The enigma of camel-types: localities, utilities, names, and breed statuses

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Abstract

The dromedary camel is unique among livestock for being adapted to hot deserts. This livestock was domesticated for its beneficial uses to desert dwellers. Unlike other domesticated animals, camels lack breed standards, registries, or governing breeders' organizations. Nonetheless, over 200 camel populations worldwide are assigned local names, which are occasionally defined by general characteristics. These camel populations are generically considered separate breeds despite the lack of a thorough examination of their 'true' breed status. In this review, we document named camel populations that we refer to as "camel-types" and discuss the likelihood that they represent true breeds. We focus our discussion on seven categories of camel-types, which are based on each of: (1) ecotype, (2) phenotype, (3) rearing tribes, (4) region of existence, (5) country of origin, (6) general use, and (7) individual camels (i.e., a population named after a well-known camel). Based on this review, we favor careful examination of camel-types prior to the selection of specific populations for breeding/production programs or for genetic studies.

Keywords: camel classification, dromedary, *Camelus dromedarius*, camel populations

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Background

The dromedary camel (*Camelus dromedarius*) is unique among livestock in being both highly adapted to deserts and having multiple uses to humans. Dromedary camel domestication, which occurred around ~2,000 – 3,000 BC is a recent event (Beech et al. 2009; Almathen et al. 2016), especially when compared to the domestication of Bactrian camels ~3,000 – 5,000 BC (Han et al. 2002), horses ~3,500 BC (Outram et al. 2009), cattle ~10,000 BC (MacHugh et al. 1997), sheep ~10,500 BC (Francis 2015), and goats ~10,000 BC (Zeder and Hesse 2000). Camel domestication differs from that of other livestock in its goals of utilizing the natural adaptation to the desert environment more so than a focus solely on milk and meat production as in cattle. The camel was an especially suitable target for domestication in hot deserts as it was already extremely well-adapted to those regions (i.e., can easily survive and thrive there), such as by having heat tolerance capacity (Schmidt-Nielsen et al. 1957) and efficient water management (Schmidt-Nielsen et al. 1956). This allows these animals to transport people and their goods across the deserts with relative ease (Magee 2015). Perhaps more importantly, dromedary milk and meat are ideal sources of nutrients for humans in those nutritionally scarce regions (Faye 2014). Camel milk is highly nutritious to humans, due to being high in water, calcium, vitamin C, and β-casein (natural antioxidants), and being low in fat and lacking β-lactoglobulin (a cause of bovine milk allergies) (Konuspayeva, Faye, and Loiseau 2009; Singh et al. 2017; Al Haj and Al Kanhal

2010; Salami et al. 2011; Dziuba and Dziuba 2014). Camel meat is similarly nutritious, with 78% water, 19-22% protein, and 3% fat content (Kadim, Mahgoub, and Purchas 2008). What makes this even more important is the fact that other milk- and meat-producing livestock, such as cattle, are often more adversely affected by hot desert conditions than camels (Kadim et al. 2006; Kadim, Mahgoub, and Purchas 2008). As such, and with only limited human intervention, camels' original adaptations to the scarcity of hot deserts made them extremely useful for humans to survive in that region, by providing milk, meat, hide, and transportation, all in a single animal. Artificial selection by breeders, such as to increase camel productivity, is therefore simply a co-option and an exaggeration of this animal's preadaptation to deserts.

