; but in 1866 a Tarpan foal was captured in the Zagradoffe Steppe and reared by a domestic mare. When about eighteen years old this specimen was sent to the Moscow Zoological Garden, and eventually described in a paper published by Schatiloff.

This, like Gmelin's specimen, had a somewhat coarse head, was of a mouse colour, with legs black below the knees and hocks. The mane, however, instead of being short and crisp, as in Gmelin's specimen, was 48 cm. in length and hanging to one side of the neck.

As clearly realised some years ago by Gray, of the British Museum, certain vestigial structures, known as callosities, warts, or chestnuts, are of considerable taxonomic value. Warts or chestnuts, as is well known, are present on both the fore and hind limbs of the common horse, and they also occur on the hind as well as the fore limbs of Prejvalsky's horse; while in the Celtic pony, as in asses and zebras, the hind chestnuts are completely absent. It is especially worthy of note that though the hind chestnuts were not invariably present in Tarpans (they were absent in a Tarpan described by Krymsch), they were present in the Moscow specimen.

It thus appears that the Moscow Tarpan agreed in its colour with the specimens referred to by Gmelin and Pallas, but differed in the mane and tail, in both of which, as in its callosities, it resembled the common horse, *Equus caballus*. Two Tarpan skeletons have been preserved. The chief point of interest about these skeletons is that, as in the kyang and Prejvalsky's horse, and in certain Arabs, there are only five lumbar vertebræ.

In having only five lumbar vertebræ these Tarpans differed from the common horse of Europe, at least from the forest variety *E. caballus typicus*, in which I have invariably found eighteen pairs of ribs and six lumbar vertebræ.

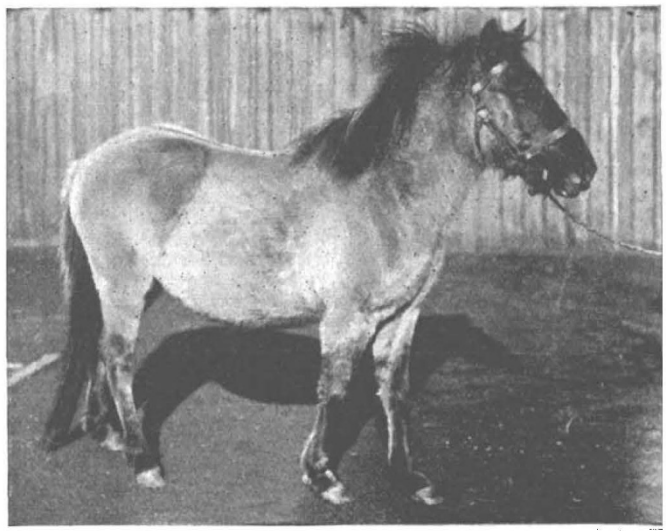

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FIG. 1.—The mouse-dun Tarpan-like cross between a Shetland mare and a black Welsh pony. This pony, though a cross, looks as if it belonged to an old-established race. It has a striking, well-formed, massive head, well-placed ears, full eyes, good quarters, and excellent limbs. The mane is, however, short and semi-erect, while the tail consists of three kinds of hair which differ in structure, thickness, colour, and arrangement. From a photograph taken September, 1905.

From this striking difference in the skeleton it follows that, even should the Tarpan turn out to be a true wild species, it cannot be regarded as the sole ancestor of the common horse of Europe.

As to the skull of the Moscow skeleton, Czerski came to the conclusion that it has, on the one hand, all the characteristics of Oriental horses, while on the other it approaches the Scottish breed to which belongs the pony.

The skull of the Tarpan in the St. Petersburg Museum resembles skulls of immature specimens of *E. prejvalskii*, but the bones of the limbs and limb girdles are decidedly more slender, and have less pronounced muscular ridges than in the wild horse of Central Asia.

It may here be mentioned that for more than a century all the horses living in a wild state in Europe, which happened to be of a mouse-dun colour, seem to have been regarded as Tarpans.

Seeing that herds of mouse-dun wild horses no longer occur in Europe, and have not during recent years been met with in even the most remote parts of Central Asia, it might perhaps be assumed that the Tarpan's place in nature must for ever remain a mystery.

[1] By Prof. J. C. Ewart, F.R.S. Abridged from the Proceedings of the Royal Society of Edinburgh, Session 1905–6, vol. xxvi., part i.

[2] "Origin and Influence of the Thoroughbred Horse" (Cambridge, 1905).

[3] By the Tarpan I mean the mouse-dun horse of Russian and other Continental naturalists, not the so-called "true" Tarpan of Hamilton Smith ("Naturalists' Library," vol. xii., 1841).

