Appendix 1

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Introduction

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1 Introduction

"Gene flow" (movements and exchange of animal breeds and germplasm) in livestock species has been taking place since prehistoric times, and has been driven by a range of factors. On a global scale, the most significant gene flows have involved the "big five" livestock species: cattle, sheep, goats, pigs and chickens. Focusing mainly on these five species, this section draws information from FAO's DAD-IS Global Databank and selected literature to provide a description of the provenance and distribution the world's major breeds.

The terms "North" and "South" are used here to refer to developed countries and developing countries respectively. Note that Australia, although it is geographically in the south is here considered as part of the "North". The information available is often sketchy and incomplete. Statistics rarely specify both the source and the destination countries of breeding animals, and often differentiate data by species rather than breed. Other limitations include:

- there are no systematic records of breed population sizes – a breed's presence in many countries does not necessarily mean it has a large global population;
- breeds from temperate zones are often better defined and documented than breeds from tropical regions and marginal areas;
- gene flows within large countries do not show up in the international statistics, unlike flows between small countries – a breed's presence in many small countries may exaggerate its actual worldwide importance; and
- in contrast to plant genetic resources, no quantitative share of gene introgression can be given for livestock breeds due to the high levels of within-breed genetic variation.

These limitations mean that it is not possible to provide a comprehensive quantitative analysis of global exchanges between the North and the South. Despite these limitations, the data do allow the assessment of trends in, and the approximate magnitude of, the movements and exchanges of live animals, semen, and embryos.

2 Driving forces and historical phases in gene flows

Gene flows have been determined and influenced by a wide range of factors – cultural, military, organizational, institutional, political, market, technological, research, disease and regulatory. The relative importance of these factors has changed during the course of history. Broadly speaking, three distinct periods can be distinguished in the pattern of global gene flow.

Prehistory to the eighteenth century: This phase spanned about 10 000 years, from the early days of domestication to the late eighteenth century. During this time, genes spread as a result of the dispersal of domestic animals by means of gradual diffusion, migration, warfare, exploration, colonization and trade.

Nineteenth to mid-twentieth centuries: During the period from the beginning of the nineteenth century until about the mid-twentieth century, breeding organizations were established in the North. These organizations formalized the existence of numerous breeds, recorded their pedigrees and performance, and facilitated rapid improvements in productivity. The flow of genes was mainly among countries in the North (North–North flows), and from North to South. The driving forces behind this movement were technological developments, the demand for higher-producing animals, and the beginning of the commercialization of animal breeding in the North.

Mid-twentieth century to the present: During this phase, gene flows have been propelled by the existence of commercial breeding companies in the North, production differentials between North and

South, and rapid globalization. Technological advances have made it possible to ship semen and embryos instead of live animals. More recently, it has become possible to transfer entire production systems – to create controlled environments in other parts of the world. Furthermore, it is becoming feasible to identify and isolate genes. Focus is shifting to individual genes, rather than traits or entire genotypes. There are emerging international legal frameworks which regulate exchange mechanisms for genetic material, and intellectual property rights (IPRs) are beginning to be exerted.

These trends are ongoing, and have affected different parts of the world to different degrees. For example, in much of the world, breeding stock is still traded without any involvement of breeding organizations, much less of specialized breeding firms. Nevertheless, modern breeding approaches are increasingly being used in the South, and are promoting the spread of specialized breeds and production systems.

2.1 Phase 1: prehistory to the eighteenth century

In the early phases of stock breeding, domesticated animals were dispersed by gradual diffusion from their centres of domestication (see Section A). One major centre of domestication was in western Asia and the eastern Mediterranean. During what is now known as the “Neolithic revolution”, the four major mammalian livestock species – sheep, goats, cattle and pigs – were first domesticated in this region. Other centres of domestication were Southeast Asia (pigs, swamp buffaloes and possibly chickens), the Indus Valley (chickens and riverine buffaloes), North Africa (cattle and donkeys), and the Andes of South America (llamas, alpacas, and guinea pigs). From these centres, domesticated animals spread gradually from neighbour to neighbour, and also as their keepers migrated to new areas. Livestock husbandry spread fairly rapidly throughout the Old World, with the exception of sub-Saharan Africa, where movement was much slower, probably because of endemic diseases (Clutton-Brock, 1999).

Domestication and dispersal contributed to increased variability within each species. As animals adapted to new environments and were subjected to different selection pressures, populations with new characteristics developed. Even in early historic times, selection was not only natural, but also influenced by cultural preferences. These processes led to the development of many local breeds (Valle Zárate *et al.*, 2006). Warfare and trade were important motors for the spread of animals such as horses and camels that are used for transport and riding. A supply of good horses was a vital element of military power, and this species dominated trade in genetic resources for centuries.

Colonization of new areas was another important vehicle for gene flow. The Romans invested in livestock breeding, and there is archaeological evidence that their improved, larger-sized breeds were disseminated to the countries that they occupied. However, with the decline of the Roman Empire, these improved animals faded away. Colonization also played an important role in later times: when Europeans colonized new continents they always brought their livestock with them (Box 7). It has been observed that Europeans managed to establish a permanent hold and cultural dominance only in temperate climates where European livestock also thrived (North America, southern South America, Australia, New Zealand and South Africa). These regions now dominate the export of livestock and animal products, although most had no cattle, sheep, pigs, or goats 500 years ago (Crosby, 1986).

Box 7
Gene flows resulting from colonization

The main domesticated species reached the New World and Australia only with the arrival of European explorers and colonizers. Columbus brought eight pigs from the Canary Islands to the West Indies in 1493, where they multiplied rapidly. Pigs then followed in the footsteps of Pizarro to the Inca Empire. Explorers and others released pigs on remote islands to ensure a food supply for the next generation of transient Europeans. Populations had often become established before the islands were named and documented.

Columbus also carried cattle, whose descendants were living as breeding herds in the West Indies (1512), Mexico (1520s), Incan region (1530s) and Florida (1565). In humid areas they took many generations to adapt, but in more favourable environments they doubled their populations every 15 years or so. The majority of cattle in the Americas were probably feral from the sixteenth to the nineteenth centuries. The cattle of Iberian descent had long horns and were more agile than the British and French breeds later introduced to North America.

Source: Crosby (1986)

2.2 Phase 2: nineteenth to mid-twentieth centuries

Until the end of the eighteenth century, European farmers did not generally put much emphasis on stock breeding. The introduction of the Arab horse into Britain stimulated livestock breeders to copy the Arab breeding practices of careful selection and maintaining pure lines. After the pioneering work of Robert Bakewell (1725–95), British breeders began to apply the same principles to their cattle and sheep, leading to the establishment of breeding societies and herd books in the early nineteenth century. From the 1850s onwards, gene flow in the form of registered pedigree animals became more commercial (Valle Zárate *et al.*, 2006). Breed societies initially focused on setting standards for external characteristics; performance testing began only in the early twentieth century.