Dromedary camel distribution

The dromedary camel is mostly reared in the hot and dry regions of Asia and Africa (**Figure 1**). Determining the exact numbers of dromedary camels worldwide is quite challenging, due to (1) the nomadic and pastoralist lifestyle of camel owners, (2) the lack of health-associated programs such as compulsory vaccinations, and (3) the absence of dromedary registry databases (Kadim 2012). Nonetheless, according to a recent report by the Food and Agriculture Organization (FAO) of the United Nations (UN), there are around 35 million dromedary camels worldwide, excluding the feral population of Australia (FAO 2018). This camel population is estimated to have an annual growth rate of ~2.1% (Faye and Bonnet 2012). Nearly 83% of this worldwide dromedary camel population is found in Africa and ~34% is specifically in Eastern Africa (**Figure 1a**). The largest camel populations in Africa are found in Chad, followed by Somalia, and then Sudan (**Figure 1b**). The Asian dromedary camel population is around 13% of the worldwide population, and it is mostly concentrated in Southwestern Asia, particularly in Pakistan and Saudi Arabia (**Figure 1**). Approximately 0.02% of all dromedary camels are found in Europe, while the feral camel population of Australia is estimated to be several hundred thousand (Al Jassim and Lisle, 2016).

Camel breeds?

The dromedary camels of the world are not in a single contiguous population, but they are rather represented by over 200 recognized (named) populations (Porter et al. 2016). These named camel populations are generically referred to as camel breeds in the literature. However, the term 'breed' is rather subjective. It often describes a group of individuals (i.e., animals) which share naturally or artificially selected characteristics, and also form a group that is distinct from other similar groups of the same species (FAO 2013). Most definitions of the term "breed" provide only general guidelines to what constitutes a breed, but also highlight the subjectivity of the process of assigning a breed, and its distinctive characteristics, which may not be biologically meaningful, and thus could be used differently based on the geographic region and the species (Lloyd-Jones 1915; FAO 2013).

Probably the most useful definition of a breed is that of a group of domestic animals whose name is agreed upon by the breeders themselves (Lloyd-Jones 1915). Thus, each group of animals within a domesticated species is given its breed definition, name, and standards, by breeders who use artificial selection to form a genetically and phenotypically distinctive population. Therefore, breeders may apply strict standards to their named animal groups (i.e., breeds) or apply loose standards. Cattle, for example, have breeds that are recognized by phenotypic features (color, body type, head size, and presence of horns) or their functions (The Cattle Site 2019), while horse breeds require documented pedigrees as in one of the oldest pedigree records: "The General Stud Book" (Weatherby and Weatherby 2016).

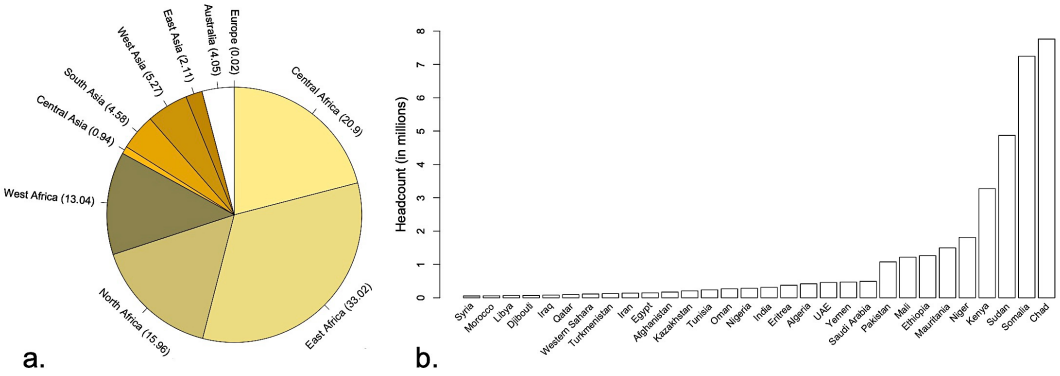

Figure 1. Worldwide headcount of dromedary camels. a. Percentage of camel headcounts across geographic regions. The numbers beside region names represent the headcount percentages of all countries located in the same geographic region. b. Camel headcounts (in millions) across countries. Countries that have fewer than 40,000 camels are not shown in the chart. Data were obtained from FAO (2018).