[4] The chief papers on the Tarpan are mentioned by Salensky, "Monograph on Prejvalsky's Horse" (St. Petersburg, 1902).

This was the conclusion I arrived at when my attention was first directed to the subject. But having ascertained that, by crossing carefully selected forms, remote types are sometimes restored in all their original purity, I thought it worth while to make some experiments.

I selected for my Tarpan experiments a mouse-dun Shetland pony mare, which seemed to me to be a blend of at least three varieties—in its head it suggests the wild horse; in its mane, tail, and trunk it takes after the forest variety; while in the limbs and hoofs it approaches the Celtic pony. This mare was crossed with a black Welsh pony, which belongs to an ancient British race, and doubtless has in its veins not a little Celtic blood.

The first foal, black like the sire, but Celtic in make, failed to throw any fresh light on the question at issue. Though in the first foal the Celtic blood prevailed, the second foal by the same sire has developed into an animal (Fig. 1), now three years old, which, though bred in Scotland, will, I believe, be regarded by Continental naturalists as typical a Tarpan as ever roamed the Russian steppes.

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FIG. 2.—Tail and hind quarters of the Scottish Tarpan from a photograph taken at the same time as Fig. 1. As in the wild mare the hair of the tail consists of three portions. The basal portion only essentially differs from the corresponding portion in Fig. 3 by being of less extent and lighter in colour; the middle portion is also lighter in colour and more plentiful than in the wild mare, while the hair growing from the end of the dock in the Tarpan very closely agrees in colour and amount with the terminal portion of the tail in Prejvalsky's horse.

This Scottish Tarpan, a mouse-dun with black points, has a distinct dorsal band (10 mm. to 15 mm. in width) and faint bars above the knees and hocks, a somewhat heavy head, but a short body and well-formed limbs. The mane, of a light colour along each side, but dark in the centre, is semi-erect, some of the hair arching to the right, some to the left, and some forwards between the ears to form an imperfect forelock. The mane, which resembles that of zebra-horse hybrids, conforms to the description of the mane given by Pallas, but differs from the short crisp mane of Gmelin's specimen, and still more from that of the Moscow Tarpan, which, it will be remembered, reached a length of 45 cm., and hung to one side of the neck. In the dun Shetland dam, the mane lies close to the right side of the neck, but never exceeds a length of 35 cm. In the Scottish Tarpan the mane, from 15 cm. to 27·5 cm. in length, is either nearly upright, or, as already mentioned, arches outwards well clear of the neck (Fig. 1), whereas in a Fetlar (Shetland-Arab) pony of the same age the mane reaches a length of 45 cm. and clings to the side of the neck. The tail of the new Tarpan (Fig. 2) is even more remarkable than the mane. The dock, which is 27·5 cm. in length, is furnished with three kinds of hair. The basal portion for 6·5 cm. carries fine hair nearly circular in section, which, except in the part continuous with the dorsal band, is almost colourless; the middle portion of the dock—about 13·75 cm. —carries thicker hair, slightly oval in section, with a thick cortex containing in some cases a considerable amount of pigment; from the terminal part of the dock—about 7·5 cm.—spring coarse black hairs, which are now long enough to reach the ground. These long hairs are oval in section, have a very thick cortex, and only a small central axis or medulla.

The fine, short, light-coloured hairs (7·5 cm. to 15 cm. in length) at the base of the tail form a conspicuous somewhat lozenge-shaped bunch (Fig. 2); the thicker hairs growing from the middle section of the dock reach a length of 30 cm. They emerge from under the light-coloured root hairs and expand to form a sort of fringe, from which escape the relatively few long black hairs of the distal part of the dock.

In having a limited number of long hairs growing from the distal end of the dock, this cross-bred pony decidedly differs from the Celtic as well as from the forest types of horses. The interest of the tail in the Scottish Tarpan is not so much that it suggests a mule as that it has a very striking resemblance to the tail of Prejvalsky's horse (Fig. 3). The only difference is that in the true wild horse the upper or light-coloured section of the tail is longer than in the Shetland-Welsh cross, which has, in fact, the kind of tail one would expect in a Prejvalsky hybrid in which the wild blood was dominant.