Important prerequisites of selection for high performance were the intensification of agriculture, and the improvement of feeds. The exchange of genetic resources was facilitated by the invention of steamships. By the end of the nineteenth century, European countries had also developed specialized legislation to support and regulate animal breeding. Much of the gene flow was between European countries and their respective colonies, but there was also exchange within Europe, and from South to South. Because European cattle breeds did not do well in the humid tropics, Indian Ongole and Gir cattle were brought to Brazil, and Sahiwal cattle from India and Pakistan were introduced to Kenya.

2.3 Phase 3: mid-twentieth century to the present

Since about the middle of the twentieth century, a series of technological advances have facilitated gene flow. Commercial use of semen started in the 1960s, of embryos in the 1980s, and of sexed embryos in the mid-1990s (Valle Zárate *et al.*, 2006). Lack of artificial insemination (AI) coverage has meant slower gene flow in developing countries and in remote areas.

Towards the end of the twentieth century, gene flows to the South began to be fuelled by a growing number of consumers with a taste for, and who could afford, meat, milk, cheese and eggs – even in countries with no tradition of milk consumption. The resulting expansion of intensive livestock production systems in developing countries has been termed the “livestock revolution”. Monogastric animals (pigs and poultry) are increasing in numerical importance because they efficiently convert feed to protein. Small ruminants, especially sheep, are losing ground as grazing resources decline and the demand for wool decreases (Hoffmann, 1999).

Various factors now shape the flow of livestock genes across national borders. These include the following:

Demand for optimal performance. Gene flows are driven by the desire of producers and breeders to obtain genotypes that perform optimally in a given production environment (Peters and Meyn, 2005). Both push and pull factors are involved. Exports generate profits, which help pay for breeding activities and can be reinvested in breeding programmes. At the receiving end, motives for importing genetics can vary. Countries such as China and Brazil are in the process of building up their own intensive production systems and breeding programmes. Eastern European countries need to raise the performance of their dairy sectors, while Mediterranean, Near and Middle Eastern and African countries traditionally import because of the high costs associated with developing their own breeding programmes.

Organization of breeding. The market for livestock genetics is highly competitive. Demand is based on proven performance – a supplier can sell a bull's semen only if the bull has been shown to have sired superior calves. This means that efficient organization of breeding enterprises is decisive. It takes a long time to develop high-performing strains or hybrids, so a small number of companies and countries have established a lead and other actors find it difficult to catch up. Breeding and global gene flow in poultry and pigs has become dominated by a few large companies that have been in business since the 1960s. Concentration is also increasing in the cattle breeding sector. In sheep, multi-tiered hybrid production is less common at present. An example is Australia's Awassi Joint Venture, established to supply live sheep to the Middle East for slaughter (Mathias and Mundy 2005). In many parts of the South, this pattern of large-scale structured commercial breeding programmes has not yet taken hold.

Changes in consumer preferences. Changing consumer preferences and newly emerging market demands influence gene flow. For instance, demand for naturally grown beef has led to the importation of British and French beef breeds to Germany. There are predictions that pressure from the animal welfare lobby will promote the keeping of pigs in more extensive conditions, including in outdoor systems. This would require the development of new strains that are able to thrive under these conditions (Willis, 1998). Slackening demand for wool is promoting the spread of hair sheep.

Animal health and hygiene standards. High standards of hygiene and disease-free status enable a country to participate more easily in the market for genetic material. Australia, for example, is considered disease-free and faces no restrictions on exporting its genetic material. At the same time, it imposes strict quarantine standards to maintain this status and accepts semen and embryo transfers rather than live animals. Developing countries are at a disadvantage because they often cannot fulfil required standards. For instance, the Philippines imports milk-buffalo germplasm from Bulgaria rather than from India – a closer and cheaper source – because the latter can not meet international sanitary standards.

Government policies. Governments often subsidize exports of their national genetics to assist their farmers, or they support the import of exotic genetics to build up national production systems. The latter has often been financed by bilateral and international aid. Alternatively, governments sometimes restrict export of their genetics in an attempt to monopolize them; examples include South American countries that have banned the export of camelids. History, however, shows that attempts to limit the spread of genetic resources are difficult to maintain. The Merino sheep spread throughout the world after the fall of the Spanish monopoly, Turkey was unable to prevent the global distribution of its Angora goat, and South Africa could not prevent the transfer of its ostrich genetic resources to other countries . History is now repeating itself in the commercial sector, as firms find it impossible to avoid the "leakage" of genes from primary customers to the whole industry, despite contractual arrangements prohibiting pure-breeding with the outsourced animals (Schäfer and Valle Zárate, 2006; Alandia Robles *et al.*, 2006; Musavaya *et al.*, 2006).

Ecological services. Use of livestock in landscape protection and biodiversity conservation – notably in Europe – has led to new demands for climate-tolerant, low-input breeds that can be kept outside even in harsh winters.

Search for specific characteristics. Scientific interest in specific genetic traits, related to disease resistance, fertility, and product quality, also contributes to gene flow, though on a relatively small scale. Fayoumi chickens from Egypt, for example, were brought to the United States of America during the 1940s because of their resistance to viral diseases, and in 1996 the University of Göttingen imported frozen embryos of Dorper sheep to study their suitability for meat production in Germany (Mathias and Mundy, 2005). Similarly, Boer goats were brought to Gissen University (also in Germany).

3 The "big five"

During the past two centuries, global livestock numbers and the exchange of breeds and animal genetic material have greatly increased. North–North exchanges have prevailed; North–South and South–South exchanges have been more limited, and South–North flows have been the least frequent. Movements and exchanges have been particularly intensive in the dairy cattle, pig and chicken sectors (Mathias and Mundy, 2005; Valle Zárate *et al.*, 2006).