Dromedary camels lack the breed standard criteria and definitions that are prevalent for other livestock (Dioli 2016). Several systems have been developed to classify and categorize dromedary populations. One such system divides camels according to their ecological location into "ecotypes" (Leese 1927). Dromedary camel populations are grouped into "Hill" (or mountain) and "Plains" types, where the latter is further divided into desert and riverine groups (Leese 1927; Wilson 1997). Another system divides camel populations based on their use into riding and pack camel types (Leonard 1894). Following a similar system of classification, camels have been differently divided into three groups: milk, multi-purpose, and racing (Köhler-Rollefson 1993), or sometimes four groups: dairy, meat, dual purpose, and racing (Wardeh 2004). Also, there were attempts to classify camel populations into breeds based on similarities in phenotypic features or functions, but so far this process has not been applied systematically (Wardeh 2004).

The drawbacks of the aforementioned classification systems include: (1) their limited applicability across all named camel groups, (2) the lack of a clear distinction between named breeds, and most importantly (3) that these camel breed classifications do not take into account the cultural aspects associated with the presence of named camel groups (e.g., local names with specific meanings or breeders' agreements). Therefore, throughout this review, instead of referring to a group of camels with shared characteristics as a breed, we simply refer to them as a 'camel-type', with the understanding that such types should only be referred to as breeds after their breed status is confirmed through studying their genetic population structure. Our discussion of such camel-types is based on a thorough review of the recent literature, including Abdallah and Faye (2012), Abdussamad et al. (2015), Al-Hazmi et al., (1994), Almathen et al. (2018), Belkhir et al. , (2013), Chniter et al. (2013), El-Seoudy et al. (2008), Gautam et al. (2004), Porter et al. (2016), Kadim and Mahgoub

(2004), and Wilson (1997) (for details see **Supplementary Table S1**).

Geographic distribution of camel-types

Most dromedary camels are spread between Africa and Asia; these regions also contain the most numbers of camel-types (**Figure 2**). Our search of the literature returned 94 camel-types in Africa, distributed over 18 African countries, with an average number of camel-types per country of five, and a range of 1–14 camel-types per country (**Figure 2a**). The largest concentration of named camel-types that we could find all over Africa was in Sudan (14 types), while the lowest number was in the Canary Islands, Djibouti, and Tunisia, which were represented by a single camel-type each (**Figure 2b**). On the other hand, we were able to find 138 camel-types distributed over 16 countries in Central to Western Asia, with an average of nine camel-types per country, and a range of 1–27 types per country (**Figure 2a**).

We found a total of 21 camel-types in the Arabian Peninsula (all countries combined) (**Figure 2**). The number of camel-types in each country does not seem to be proportional to the total camel head counts. For example, Chad has the highest number of dromedary camel head counts and a low number of reported camel-types. In contrast, Pakistan and Saudi Arabia have a moderate dromedary camel head count but the highest number of camel-types. The high number of camel-types in Pakistan and Saudi Arabia may reflect an interest in developing the camel breeds (**Figure 3**). Also, the large number of camel-types relative to the total head counts may reflect a fragmentation of a single population into multiple interrelated named lineages, which is suspected in the case of Oman and UAE where many named camel-types are likely to be lineages of racing camels all of which belong to the "Omani" camel-type (**Figure 3**).

