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CAMELOLOGY : DEFINITIONS, HISTORY AND SCIENTIFIC CHALLENGES

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ABSTRACT

Since centuries, the camel is fascinating scientists over the world. If the first scientific investigations were focused on his remarkable adaptability to desert conditions and to his health management in the context of colonial expansion of European countries in desert areas, recent researches have mobilised several specific disciplines as archaeology, physiology, immunology, breeding and genetics, parasitology, surgery, imaging, diseases, food sciences, economy, or sociology. However, the camel can be regarded as a “full scientific object” legitimising the use of the word “camelology”. Present paper is an overview of chronological development of camel cultures, production and science.

Key words: Adaptation, camel, science history, scientific approach

The concept of “camel science” or “camel research” is commonly used by the scientists working on camel as “object of study”, but as researcher, they decline their speciality as parasitologist, or anatomist, or immunologist or those of other specialities. Moreover, in language other than English, the literal translation is usually not correct. In French for example, the translation of the sentence “I’m camel scientist” will mean “I am a scientist with a camel character”. Unless you use a periphrasis (“I am a scientist studying camel”), your interlocutor will not understand you properly. It is the reason why the concept of “camelology” is better to be used. In French, the word “camelologie” was reported for the first time on the website <https://camelides.cirad.fr> in 2002 as a neologism regarding camel among other words as “camelodrome” or “cameliculture”. Few times later, the word was discussed to be included in the dictionary of the French Academy. It was therefore, the humble reply was “I’m a camelologist” when people asked for our speciality.

The concept of camelology needs to be elaborated. If camelology is a discipline, we have to define the history and the field or scope of this science. The present paper is specially proposed for the international year of camelids (2024) and it aims to investigate the chronological development of camel culture and science from its primitive form to a modern but updated format.

A brief history of the camelology in the world

• *The pioneers*

Georges-Louis Leclerc, Count of Buffon, known usually under the single name of Buffon, a French aristocrat living in the XVIIIth century, was probably one of the first “naturalist” describing the camel in his book “Histoire Générale des animaux” (General history of the animals), written between 1753 and 1767. Dromedary and Camel (in fact Bactrian camel) anatomy, physiology, feeding behaviour, geographical distribution and utilisations were widely described with accuracy (Fig 1). It was the first scientific description of the large camelids since the succinct mentions of Aristote in his “history of animals” written in 343 BC (Gallimard Ed., Paris, 1994). There appears to be no specific mention of camel in the studies or publications of the most famous Arabic scholar during the middle age (except Ibn Al-Awwâm, the master of Moorish Agronomy-Pereira, 2024) although it was mentioned several times in the Holy Koran.

In the XIXth century, Alexandre Vallon, a French veterinarian from the imperial School of Cavalry, published a book on the natural history of camel (Vallon, 1856). But, the first scientific investigations regarding camel could be dated to the colonial period, especially when the French and English troops were invading North Africa and Sahara from Mauritania to Somaliland, especially

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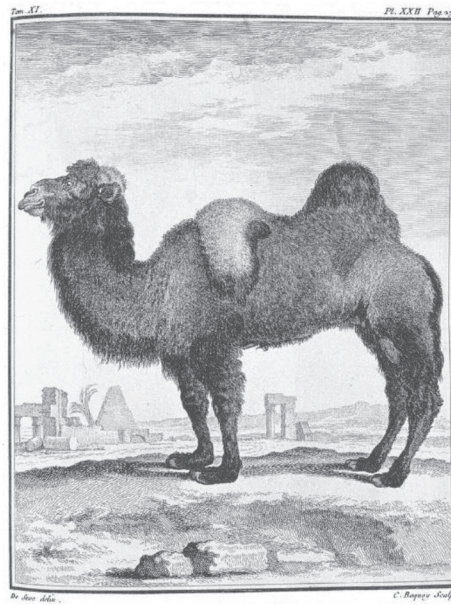
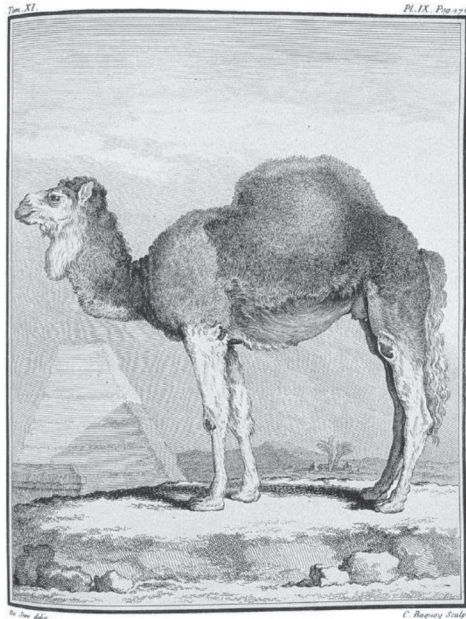