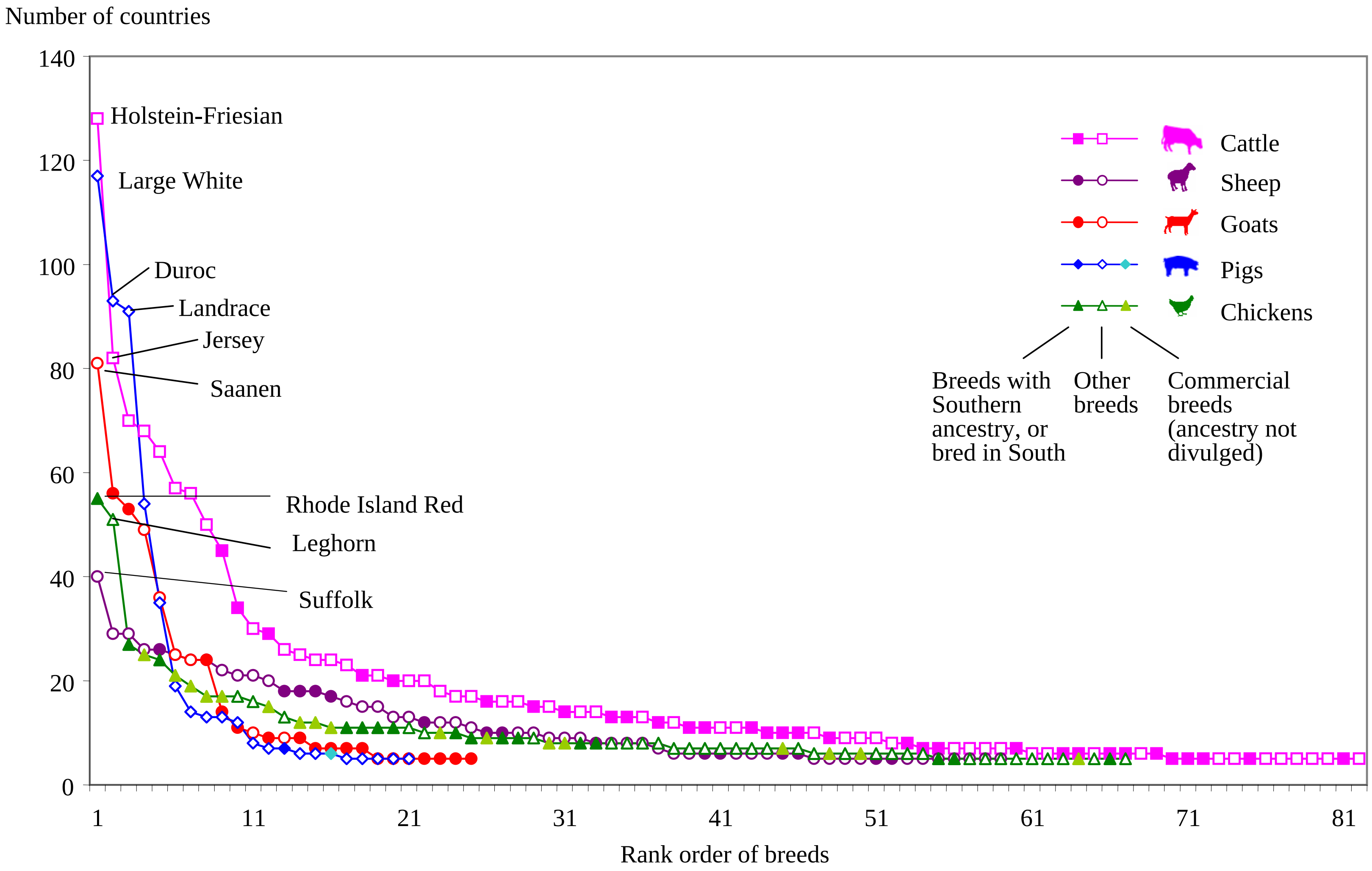
Very often, breeds have been developed or further improved outside their areas of origin, and then exported to third countries. Examples are the familiar Holstein-Friesian black and white dairy cow, the American Brahman and the Brazilian Nelore.

Nowadays, about 1 080 livestock breeds of all species are recorded as "transboundary" – meaning that they occur in more than one country (DAD-IS, 2006). Some 70 percent of these belong to five species – 205 breeds of cattle, 234 of sheep, 87 of goats, 59 of pigs, and 156 of chickens. Exchanges of these five species are discussed in detail below. A description of their current global distribution can be found in Section B.

Other livestock species (water buffalo, yak, horses, asses, camels, llamas, alpacas, reindeers, ducks, geese and turkeys) do not have such large populations, but are nevertheless important as they are crucial to the survival of millions of poor livestock keepers in developing countries and for the utilization of marginal areas.

Figure 19 shows the number of countries in which individual livestock breeds of the five major species are found. Note that the figure shows the numbers of countries where a breed is found, and not the size of the population. It is likely that in some countries an international breed is documented but has a small population.The graph shows all breeds reported from five or more countries. Each point in the graph corresponds to a single breed; the top few breeds of each species are named. For example, the most widespread dairy cattle breed, the Holstein-Friesian, is found in 128 countries worldwide.

Figure 19
Distribution of transboundary breeds



Source: DAD-IS (2006)

3.1 Cattle

Cattle genetics are exchanged in the form of live breeding animals (heifers, pregnant cows and bulls), semen and embryos. Large numbers of live animals are traded each year, but the majority are intended for fattening and slaughter rather than for breeding. The high cost of transport means that three zonal markets exist for live breeding animals: Europe, North America and the Southwest Pacific. From 1993 to 2003, the 15 countries that were then members of the European Union (EU-15) exported more than 150 000 breeding heifers a year. Roughly half of these stayed within the EU-15; almost all the rest went to North Africa, West Asia and Eastern Europe. At the same time, the EU-15 imported about 15 000 breeding heifers a year from outside, almost all from Eastern Europe and Switzerland, with small numbers coming from Canada and elsewhere. Imports from the United States of America were restricted because of disease considerations (Mergenthaler *et al.*, 2006).

The trade in semen is much larger than the trade in live animals – semen is easier to transport and is not subject to such stringent health and quarantine restrictions. According to Thibier and Wagner (2002), close to 20 million doses of semen were traded internationally in 1998. That was about 8 percent of the total number of deep-frozen doses produced worldwide. North America and Europe were the major exporters, and South America was the major importer. North America produced 70 percent of global semen exports, and the EU another 26 percent; the remainder came from other European countries, Australia, New Zealand and South Africa. The EU supplied about 3 million doses in 2003, mainly to other countries in Europe, Latin America, North Africa and North America. Asia (outside the Commonwealth of Independent States and Turkey) and sub-Saharan Africa received only 5 percent of the total (Eurostat, cited in Mergenthaler *et al.*, 2006). In 2003, EU countries imported about 6.8 million semen doses, most from other countries within the EU, and much of the remainder from the United States of America and Canada.

In 1991, three-quarters of global semen exports were of one breed – Holstein-Friesian. Other dairy breeds accounted for another 13 percent, beef breeds for about 10 percent, and tropical breeds, mainly Brahman, Red Sindhi and Sahiwal, for about 2 percent (Chupin and Thibier, 1995 cited in Mergenthaler *et al.*, 2006).

Trade in embryos has not reached the magnitude of trade in semen. Nevertheless, small numbers of embryos have sometimes sufficed to build up a large population. Examples are France’s upgrading of its Black-and-White cattle to Holstein-Friesian which was achieved mainly through the import of fewer than 1 000 embryos from the United States of America (Meyn 2005 – personal communication cited in Mergenthaler *et al.*, 2006).

Breeds with European ancestry

Breeds of European descent account for eight of the top ten breeds, and 49 of the top 82 breeds (those distributed to five or more countries – see Figure 19). By far the most widespread breed is the Holstein-Friesian, which is reported in at least 128 countries, and in all regions (Figure 20). Next come Jersey (also a dairy breed, 82 countries), Simmental (dual-purpose, 70 countries), Brown Swiss (dual-purpose, 68 countries), and Charolais (beef, 64 countries – see Figure 21).