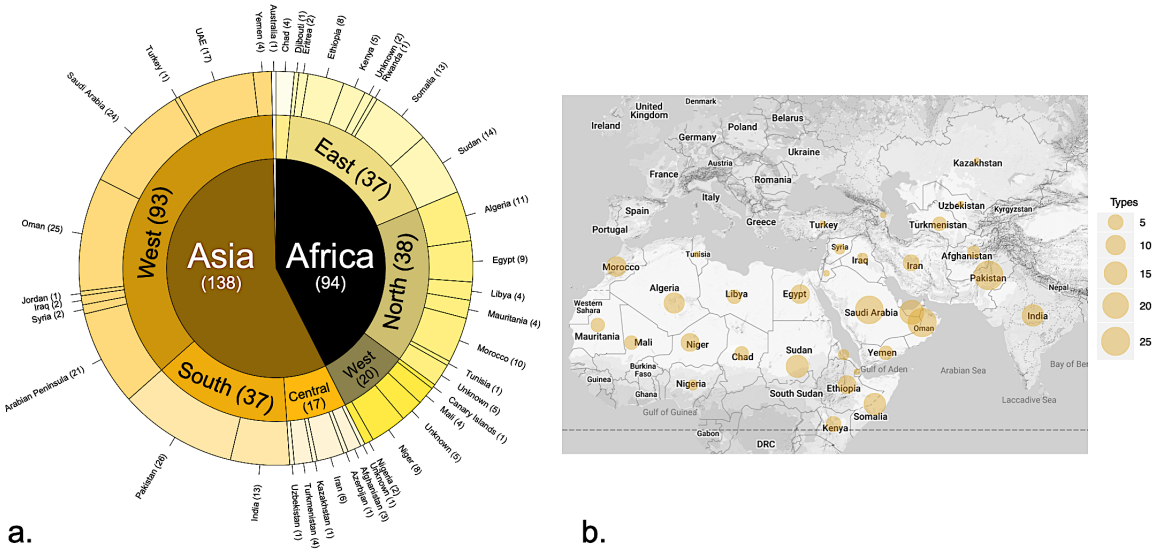

Figure 2. Number of dromedary camel-types worldwide. a. Camel-type numbers in Africa, Asia, and Australia (inner circle). The middle circle represents the number of camel-types within each continent grouped by general location (North, South, East, West). The outer circle displays the number of camel-types within individual countries. The total number of camel-types represented by the pie chart is 233. b. Geographic distribution and numbers of camel-types. The size of the circles is proportional to the number of reported types within each country.

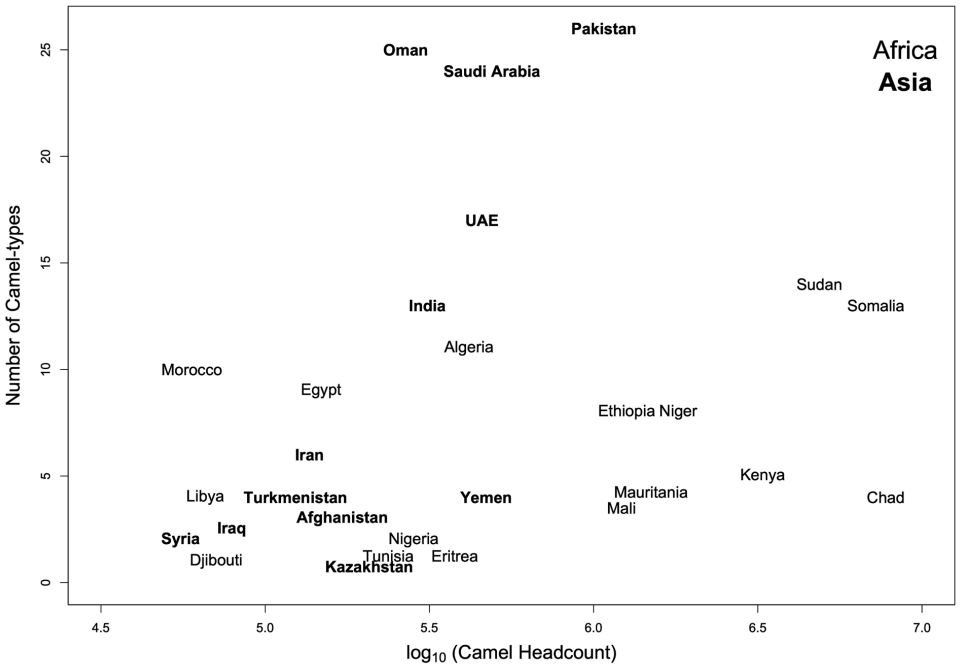

Figure 3. Number of camel-types within individual countries in relation to headcounts. Headcounts were log-transformed for ease of presentation. Asian countries are displayed in bold, to differentiate them from African countries.