Fig 1. The “dromedary” and the “camel” (Bactrian) represented in the volume VI of the General history of the animals (“*les quadrupèdes*”) written by Buffon in the XVIIIth century.

with the support of “Mehtarist companies” and other “camel corps” where military veterinarians played military and medical role.

Indeed, the first publications were mainly focused on camel diseases. Among the first books regarding camel, one could cite that of Cross (1917), a British vet serving as “camel specialist” to the Punjab Government, in India. Later, another British vet serving in India, then in Somaliland, Arnold Leese, was known for his wide experience regarding camel diseases and management, before known to be as a fascist activist. His book, “A Treatise on the Humped Camel” was published in 1927 (Leese, 1927), but previous papers were published in the Journal of Tropical Veterinary Science from 1909. The Italian military vets contributing to the colonial invasion of Libya and Somalia were not left out: Ivo Droandi who published many papers from 1920 in the Italian Colonial Institute of Agriculture (Florence) on camel surgery and diseases, published a book in 1936, after his experience in Libya. In France, the first military group using camel was created by Napoleon Bonaparte during the Egyptian campaign in 1799, but the “Mehtarist company” was established in 1902 in Sahara and some description regarding camel management were proposed by the vets accompanying the soldiers, as it was the case of the commandant Cauvet (Cauvet, 1925). However, the first comprehensive book regarding camel diseases was written by Gaston Curasson, a French general inspector of Veterinary Services in French colonies

(Curasson, 1947). In the same period, some books focused on generalities regarding the life of camel were published, for example, in France (Finbert, 1938).

• ***The mysteries of the camel physiology***

After the second world war and before the independence of the colonies in the years 60, the first studies on camel were focused on the physiology of adaptation, notably the works of Knut Schmidt-Nielsen (Norwegian) and his wife Bodil (American scientist) who established the bases of the camel physiology, for example on water balance or urea excretion (Schmidt-Nielsen *et al*, 1956 and 1957). At the same time, Hilde Gauthier-Pilters started publications on camel ecology in 1958 and gathered all these observations in a book in 1981 (Gauthier-Pilters and Dagg, 1981). Physiological studies, especially regarding metabolism were continued by Emmanuel from the University of Shiraz, in Iran (Emmanuel, 1979). Renal function and physiology were later studied in details by Dr Reuven Yagil, Israel (Etzion and Yagil, 1986) and Dr N.Kataria from India (Kataria *et al*, 2002 a,b,c,d,e; 2003 and 2007). Physiology of forestomach of camelids was studied in detail by Engelhardt *et al* (1988). Physiology of racing camels was studied by Saltin and Rose (1994). More recently, “Camel Clinical Biochemistry and Haematology” was another important publication in 2018 by Bernard Faye and Mohammed Bengoumi. In Morocco, the University of Casablanca and Agro-veterinary Institute at Rabat, achieved many studies

in collaboration on water and mineral metabolism (Bengoumi *et al*, 1993; Riad *et al*, 1994). Later, the team of Casablanca University was renowned for its work on camel stress (Lemrahmed *et al*, 2019).