Figure 20
Distribution of Holstein-Friesian cattle

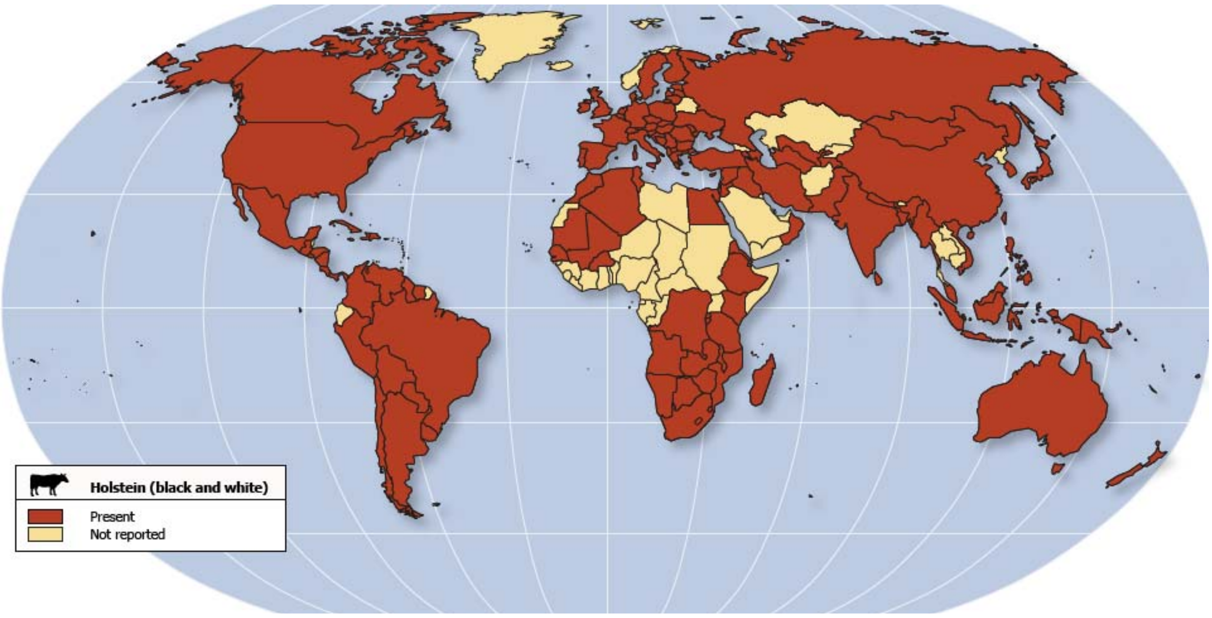
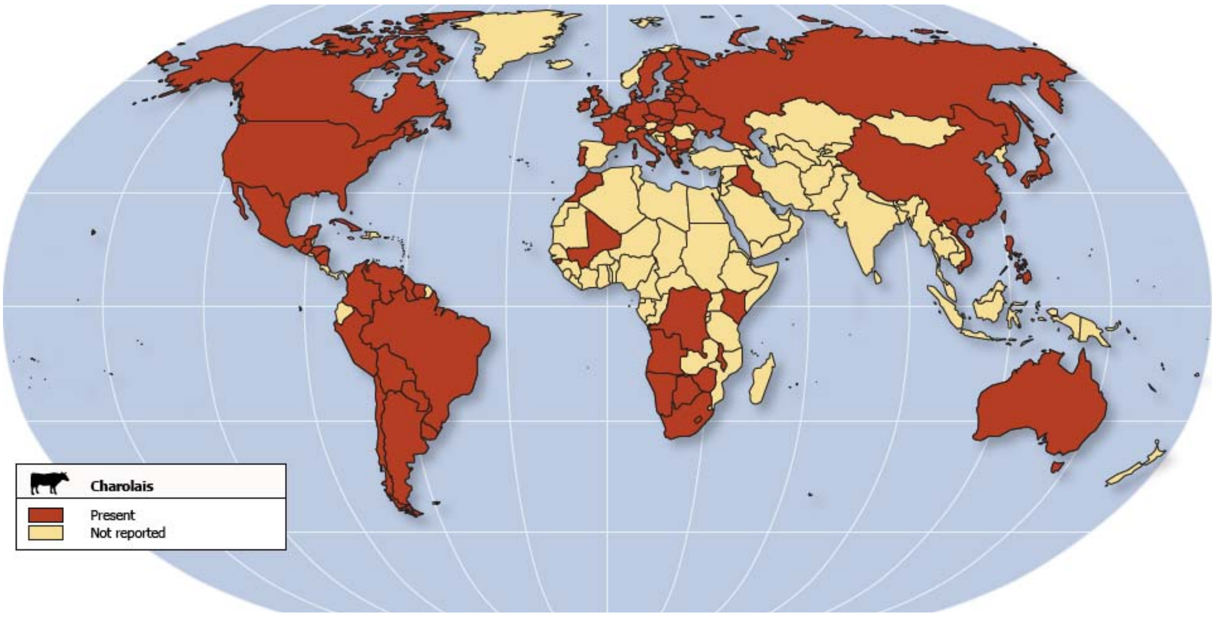


Figure 21
Distribution of Charolais cattle



Almost all the most successful European cattle breeds stem from northwestern Europe: principally the United Kingdom (11 breeds in the top 47), France (six breeds), Switzerland and the Netherlands. Relatively few come from the southern and eastern parts of the continent.

Many of these breeds are based on traditional breeds that emerged in the Middle Ages or earlier, often under the sponsorship of individual noblemen, wealthy individuals or monasteries. They were formalized in the nineteenth century with the formation of herd books and breeding societies. This occurred first in the United Kingdom, and then on the European continent, in the Americas and in the rest of the English speaking world (Valle Zárate *et al.*, 2006).

Several important breeds were developed on small islands (Jersey, Guernsey) or in remote mountainous areas (Simmental, Brown Swiss, Aberdeen Angus, Piedmont, Galloway, Highland) –

areas which offered both isolation from other breeds and (in the case of mountains) the environmental stress needed to select for the hardiness prized in these breeds.

The spread accelerated in the 1800s. By 1950, most European breeds had been exported to other countries in the North. Exchange has continued right up to the present time: for example, the French Maine-Anjou breed was first imported into North America in 1969; and Blonde d'Aquitaine, Salers and Tarentaise arrived in 1972. A breeders' association in the United States of America for the Parthenais breed was formed only in 1995.