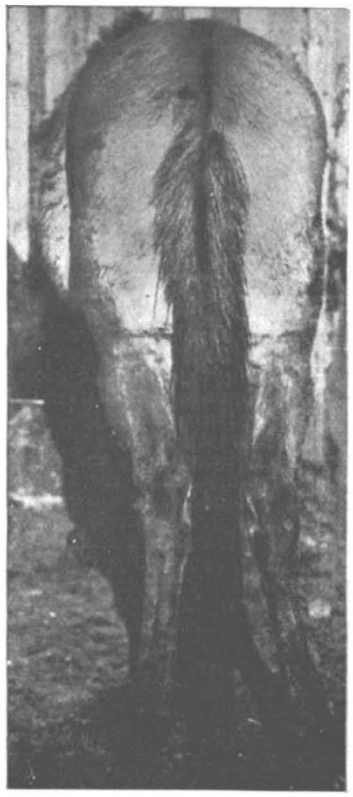

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FIG. 3.—Hind quarters and tail of a three-year-old wild mare (*E. prejvalskii*) from a photograph also taken in September, 1905. In the upper part of the tail the hair, light in colour and relatively fine, grows obliquely outwards from the caudal portion of the dorsal band; the hair of the middle part of the tail, darker and stronger than that of the root, lies nearly parallel with the dock and reaches to the level of the hocks; the hair of the tip, black, coarse and scanty, but long enough to reach the ground, emerges from within the hair forming the middle part of the tail. Like the hair of the mane, the light hair at the root of the tail is shed annually.

A study of the mane and tail of the Shetland-Welsh cross, and of certain other crosses and breeds, strongly suggests that we must include amongst the ancestors of our domestic horses a species having a mane and tail such as we find in the wild horse still living in Central Asia. In the body hair and the foot-locks the Scottish Tarpan closely resembles the wild horse. Further, it resembles the wild horse in having a very short flank feather, but differs in having the face whorl situated above the level of the eyes, as in the Celtic pony; in Prejvalsky's horse, as in the kyang, this whorl lies well below the level of the orbits.

In the Shetland mare the dorsal band is nearly as narrow as in the Celtic pony; the right hind chestnut measures 1·5 cm. by 0·4 cm., while the left is only 0·5 cm. in diameter; the front ergots are absent, and the hind ergots are very small. In all these points the Shetland mare approaches the Celtic type. In the Scottish Tarpan the front ergots are small, the hind normal; the front chestnuts are oval as in the wild horse, but decidedly smaller, while the hind chestnuts are only one-fifth the length of those in the wild horse. Finally, in the head, ears, form of the limbs and hoofs, the Tarpan-like Shetland-Welsh

cross is as nearly as possible intermediate between a wild horse and a Celtic pony. Of the skeleton it is, of course, impossible to speak, but, judging by the shortness of the trunk, the form of the head, and the conformation of the limbs, the probability is that there are only five lumbar vertebræ, as in the Moscow and St. Petersburg skeletons, and that the skull and limb bones resemble those of a young Prejvalsky horse. After very full consideration, Salensky some years ago came to the conclusion that the Tarpan is a type specialised more to the side of *E. caballus* than to *E. prejvalskii*.

When all the facts now available are taken into consideration, there seems no escape from the conclusion that the Tarpan, once common in the east of Europe, cannot be considered as a true wild species.

Further, it may be assumed that the Tarpan herds were derived from at least three primitive stocks, viz.:—(1) from a variety or species identical with or closely related to the wild horse (*E. prejvalskii*) still surviving in Central Asia; (2) from a variety having the characteristics of the Celtic pony—*E. c. celticus*; and (3) from a variety resembling the forest horse—*E. c. typicus*. It is only by assuming the multiplex origin of Tarpans that it is possible to account for some of them having a heavy head, long ears, a nearly upright mane, a mule-like tail, and five lumbar vertebræ, thus suggesting *E. prejvalskii*; for others, wanting the hind chestnuts and possessing a skull like that of certain Scottish ponies, thus suggesting *E. c. celticus*; and for others having a thick head, full mane and tail, and hind as well as front chestnuts, thus suggesting *E. c. typicus*.

By experiments now in hand I hope to settle what part Prejvalsky's horse has taken in forming the Tarpan. If I succeed in showing that crosses between Prejvalsky's horse and either the forest, Celtic, or Libyan variety are practically identical with the cross between the Shetland mare and the Welsh pony stallion, I shall prove that at least certain of the domesticated breeds are indebted to Prejvalsky's horse for some of their characteristics, and at the same time bring additional evidence in support of my view that domesticated races have had a multiple origin, and include plain as well as striped forms amongst their less remote ancestors—have not, in fact, as Darwin thought, descended from a single dun-coloured more or less striped primitive stock.

THE FIGURE AND STABILITY OF A LIQUID SATELLITE.[1]

MORE than half a century ago Edouard Roche wrote his celebrated paper on the form which a liquid satellite will assume when revolving, without relative motion, about a solid planet.[2] As far as I know, his laborious computations have never been repeated, and their verification and extension form a portion of the work contained in the present paper.