• ***The emergence of the camelology in the southern countries: Research institutes, specialised journals and general books***

After most of independences following the colonial time, more and more scientists from southern countries, especially from Egypt, Sudan, India, Morocco started to publish papers on camel anatomy, physiology and diseases. Some institutions began to be recognised for their research activities on camel, i.e. College of Veterinary and Animal Science, Bikaner and the National Camel Research Centre (NRCC), Bikaner, India, University of Alexandria and the Desert Research Centre (DTC) in Egypt and University of Khartoum in Sudan, Agro-veterinary Institute (IAV) in Morocco and later the Institute of Arid Lands (IRA) in Tunisia. Meanwhile, the Central Veterinary Research Laboratory (CVRL) was founded in 1985 by HH Sheikh Mohammed Bin Rashid Al-Maktoum, Vice President and Prime Minister of the UAE and it was a Government diagnostic centre that provided testing and research facilities on camels and other animals including falcons and raptors, to the UAE and neighbouring countries. CVRL is the OIE Reference laboratory for Glanders, Camel Pox, Brucellosis (*Brucella abortus*, *B. melitensis*, *B. canis*) and MERS (Middle East Respiratory Syndrome). As Scientific Director of CVRL, Dr. Wernery leads to his disease diagnosis research in camels among other species. He and the CVRL team pride themselves on being at the forefront of camel research worldwide, especially in veterinary field. In the year 2000, the World Animal Health Organisation (OIE) in Paris, decided to create a camel disease ad-hoc group gathering some camel experts in order to define the list of infectious diseases, their convenient diagnosis tools and the list of reference labs throughout the world. Dr Wernery with the authors of the present paper were among the first experts contributing to this group.

The Camel Applied Research and Development Network (CARDN) was created at Damascus (Syria) in 1991 under the umbrella of the Arab Centre for the studies of Arid Zones and Drylands (ACSAD), publishing a Camel Newsletter, then the first specific journal devoted to camel, the Journal of Camel Sciences (Wardeh, 1986) which unfortunately was stopped after few issues. In India, a book on Camels

and their Management was published in 1986 by Rathore (Rathore, 1986). The book "The Camel" authored by R. Trevor Wilson in UK (Wilson, 1984) was published as an important reference book. In 1984, too, the British Veterinary Journal also published a series of papers on Camel in Health and Disease (Higgins and Kock, 1984). In 1986, another book on camel in health and disease was authored by Higgins (1986). Then, Camel Publishing House at Bikaner (India) started publishing the Journal of Camel Practice and Research since 1994 as biannual but later in 2017, it became a triannual journal (Gahlot, 1994). In the year 2000 onwards, "The Camelid Publishers" brought out 3 important publications edited by T.K. Gahlot from India (Gahlot, 2000, 2004 and Gahlot *et al*, 2002). Compilations of the papers published in the Journal of Camel Practice and Research in the field of parasitology (Gahlot and Chhabra, 2009), gross anatomy and histology (Gahlot *et al*, 2011) and immunology (Gahlot *et al*, 2016) were proposed by Camel Publishing House. In Israel, Yagil and his team from University of Negev published many papers on physiology of adaptation and contributed also by a book on camel physiology (Yagil, 1985) to advance the knowledge of the camel. In Soviet Union also, camel sciences were implemented, especially in genetic and milk production and many books were published in Russian language (Terentyev, 1975). Few books on camel surgery were also published (Gahlot and Chouhan, 1992; Ramadan, 1994; Siddiqui and Telfah, 2010).

Scientists from the French speaking countries in Africa also started to publish the papers on camel science in the Revue d'Élevage et de Médecine Vétérinaire des pays Tropicaux (REMVT) which was integrated to CIRAD in 1996 where the coordination unit on camel breeding (UCEC in French) was created. A first comprehensive book was edited by Richard in 1984 (Hoste *et al*, 1984) and a special issue of REMVT was published in 1989 ("Le dromadaire", n°1, 1989). Then, Faye and other contributors participated to one book as support for new line of veterinary medicine proposed by SANOFI © ("Guide l'élevage du dromadaire", 1997), available also in Arabic. In Germany, in 1992, the book was published on the "One-Humped Camel In East-Africa" (Schwartz and Dioli, 1992) and in Pakistan, another book was edited (Chaudhary and Akbar, 2000). From this period, many books were published in local languages in Mongolia (Indra *et al*, 2003; Adams, 2024), China (Zhao Xin Xu, 1996), Kazakhstan (Moussaiev *et al*,

2007) and Germany (Weiss and Wernery, 2021). Recently, the French general book “Elevage des grands camélidés” (Faye *et al*, 2022) was translated in Turkish, Arabic, Spanish, Kazakh and English (Faye *et al*, 2023).