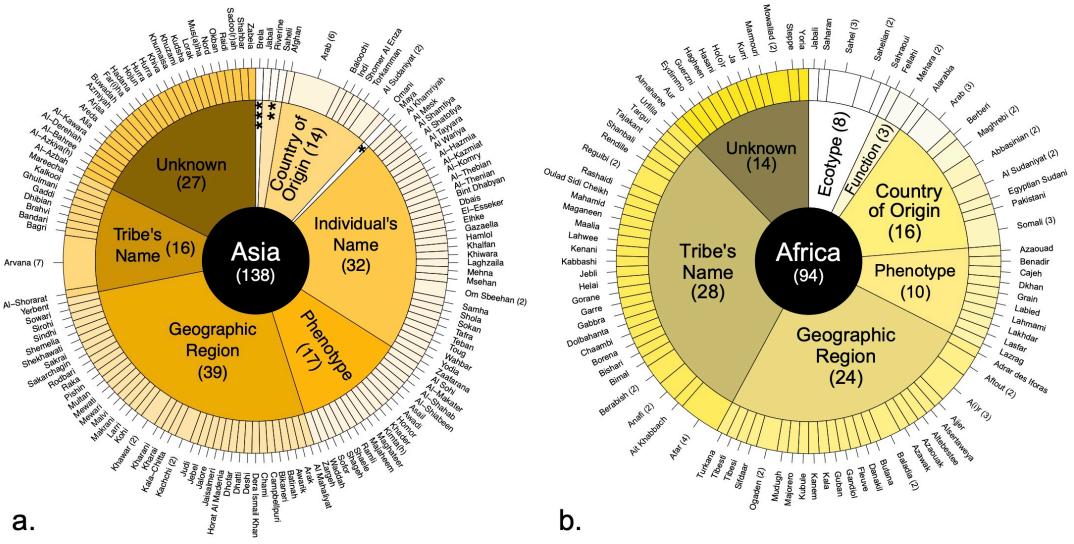

Figure 4. Meaning of the camel-types' names in Asia and Africa. Inner circles represent the total number of camel-types in (a.) Asia and in (b.) Africa. The middle circle displays the origin of the name of each camel-type and their respective numbers in each continent. a. Camel-types in Asia are mostly named after an individual camel's name, phenotype, geographic region, and tribe's name. (* function [n=1], ** ecotype [n=3], *** behavior [n=1]). b. Camel-types in Africa are mostly named after a geographic region or after the name of owners' tribes.

Named camel-types

The over 200 documented camel-types that we found often exhibit overlapping characteristics, shared uses, and synonymous names, as previously noted by Porter et al. (2016). Examining the names of individual camel-types can aid in (1) re-evaluating the current 'breed' classifications, (2) understanding breeding history and the relationships among camel-types, (3) identifying breed status and defining breed standards, and (4) reclassifying camel-types into 'breeds' as needed. Camel-types are generally named based on and in relation to (1) ecotype (Leese 1927), (2) phenotype (Almathen et al. 2016; Saad et al. 2017; Alhaddad and Alhajeri 2019), (3) rearing tribes (Ishag et al. 2010; Mburu et al. 2003), (4) region of existence (Mehta, Mishra, and Sahani 2006; Shah et al. 2009), (5) country of origin (Ahmad et al. 2010; Mahrous et al. 2011), (6) general use (Ahmad et al. 2010), or (7) the name of an individual (e.g., a lineage parent camel, competition winning camel, or a famous breeder's name) camel. We discuss each of these seven camel-type naming criteria below.