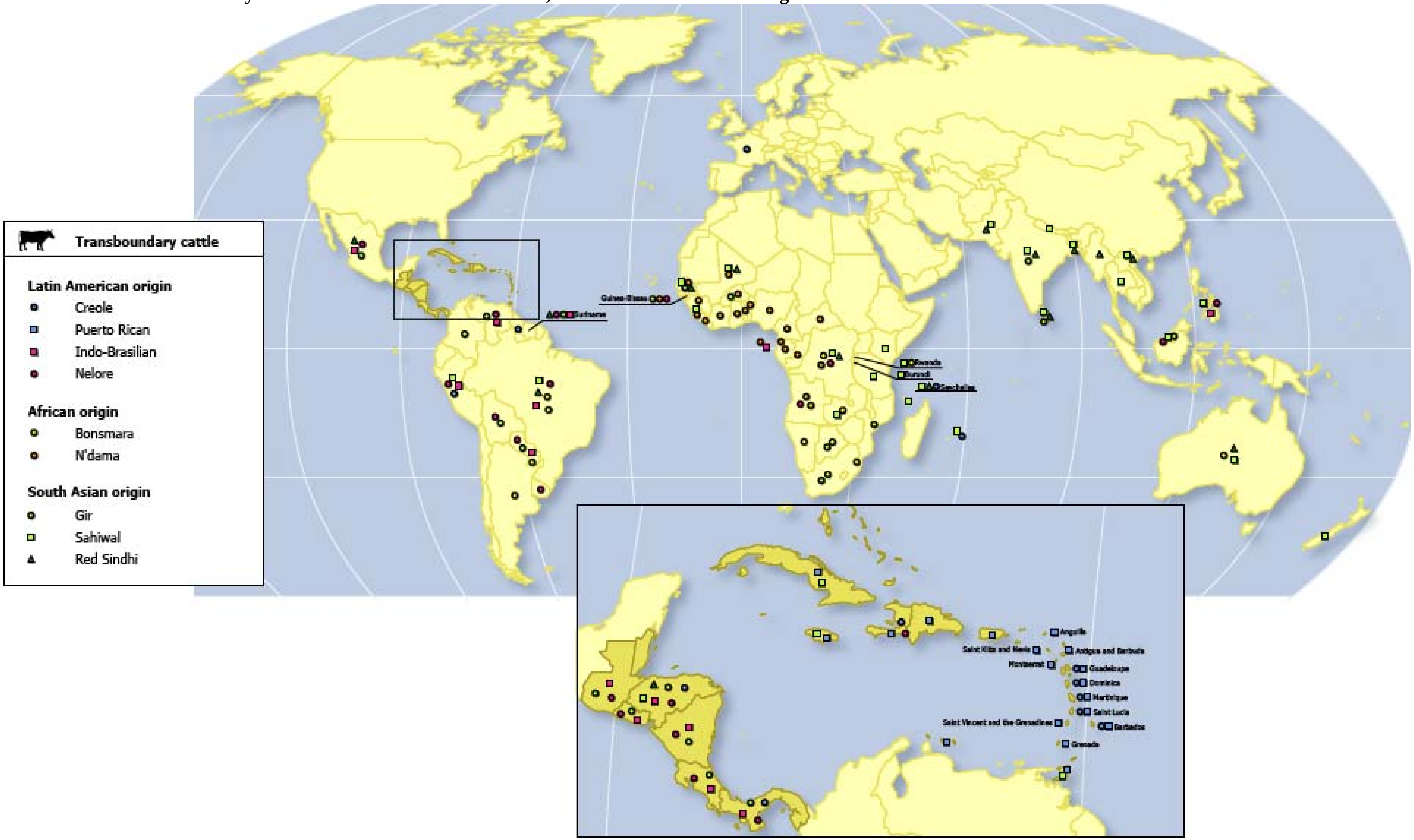
Particularly in the United States of America and Australia, European breeds have been further developed, and production of meat and milk often outstrips that achieved in their home areas. They have also been used as the basis of new breeds suited to temperate areas. Examples include Polled Hereford, Red Angus and Milking Devon in the United States of America. Indeed, North America has become an important source of genetic material for European livestock producers.

European breeds have also been successful in temperate areas of South America and in South Africa, as well as in the dry tropics. Numerous attempts have been made to introduce them into the humid tropics, but they have mostly failed (except in some highland and peri-urban areas) because the breeds are poorly adapted to the heat and poor-quality forage, and often suffer from parasites and diseases. Nevertheless, the top five European breeds (Holstein-Friesian, Jersey, Simmental, Brown Swiss and Charolais) are reported in 11 or more countries in Africa, 16 or more in Latin America and the Caribbean, and five or more in Asia. In Latin America and the Caribbean, European cattle introduced by colonists developed into various breeds, the most prominent of which is the Creole. European breeds have been crossed with various tropical breeds to create new composite breeds that are more suited to the tropics (see under South Asian and African breeds below).

Breeds with South Asian ancestry

The second most successful group of breeds (in terms of their worldwide distribution) have South Asian ancestry. They include the Brahman (ranked ninth overall and found in 45 countries), Sahiwal (29 countries), Gir, Red Sindhi, Indo-Brazilian, Guzerat, and Nelore. These breeds are all of the humped *Bos indicus* type, rather than the humpless *Bos taurus* (Figure 22).

Figure 22
Distribution of transboundary cattle breeds with Latin American, African or South Asian origin



Outside their home area, South Asian breeds have been most successful in tropical Latin America and Africa. The Sahiwal, the best Southern dairy breed, originates from Pakistan and India. It has been introduced to 12 African countries. Indeed, several South Asian breeds have been more successful abroad than at home (Box 8; Figure 22) – presumably because abroad they are prized for their meat (unlike in many areas of India, where cattle are mainly used for milk and draught, and for cultural reasons often cannot be sold for slaughter).

Box 8
Nelore cattle

The Nelore originates from Indian Zebu-type Ongole cattle which Brazil started to buy from India in the early 1900s. In Brazil the breed came to be known as Nelore, after the district of Nellore in present-day Andhra Pradesh, India. The breed thrived in South America, and in the 1950s Argentina started its own breeding programme for the "Nelore Argentino". The Nelore was later exported to the United States of America and there became one of the progenitors of the Brahman. In 1995, the breed made up more than 60 percent of Brazil's 160 million cattle and in 2005 some 85 percent of Brazil's 190 million cattle, had Nelore blood.

Ironically, while the Ongole has been successfully established in a number of countries in North and South America, the Caribbean, Southeast Asia, and Australia, its population has greatly declined in its original range in coastal Andhra Pradesh, and it is qualitatively inferior to the Nelore population in Brazil.

Source: Mathias and Mundy (2005)

Pure South Asian breeds have had little influence in most developed countries. However, breeds based on South Asian stock have had a major impact in the warmer parts of the United States of America and in northern Australia, where they have been bred primarily for beef production. From there, they have been exported to many tropical countries. The Brahman, for example (developed in the United States of America based on stock originally from India), is found in 18 countries in Latin America and 15 in Africa – figures similar to those for the Simmental, the most widely-spread European dual purpose breed in these regions.