• *The camel conferences*

During the post-independence period, there were few camel conferences. These were held in the year 1970-90s in Khartoum (Sudan), Tobruk (Libya) and later in Paris (France) on the reproduction (1990) and in Nouakchott (Mauritania) on camel milk (1994) by UCEC (Saint-Martin, 1993; Bonnet, 1998), Israel (1996), Al-Ain (1998), Algeria (1989) and Kazakhstan (2000). However, one of the first important organised camel conference was at Dubai in 1992, concomitant with emergence of advanced research in the Gulf countries on the physiology of racing camel (Saltin and Rose, 1994), biotechnology of reproduction (Tibary and Anouassi, 1997) and camel diseases (Wernery and Kaaden, 1995).

In some cases, more specialised workshops were organised. For example in Morocco (1999) on the young camel and in 2000 on camel diseases (Dakkak, 2000), in Niger (2003) on camel milk in Africa organised by FAO (Lhoste, 2003), in Turkmenistan in 2004 on the role of camel in desertification combat (Faye and Esenov, 2005). Other conferences were organised in UAE (1991), India (2004 and 2007), Saudi Arabia (2007), Kenya (2010) and many others that we cannot cite all these here. The proceedings of those conferences have significantly added to the camelid literature.

In 2006, four camel scientists (B. Faye, M. Bengoumi, K. Alhadrami, A. Tibary) created the International Society of Camelid Research and Development (ISOCARD) with the objective to gather all the camelid scientists (camelologists) of the world in triennial international conferences. Nowadays, 6 conferences were organised, i.e. in 2006 (Al-Ain-UAE), 2009 (Djerba-Tunisia), 2012 (Muscat, Oman), 2015 (Almaty, Kazakhstan), 2018 (Laayoune, Morocco) and 2023 (Al-Ahsa, KSA). The Society also published an on-line journal (Journal of Camelids Sciences) available on line on the website of the society. Some of the proceedings of the ISOCARD conferences are also available on the website (Johnson *et al*, 2012; Konuspayeva, 2015; Sghiri and Kichou, 2018).

Some advanced camel researches

It is not possible to be exhaustive and obviously, some important topics regarding camelology are not

mentioned in detail here. The authors assume that the selected topic below are subjective.

• *Immunology*

Camel immunology has experienced important progress (Hussen and Schuberth, 2021), One of the most remarkable features of the camelid family is their unique immune system. A break-through in the camelid humoral immune system was achieved by Hamers-Casterman *et al* in 1993, who showed that the camel possesses novel class single-domain antigen binding fragments. These proteins are the naturally occurring antigen-binding domains known today as VHHs (single variable heavy-chain) or nanobodies. These nanobodies are very small and possess several bio-physical properties, that offer great advantages in various medical and biotechnological applications (Muyldermans and Lauwereys, 1999), including cancer treatment (Al-Numair *et al*, 2022), producing hyperimmune serum against snake bites and more (Tanwar *et al*, 2017). These extra ordinary camelid nanobody particularities were shown in a recent documentary by Marc Jampolsky film, DW documentary. A.K. Kataria and co-researchers from India carried out important research and studies on dromedary immunoglobulins (Kataria *et al*, 1994, 1999, 2002; Kataria, 2001; Kataria and Sharma, 1999, 2000, 2003; Kataria and Kataria, 2004).

Genetics and genomics

Since the years 2000, important advanced researches were performed on genetics and genomics (Burger *et al*, 2019) allowing new knowledge regarding camel biodiversity (Gaouar and Ciani, 2023), history of domestication (Almathen *et al*, 2014) or selection (Al-Abri and Faye, 2019). Scientists from Riyadh’s King Abdulaziz City for Science and Technology and China’s Shenzhen-based BGI (formerly the Beijing Genomics Institute) were able to decode the entire genetic makeup of the single-humped camel (*Camelus dromedarius*), thus the Arabian camel today enters a highly exclusive club of selected few mammals which have had their full genome sequenced and analysed. Genomic sequencing and analysis of eight camel-derived middle east respiratory syndrome coronavirus (MERS-CoV) isolates was done in Saudi Arabia (Al-Shomrani *et al*, 2020). Chinese scientists found origin and migration of domestic and wild Bactrian camels through genome sequencing (Jirimutu *et al*, 2012; Ming *et al*, 2020). The preservation of the camel biodiversity as an important element of the sustainable development, especially among

pastoralists is also recommended in several research papers (Kohler-Rollefson, 2022 and 2023).