Two problems involving almost identical analysis, but very distinct principles, are here treated simultaneously. If we imagine two detached masses of liquid to revolve about one another in a circular orbit without relative motion, the determination of the shapes of each of them is common to both the problems; it is in the conditions of their secular stability, according to the suppositions made, that the division occurs.

The friction of the tides raised in each mass by the attraction of the other is one cause of instability. If now the larger of the two masses were rigid, whilst still possessing the same shape as though liquid, the only tides subject to friction would be those in the smaller body. It amounts to exactly the same whether we consider the larger mass to be rigid or whether we consider it to be liquid, and agree to disregard the instability which might arise from the tidal friction of the tides generated in it by the smaller body. Accordingly I describe secular stability in the case just considered as "partial," whilst complete secular stability will involve the tidal friction in each mass.

The determination of the figure and partial stability of a liquid satellite is the problem of Roche. It is true that he virtually considered the larger body or planet to be a rigid sphere, but in this abstract the distinction introduced by the fact that I treat the planet as ellipsoidal may be passed over. It appears that, as we cause the two masses to approach one another, the partial stability of Roche's satellite first ceases to exist through the deformation of its shape, and certain considerations are adduced which show that the most interesting field of research is comprised in the cases where the satellite ranges from infinite smallness relatively to the planet to equality thereto.

The limiting partial stability of a liquid satellite is determined by considering the angular momentum of the system, exclusive of the rotational momentum of the planet. This corresponds to the exclusion of the tidal friction of the tides raised in the planet. For any such given angular momentum there are two solutions, if there is any. When these two solutions coalesce for minimum angular momentum, we have found a figure of bifurcation; for any other larger angular momentum one of the solutions belongs to an unstable series and the other to a stable series of figures. Thus, by determining the figure of minimum partial angular momentum, we find the figure of limiting partial stability.

The only solution for which Roche gave a numerical result was that in which the satellite is infinitesimal relatively to the planet. He found that the nearest possible infinitesimal satellite (which is also in this case the satellite of limiting partial stability) has a radius vector equal to 2·44 radii of its spherical planet. He showed the satellite to have an ellipsoidal figure, and stated that its axes were proportional to the numbers 1000, 496, 469. In the paper the problem is solved by more accurate methods than those used by Roche, and it is proved that the radius vector is 2·4553, and that the axes of the ellipsoid are proportional to 10,000, 5114, 4827. The closeness with which his numbers agree with these shows that he must have used his graphical constructions with great care.

For satellites of finite mass the satellite is no longer ellipsoidal, and it becomes necessary to consider the deformation by various inequalities, which may be expressed by means of ellipsoidal harmonic functions.

The general effect for Roche's satellites of finite mass in limiting partial stability is that the ellipsoidal form is very nearly correct over most of the periphery of the satellite, but at the extremity facing the planet there is a tendency to push forth a protrusion towards the planet. In the stable series of figures up to limiting stability this protrusion is of no great magnitude, but in the unstable series it would become strongly marked. When the unstable figure becomes much elongated, we find that it finally overlaps the planet, but before this takes place the approximation has become very imperfect.

Turning now to the case of complete secular stability, where the tidal friction in each mass is taken into account, we find that for an infinitely small satellite limiting stability occurs when the two masses are infinitely far apart. It is clear that this must be the case, because a rotating liquid planet will continue to repel its satellite so long as it has any rotational momentum to transfer to orbital momentum through the intervention of tidal friction. Thus an infinitesimal satellite will be repelled to infinity before it reaches the configuration of secular stability. As the mass of the satellite increases, the radius vector of limiting stability decreases with great rapidity, and for two equal masses, each constrainedly spherical, the configuration is reached when the radius vector is 2·19 times the radius of either body.

When we pass to the case where each liquid mass is a figure of equilibrium, the radius vector for limiting stability is still infinite for the infinitely small satellite, and diminishes rapidly for increasing mass of the satellite. When the two masses are equal the radius vector of limiting stability is 2·638 times the radius of a sphere the mass of which is equal to the sum of the masses of the two bodies. This radius vector is considerably greater than that found in the case of the two spheres, for the 2·19 radii of either sphere, when expressed in the same unit, is only 1·74. Thus the deformations of the two masses forbid them to approach with stability so near as when they were constrainedly spherical.

[1] By Sir G. H. Darwin, K.C.B., F.R.S. Read before the Royal Society on February 8.

[2] Mém. Acad. Sci. de Montpellier, vol. i., 1847–50, p. 243.