South Asian animals have also made a major contribution to composite breeds used elsewhere in the tropics. These include the Santa Gertrudis (descended from Shorthorn × Brahman crosses, and found in 34 countries around the world), Brangus (Angus × Brahman, 16 countries), Beefmaster (Shorthorn and Hereford × Brahman), Simbrah (Simmental × Brahman), Braford (Brahman × Hereford), Droughtmaster (Shorthorn × Brahman), Charbray (Charolais × Brahman) and Australian Friesian Sahiwal (Holstein-Friesian × Sahiwal). Virtually all this breeding work has been done in the southern United States of America and in Australia, beginning in the twentieth century. Many of these breeds have been re-exported to other countries, especially in the tropics, where they generally perform better than the European pure-breeds.

Other South Asian cattle breeds have not broken out of their home region. They include the Hariana, Siri, Bengali, Bhagnari, Kangayam and Khillari breeds – which are found in two or more countries in South Asia – along with numerous local breeds.

Breeds with African ancestry

African breeds account for relatively few of the breeds that have spread outside their home ranges. The N'dama, a trypanotolerant beef breed thought to have been developed in Fouta-Djallon highlands of Guinea, is reported in 20 countries, all of them in West and Central Africa (Figure 22). It ranks only equal 20th among breeds in terms of the number of countries where it is reported. The Boran, a breed developed by Borana pastoralists in Ethiopia and improved by ranchers in Kenya (Homann *et al.*, 2006), is reported from 11 countries (nine in East, Central and Southern Africa, plus Australia and Mexico). The Africander is South Africa's most popular native breed; it is reported from eight other countries in Africa, as well as from Australia. The Tuli from Zimbabwe is found in eight countries (four in Southern Africa, plus Argentina, Mexico, Australia and the United States of America).

African breeds have been crossed with European breeds to produce breeds such as the Bonsmara (the result of Africander × Hereford and Shorthorn crosses in South Africa – see Figure 22), Senepol (an N'dama × Red Poll cross, bred in the US Virgin Islands and then imported into the United States of

America) and Belmont Red (Africander × Hereford and Shorthorn crosses bred in Australia). As the examples show, this cross-breeding has been carried out both in Africa (mainly South Africa) and elsewhere.

Breeds from other regions

Very few breeds from other parts of the world have spread far beyond their original ranges. Cattle from Eastern Europe and the Russian Federation, and from Central, East and Southeast Asia, have had little impact on the world's herds.

3.2 Sheep

Sheep are among the most widely distributed domestic species. They are multifunctional, adaptable, and there are no religious restrictions on their use for meat (at least among the dominant faiths).

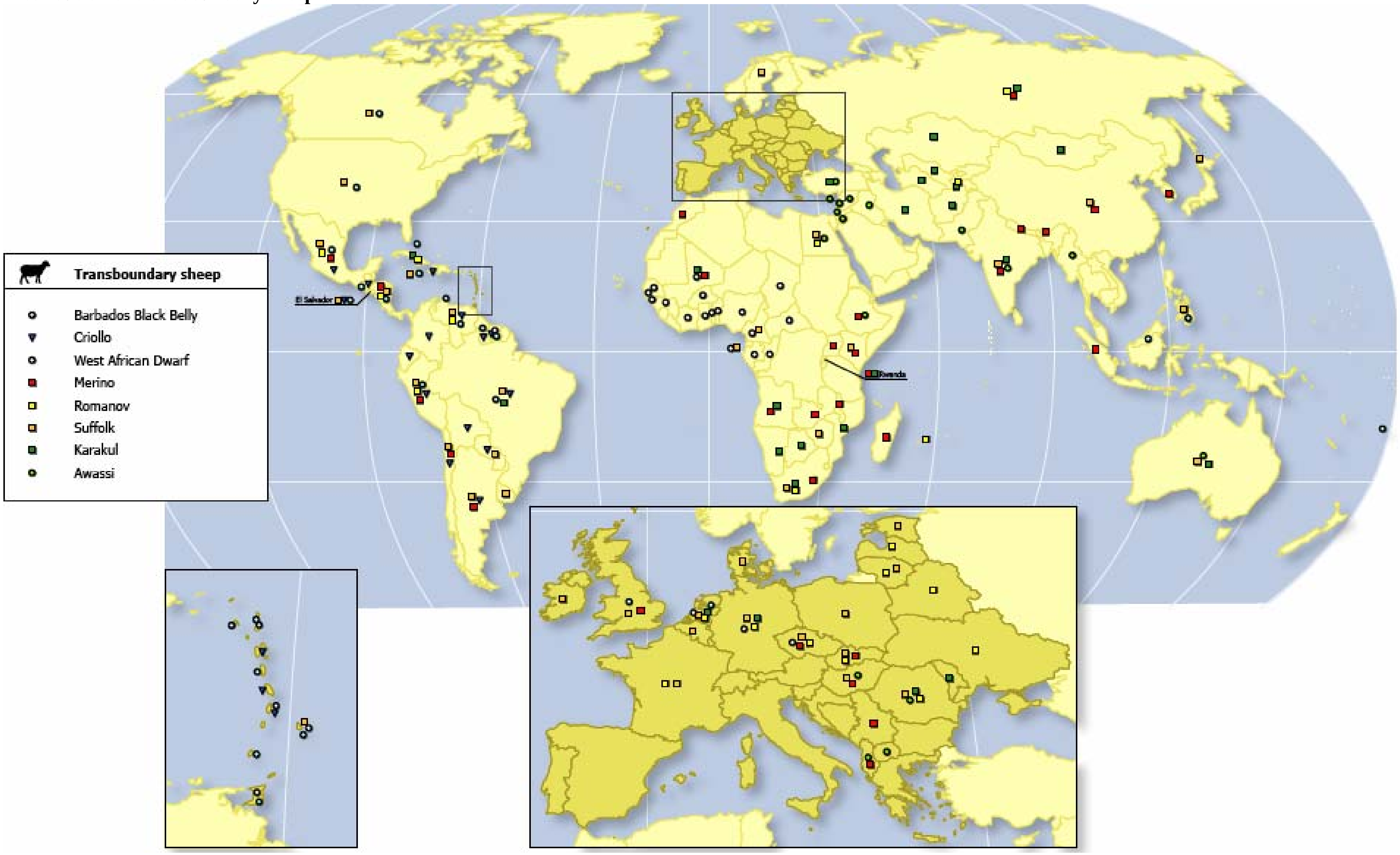
Breeding sheep are mainly exchanged as live animals. AI is less successful in sheep than in cattle. It requires capital-intensive production systems, and is important only where the use of fresh semen is practical, such as breeding programmes for dairy sheep in France, Italy and Spain (Schäfer and Valle Zárate, 2006).

Some 59 breeds of sheep are reported from five or more countries. The most widely distributed breeds are the Suffolk, Merino and Texel, followed by the Corriedale and Barbados Black Belly.