Camel-types based on ecology (ecotype)

Relatively few camel-type names are based on ecotype (**Supplementary Table S1**). For example, the Jebli camel-type of Morocco means a mountain camel, and the Pakistani Dhatti and Algerian Sahraoui camel-types both mean desert camel (Belkhir, Chehma, and Faye 2013). This naming system is not continent-specific but is more prevalent among the camel-types of Africa (**Figure 4**). Ecotypic names do not indicate any selection criteria or specific population standards, except for the locality of existence. Therefore, such named camel-types are unlikely to be a genetically distinct true breed with recognized characteristics by breeders. It is also worth highlighting that a distinction based on ecotypes might be more meaningful when applied to natural populations than to livestock, which are subject to human movements and trade.

Camel-types based on phenotypic features

Phenotypic features are commonly used to name breeds across domesticated animals. The phenotypic trait that is most used to name camel-types is coat color (**Supplementary Table S1**). In Asia, 17 camel-types are named in reference to their coat color, including the Ramli type (meaning sandy) of Oman (**Figure 4a**). This naming approach is particularly prevalent in the Arabian Peninsula camel-types that are locally known as 'Mezayen' camels and famous for breeding excellence competitions (Alaibil Festival 2017). The six 'Mezayen' camel-types are all named based on the coat color (e.g., Majaheem-black, Homor-red, and Waddah-white) (Alhaddad and Alhajeri 2019). In Africa, only 10 camel-types are named in reference to their coat color, including the Moroccan Dkhan type (meaning smoky white) and the Azaouad type (meaning black) of Mali (**Figure 4b**). Naming camel-types based on coat color implies selective breeding and maintenance of the phenotype (i.e., breed standards), which may suggest true camel breeds. To the best of our knowledge, no camel-types are named after milk or meat phenotypes (**Supplementary Table S1**).

Camel-types based on tribal affiliation

Tribesmen rely greatly on camels as a transportation vehicle and a nutritional source (i.e., milk and meat). Camel-types that are mostly owned by certain tribes are often named after that tribe (**Supplementary Table S1**). This type of camel-type naming system is mostly found in Africa. Asia has only 16 camel-types named after tribes, such as the Bandari type (Iran), the Brahvi type (Pakistan), and the Dhibian type (Oman) (**Figure 4a**). On the other hand, we found 28 different camel-types named

after tribes in Africa, including the Gorane type (Chad), the Afar type (Djibouti), the Kenani type (Sudan), and the Borena type (Ethiopia) (**Figure 4b**). Tribesmen constantly travel, which increases the chances of gene flow between their camels and camels in areas they visit. These camel-types are also often bred for multiple purposes, with no unique phenotypic traits under intentional selection (Porter et al. 2016). Hence, camel-types named according to this system most likely contain mixed camel-type individuals, rather than genetically homogenous populations, and thus are unlikely to represent true breeds.

Camel-types based on regional association

Camel-types can also be named after the regions that they occupy or originate from (i.e., within a particular country) (**Supplementary Table S1**). Asia has the highest number of such camel-types (39 types), most of which come from India (e.g., Bikaneri, Jaisalmeri, Jalore, and Kachchi types) and Pakistan (e.g., Kohi, Rodbari, Pishen, Campbelpuri, and Larri types) (**Figure 4a**). Only 24 camel-types in Africa are named based on their region of occupation, such as the Aïr (Mali), Altebestee (Libya), and the Turkana (Kenya) types (**Figure 4b**). Referring to camels based on the region that they occupy or originate from is as general as the tribe-based naming system and implies no selective breeding for specific traits or phenotypes and are similarly unlikely to represent true breeds.