• *Camel milk and meat studies*

Considerable progress was done in the knowledge of camel milk gross composition and fine composition of camel milk since the pioneer work of Farah (1993). A first book on milk and meat composition and processing milk was published in 2004 by Farah and Fisher. The first meta-analysis of camel milk composition was proposed by Konuspayeva *et al* (2009). The fine composition was explored by many scientists emphasising the particularities of camel milk (El-Agamy, 2017). Based on the research of Kappeler *et al*, on the camel chymosin structure in 2006, significant progress were done on the camel cheese making (Konuspayeva *et al*, 2017) and knowledge of milk microflora (Kaindi and Njage, 2020). With the emergence of the camel milk industry, especially in the Gulf countries and Central Asia, notably the establishment of Emirates Industry For Camel Milk & Products (EICMP) in the year 2006, camel milk products appeared on the market (including at international level thanks to the EU agreement) under more diversified form (Konuspayeva and Faye, 2021). The implementation of big camel dairy farms as Camelicious (EICMP) gathering thousands camel under similar environment has boosted original research on camel milk production, milk microbiology and milking management (for example, Nagy *et al*, 2013a and 2015). Intensification of the camel milk production (Nagy *et al*, 2022) by using machine milking has also boosted research on the physiology of lactation (Ayadi *et al*, 2016) and adaptation of camel to machine milking (Atigui *et al*, 2014; Nagy and Juhasz, 2016; Kaskous, 2023). The health effect linked to the regular consumption of camel milk was explored by many camel scientists with variable scientific rigour as mentioned in the recent review of Faye and Konuspayeva (2024). The impact on human diseases as autism (Adams, 2019; Gahlot and Adams, 2023), diabetes (Ashraf *et al*, 2021; Alkhurd *et al*, 2022), Crohn's disease (Rosenheck *et al*, 2012) or even some cancers (Badawy *et al*, 2021; Lal *et al*, 2023) are among the numerous recent *in vitro* and *in vivo* investigations. In addition, the interest of health effect of camel products was extended to the camel urine. Its potential anticancer, antiplatelet, gastroprotective and hepatoprotective effects were explored by different scientists in the world (Salamt *et al*, 2021). A synthetic book on the health and environmental benefits of camel products in general was published in 2020 (Alhaj *et al*, 2020).

Camel meat studies have shown recent interest due to its dietetic properties (Raiymbek *et al*, 2015 and 2018). Meat studies included research on the meat composition (Kadim *et al*, 2008), meat processing (Baba *et al*, 2021), slaughtering conditions (Moussahil *et al*, 2022) and even the health benefit of its consumption (Kadim *et al*, 2022). A synthetic book was published in 2013 (Kadim *et al*, 2013) gathering all aspects of camel meat industry, from the production to the consumption.

• *Biotechnology of reproduction and cloning*

Since the first conference on camel reproduction, held in Paris and cited above, many advanced researches were achieved especially in the Gulf countries (Skidmore *et al*, 2024), India (Purohit *et al*, 2023) or Egypt (El-Bahrawy *et al*, 2015). Artificial insemination and overall embryo-transfer are nowadays used routinely in intensive big farms (Nagy *et al*, 2013b). World's first cloned camel named "Injaz" was produced in year 2009 (Wani *et al*, 2010). A first report on interspecies embryo transfer which gave birth to Bactrian camel calves from dromedary camels, was published by the scientists of Iran (Niasari-Naslaji *et al*, 2009). Dozens of cloned dromedary camels have been produced from the embryos reconstructed with cells from racing champions, winners of beauty contestants, high milk yielders and elite bulls (Wani, 2021). The first cloned Bactrian camel calf was produced by interspecies SCNT using dromedary camel as a source for oocytes as well as a surrogate for carrying the pregnancy to term (Wani *et al*, 2017). Multiple cloned camels from racing, show and dairy exemplars were produced in a recent research (Olsson *et al*, 2021).