Breeds with European ancestry

European sheep breeds are the most widespread in the world, but are not as dominant as European cattle breeds. They account for five of the top ten breeds worldwide, and 35 of the 59 breeds reported from ten or more countries (Figure 19). The top three breeds are all European in origin: Suffolk (a meat/wool breed from eastern England, found in 40 countries in all regions), Texel (a meat breed from the Netherlands, 29 countries), and Merino (a wool breed from Spain) (Figure 23). The Merino would probably rank first if all its many derivative breeds were counted – it has been widely cross-bred and selected to produce a multitude of new breeds.

Figure 23
Distribution of transboundary sheep breeds



Eight of the top European-origin breeds hail from the southern and eastern England; three originated in France, while others came from Finland, Germany, the Netherlands, the Russian Federation and Spain. As with cattle, many of these breeds are traditional landraces that were formalized into breeds in the nineteenth century. European sheep breeds have spread to many other countries. They have been most successful in the temperate areas of North America and the Southwest Pacific. Transfers began with the first European settlement of these areas, and continue to the present. Canada is a frequent staging-post for European breeds before they are imported into the United States of America, presumably because of the latter country's regulations to prevent the spread of disease.

The EU-15 countries are net exporters of pure-bred sheep, with Spain playing a dominant role. Portugal, France and Germany also export small numbers of breeding sheep (Schäfer and Valle Zárate, 2006). Exchange takes place mainly among the EU-15 countries, with Eastern Europe as an important additional destination.

North America, Australia and New Zealand have active sheep breeding programmes. Three breeds developed in these areas have spread widely: the Corriedale, which is the fourth most widespread breed; the Katahdin (based on a cross between African and European breeds, and the Poll Dorset. All are based at least in part on European progenitors.

European breeds have been exported to only a few countries in the South, primarily the Merino (pure-breeds in 11 countries in Africa, six in Asia, and five in Latin America and the Caribbean), and the Suffolk (five African countries, four in Asia and 12 in Latin America and the Caribbean). Latin America and the Caribbean has been the destination of more European breeds than have other parts of the developing world. The Criollo, descended from early European imports, is present in nearly every country in Latin America and the Caribbean (Figure 23).

European breeds have contributed to many of the 440-plus composite breeds that have been developed during the past three to four centuries throughout the world (Shrestha, 2005, cited in Schäfer and Valle Zárate, 2006). Very widespread breeds with mixed European–non-European ancestry include the Barbados Black Belly and the Dorper.

African breeds

African sheep have been relatively successful. They (or their descendents) account for at least 11 of the 29 breeds found in ten or more countries. The West African Dwarf is found in 24 countries: 17 in Africa, three in Europe and four in the Caribbean (Figure 23). The Black Headed Persian, which comes from Somalia, has spread to 18 countries, including 13 in Africa. From South Africa it was exported to the Caribbean.

African breeds have also contributed to new breeds developed elsewhere in the world. The most successful is the Barbados Black Belly, a hair breed that emerged on the Caribbean island of Barbados in the mid-1600s and which has now found its way to 26 countries in the Caribbean and tropical America, and has also been exported to Europe, Malaysia and the Philippines. The South African Dorper breed is the second most common breed in South Africa, and has spread to 25 countries, mainly in Africa and Latin America. Its history illustrates the complex nature of gene flows (Box 9). The Katahdin was bred in the United States of America from crosses between West African Hair sheep and the Wiltshire Horn, and has been widely exported to Latin America. The St Croix is descended from West African Hair sheep (or possibly a Wiltshire Horn × Criollo cross). It was bred in the US Virgin Islands before being exported to other countries in the Americas and elsewhere.

Box 9
Continuous repackaging of genes –Dorper sheep

The story of the Dorper sheep demonstrates the complex nature of gene flows, and the continuous recomposition of traits which breeders undertake in response to changing market conditions. Dorper sheep were created in the 1930s in South Africa by crossing Black Headed Persians with Dorset Horns.

The Black Headed Persian breed actually has nothing to do with Persia, but was the result of four animals from Somalia that reached South Africa in 1868 on a ship that had originated in Persia, but which picked up the sheep in Somalia. One of the four sheep died, but the remaining animals formed the nucleus for a Black Headed Persian population which was registered in the South African stud book in 1906.

The Dorset Horn breed had originated from crossing Spanish sheep with native English stock during the sixteenth century. It had the unique property of producing lambs at any time of the year. These sheep were initially known as Portland sheep, but were then improved by mating with Southdown animals.

In 1995 Dorpers were imported to Germany, where they are gaining popularity because they do not require labour-intensive shearing in a situation where the market for wool has declined. Australian Dorper breeding animals are now exported to Viet Nam and India. Furthermore, the Dorper has been crossed with the Damara, a South African fat-tail breed to produce the Damper breed. Damper rams are crossed with Merino ewes to produce mutton animals which are shipped from Australia to the Middle East for slaughter.

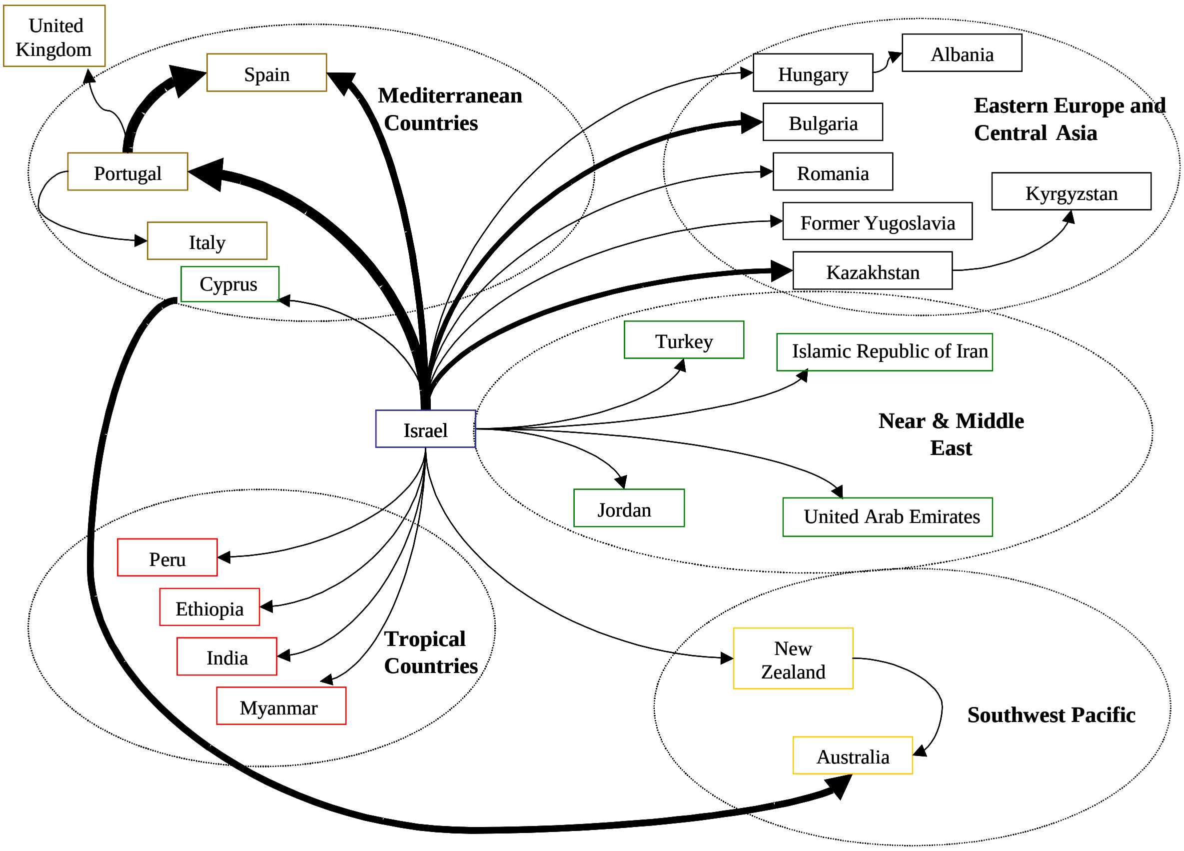
Source: Domestic Animal Genetic Resources Information System (DAGRIS) at http://dagris.ilri.cgiar.org/ (2006)