Camel-types based on the country of origin

Uncommonly, camel-types can be named after the country of origin (e.g., the Sudani and the Somali types) or even the ethnicity of the breeders (e.g., the Arab and the Barberi types) (**Figure 4, Supplementary Table S1**). This classification system is probably used by people outside the focal country, as breeders often have detailed classifications for camels within their own country. For example, the Somali camel-type, which exists in Egypt and Kenya, is a camel-type named after Somalia, but within this country there are at least 11 camel-types, none of which is called "Somali" (**Supplementary Table S1**). Also, the Sudani, the Sudanese, and the Al-Sudaniyat types are general names that describe any camel from Sudan, but camel breeders in Sudan often classify their own camel-types into the Anafi, Bishari, Butana, Kabbashi, Kenani, Lahwee, Maalia, Maganeen, Rashidi, and the Shanbali types. It is thus unreasonable for breeders from Somalia or Sudan to call a camel-type within their own country Somali or Sudani as this name is very broad and could apply to all their camels. Rather, they often assign their camel populations a native name, which is associated with a phenotype, a region, or a tribe. It is thus likely that country-based camel-types are named by non-Somali and non-Sudanese breeders to refer to any camels imported from Somalia and Sudan (and they may only share superficial traits). Similarly, some camel-types are named after the ethnicity of their owners, as is the case for the Arab camel-type which exists in Rwanda, Iran, Pakistan, Sudan, India, Syria, UAE, and Yemen (**Supplementary Table 1**). Most of these countries use the term "Arab" to loosely refer to camels that originated from the Arabian Peninsula. Therefore, it is likely that camel-types named after countries or the ethnicities of their owners are not true breeds, but rather a diverse assemblage of camel-types assigned the same label by local breeders to simplify the process of referring to them.

Camel-types based on general use

Camel-types are infrequently named after general use (**Supplementary Table S1**). For example, the Pakistani Maya breed, which means "speedy" in the Pushto language, is generally used for riding purposes. Similarly, the Algerian/Mauritanian Mehara breed, which

is a variation of the word cavalry in French, is also used for riding. Another example, is the Egyptian Fellahi breed, which refers to its use by farmers (El-Seoudy et al. 2008). The rarity of this naming system, and the fact that it is specific to a certain function, could be an indicator of true breed status.

Camel-types based on the names of individual camels

Camel-types are sometimes named after individual camels—in this system, all the progeny that descend from a specific (often a famed contest winner) camel are named after that camel (**Figure 4a, Supplementary Table S1**). These named types are almost exclusive to Asia, and particularly the Arabian Peninsula (**Figure 4a**). There are several reasons to question the breed status of such camel-types; (1) these camel-types are often found in countries where the camel populations are relatively small (e.g., UAE) (**Figure 3**), (2) the names are often not gender neutral (e.g., the Zafarana camel-type is feminine, the Hamlol camel-type is masculine, both of which are Arabic names), (3) the used names belong to famous race competition winners. Most of these camel-types are from the UAE, where racing competitions are popular and the winning camels and their descendants are valuable (AlEtihad 2017). Therefore, camel owners would want to breed with the winners and often refer to all the descendant camels as a single breed, to identify a breeding line. These camel-types may be considered true breeds due to selection. Given the population size and the naming criteria, in its current state, these camel-types may represent lineages within a likely single true breed.

Beasts of many uses

The majority of camels are used for: (1) producing commodities (Awoke and Sisay 2015; Ahmad et al. 2010), (2) racing (Khalaf 1999), (3) riding (Wilson 1997), (4) pack animals (Khanna, Rai, and Tandon 2004), and presumably for multiple purposes simultaneously. The documented record of the uses of different camel-types is not clear and definitive (Porter et al. 2016). This is apparent in the fact that (1) only a few camel-types are specialized for a single use (e.g., milk and meat production, or racing), (2) many camel-types are reported as multipurpose animals, and (3) there are a large number of camel-types with no specified use (**Figure 5**). Examples of milk and meat production camel-types are the Kohi type of Pakistan (both milk and meat production), in addition to the Alsertaweya type of Libya (exclusively milk production) (Bakory 2012), and the Jebli type of Morocco (exclusively meat production). Pack camels like the Mewari type of India are in essence multipurpose camels, and are used for long distance transportation, carrying heavy loads, and assisting in working the fields (Khanna, Rai, and Tandon 2004).