• *Camel health and welfare*

Health is one of the most important constraints in camel farming, both in traditional production and intensive system. Thus, it is not surprising to see that veterinary science was the most cited topic in the scientific literature devoted to camel as mentioned in the different scientometric studies assessing the number of publications, the different topics and the main journals, authors or institutions contributing to the camel sciences (Faye *et al*, 2000; Rathinasabapathy and Rajendran, 2013; Gupta *et al*, 2015; Kandeel *et al*, 2023). Several books or review papers are nowadays available for giving comprehensive information on infectious diseases (Wernery and Kaaden, 1995; Wernery *et al*, 2014), zoonotic diseases (Khalafalla, 2023) and even global health disorders affecting camels notably in traditional farming systems

(Kohler-Rollefson *et al*, 2001). The emergence of MERS-CoV in Middle East and the role of dromedary camel in the disease transmission has stimulated an important volume of research on virology and epidemiology (Ngere *et al*, 2020; Azhar *et al*, 2023). Few studies based on ecopathological approach of multifactorial diseases as calf diarrhoea were achieved (Bengoumi *et al*, 2003).

Camel welfare is an important emerging topic, formerly focused on the assessment of the stress in different conditions (dehydration, heat stroke, transport, slaughtering...) and nowadays, more and more is focussed on good management practices and globally good farming conditions for the camel (Menchetii *et al*, 2021). Recently, a book was gathering the knowledge regarding this topic including health management, environmental conditions, handling and assessment of behaviour (Padalino and Faye, 2024).

Camel celebrations

World Camel Day is celebrated on 22nd June in many countries to raise awareness about camels and their importance to human societies and ecosystems and to celebrate these unique creatures. United Nations has declared the year 2024 as International Year of Camelids. Several organisations are celebrating it in form of meetings, workshop or conferences as LPPS (Lokhit Pashu Palak Sansthan) in India; CAMENET (Middle East Camel Network); NACROA (North America Camel Ranch Owner Association), IAEA (International Atomic Energy Agency) in Austria, many universities throughout the world (Algeria, Morocco, Tunisia, Saudi Arabia, UAE, Kuwait...) and of course, FAO.

The camelology, a science?

In a world where disciplinary approaches are no longer enough to understand complexity, considering a livestock species such as the camel, in all its dimensions (from the cell functioning to the farming system or desert ecosystem, passing by metabolic functions and behaviour, diseases and cognition) can be considered a scientific challenge by itself. In this context, the camel is not only an animal, but an object of study that responds to 3 levels of investigation: (i) the camel as biological model, notably for medicine and adaptative studies, (ii) the camel as productive animal in desert areas or in intensive farms for providing milk, meat and other services for humanity and (iii) the camel as an element of complex desert ecosystem in relationships with changing environment, economic challenges

and human or pastoral society (Faye and Brey, 2005; Kohler-Rollefson, 2023 and Rollefson, 2004). Considering camel from such angle, the camelology faces to different challenges that can be summarised into few non-comprehensive topics as:

- To deepen the mechanisms explaining the health effect of camel milk and meat consumption
- To achieve convenient clinical trials to support the health claim of the consumption of camel products
- To implement efficient systems of selection and of feeding for improving the camel productivity (production, reproduction) in the frame of the specialisation of the farming systems
- To increase the studies for allowing sustainable development of more intensive camel systems by respecting animal welfare and health
- To investigate the multifactorial diseases by using more holistic approach and identifying the individual and environmental risk factors
- To understand and characterise the role of camel extensive systems in the desertification combat
- To evaluate the place of camel in the micro-meso- and macro-economy worldwide

And many other topics...

Conclusion

The camel, irremediably linked to arid ecosystems, has a specific physiology and metabolism allowing its adaptation, but this desert animal is also fundamentally an element of the economy in those ecosystems and of the local culture. Moreover, it allows adding zootechnical value for people, pastoralists or settlers, living in such harsh environment. Another very important fact should be highlighted that the ship of the desert is an environmentally friendly species unlike bovines, sheep and especially goats. Reducing camel numbers on open-range land could redress desertification by allowing vegetation to recover from overgrazing. Prototype camel farming should encourage owners, to move most of their camels from open range into intensive farming. Initiating camel farms, where camels are fed on native deserts or salt-tolerant plants may help further the restoration of the ecosystem (Breulmann *et al*, 2007; Kohler-Rollefson, 2023). Like

“eremology”, the science of desert (Heuse, 1992), the camelology can consider the camel as a “full scientific object”. The camel scientists should go beyond their specific disciplines for a better understanding of the camel in his all dimensions.

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