We thus question the single use designation of camel-types, like that of cattle (e.g., Angus and Holstein), especially since (1) the nomadic lifestyle of camel breeders, historically, does not permit careful selection of a single quality, (2) the harsh desert environment where camels exist does not favor prolonged selection experiments, and (3) desert cultures are dependent on camels specifically for survival. Therefore, most camel types are likely multipurpose animals, which can be used simultaneously as pack animals, as commodity producers, and as riding and racing animals (e.g., the Arvana type of Afghanistan).

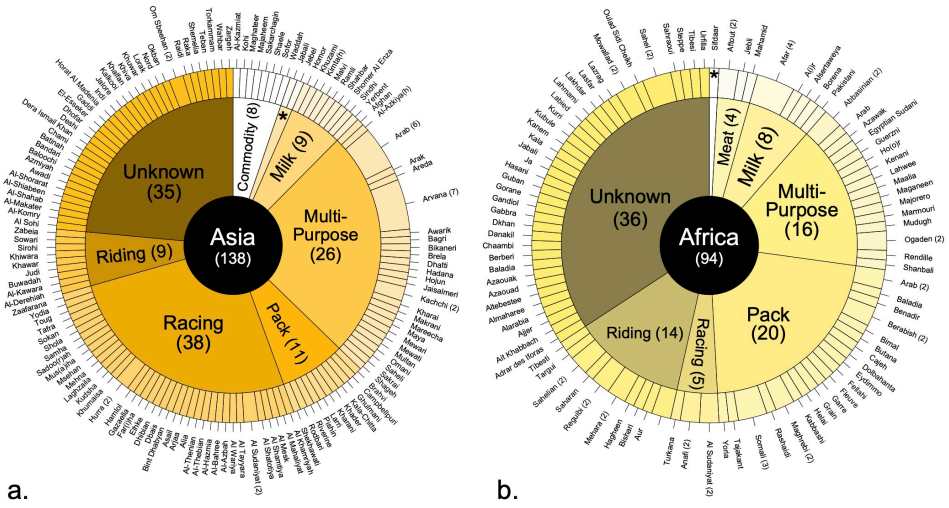

Figure 5. Uses of camel-types in Asia and Africa. Inner circles represent the total number of camel-types in (a.) Asia and in (b.) Africa. The middle circles display the general uses of the camel-types and their corresponding numbers in each continent. a. Camel-types in Asia are mostly used as multipurpose livestock and for racing competitions (* meat production, n=2). b. Camel-types in Africa are greatly used as multipurpose livestock and for riding (* commodity camels, n=1). The outermost circle represents the names of the camel-types in each continent.

Significance

Understanding the naming systems of camel-types is an important first step in the identification of true camel breeds, which in turn can transit certain traits or characteristics to their offspring. Genetic studies can be more fruitful if applied to true breeds rather than outbred populations of mixed individuals. The probability of finding an association of a trait of interest or a genetic disease with a causative gene is higher within a single (true) breed, because of the shared ancestry among the individuals (Festing 2014). Additionally, identifying true breeds may assist in defining breed-associated characteristics, or selected phenotypes, which ultimately facilitate the design of breeding programs for camel production purposes. This broad overview of camel-types allows the selection of the most relevant camel populations to study, and a better utilization of the recent developments of (1) camel genetic resources (Wu et al. 2014; Fitak et al. 2016; Jirimutu et al. 2012; Ruvinskiy, Larkin, and Farré 2019; Lado et al. 2020; Ming et al. 2020), (2) camel sample and phenotype collection methods (Alhaddad et al. 2019; Alhaddad and Alhajeri 2018), (3) camel biobanks and phenotype archives (Alhaddad and Alhajeri 2019), and (4) camel morphometrics protocols (Iglesias et al. 2020; Alhajeri, Alaqeely, and Alhaddad 2019).

Supporting information

Supplementary Table 1. A comprehensive list of the camel-types documented in this review and their associated information.

Acknowledgments

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Conflict of Interest

The authors declare that they have no conflict of interest.

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