Other African breeds have remained more or less confined to the continent. Examples are the Fulani from West Africa (ten countries), the Uda (from around Lake Chad, nine countries), and the Black Maure from Mauritania (six countries). All these breeds are kept by pastoralists, who migrate long distances and trade in livestock – accounting for the widespread distribution of these breeds in contiguous countries.

Breeds from Asia and the Near and Middle East

In contrast to Asian cattle, very few breeds from these regions have spread outside their home ranges – despite the fact that Asia has around 40 percent of the world's sheep. The exceptions are the Karakul and the Awassi. The Karakul, an ancient breed from Turkmenistan and Uzbekistan, is now found in substantial numbers in southern Africa, and has also spread to India, Australia, Brazil, Europe and the United States of America (Figure 23). The Awassi, a breed originally from Iraq, was improved in Israel around the 1960s, and has since spread to 15 countries in southern and eastern Europe, Central Asia, Australia and the Near and Middle East (Figures 23 and 24). Transfer to tropical countries in Africa and Asia has had only limited success (Rummel *et al.*, 2006).

Figure 24
Gene flow of improved Awassi and Assaf sheep from Israel



Source: Rummel et al. (2006)

3.3 Goats

Goats are of major economic significance for smallholders in the South, particularly in ecologically marginal areas such as drylands and mountains, where other domestic animals cannot easily be kept. They are of limited importance in Northern agriculture, though some highly productive dairy breeds have been developed in central Europe through upgrading local stock with dairy breeds of Swiss origin. Rising living standards in the Near and Middle East and the migration of people who prefer goat meat, have increased the demand for meat goats, furthering the spread of the Boer goat during the past few decades (Alandia Robles *et al.*, 2006).

With the exception of the top few widely distributed breeds, goats are much less widespread than either cattle or sheep. The top eight breeds (Saanen, Anglo-Nubian, Boer, Toggenburg, Alpine, West African Dwarf, Angora and Creole) are all distributed in 24 or more countries and in several regions (Figure 19). However, there is then a sharp drop: the next most successful breed is the Sahelian, which is found in only 14 countries, all but one of which are in West Africa. All in all, fewer goat breeds have spread outside their home areas. Only three breeds (Saanen, Anglo-Nubian and Toggenburg) are reported from all regions of the world. In developed countries, the number of goat breeds fell drastically during the twentieth century, as a result of the increasing importance of cattle.

Breeds with European ancestry

Purely European breeds account for only six of the top 25 breeds (those distributed in five or more countries). Most originate in the Alps, or were bred from stock coming from this area (Saanen, Toggenburg and various other Alpine breeds). Also among the top breeds (ranked 7th) is the Angora, a mohair breed from the area around Ankara in modern Turkey. This ancient breed fell out of fashion when Merino sheep became increasingly available for wool production, but with the resurgence of interest in mohair wool in the 1970s, several countries started to improve their Angora populations (Alandia Robles *et al.*, 2006).

All the six top European breeds are also found outside Europe. The Saanen dairy goat is the most widely distributed breed – found in 81 countries and in all regions of the world (Figure 25). European goats have also provided breeding material for derivative breeds such as the Anglo-Nubian, Boer (Figure 26), Creole and Criollo.

Figure 25
Distribution of Saanen goats

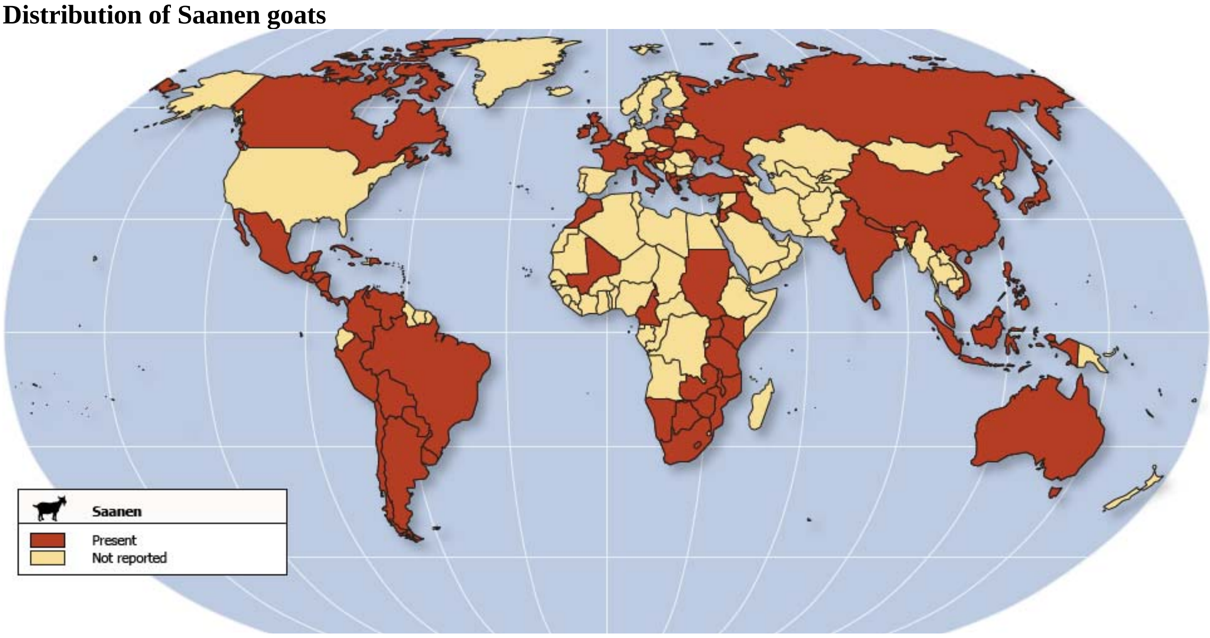
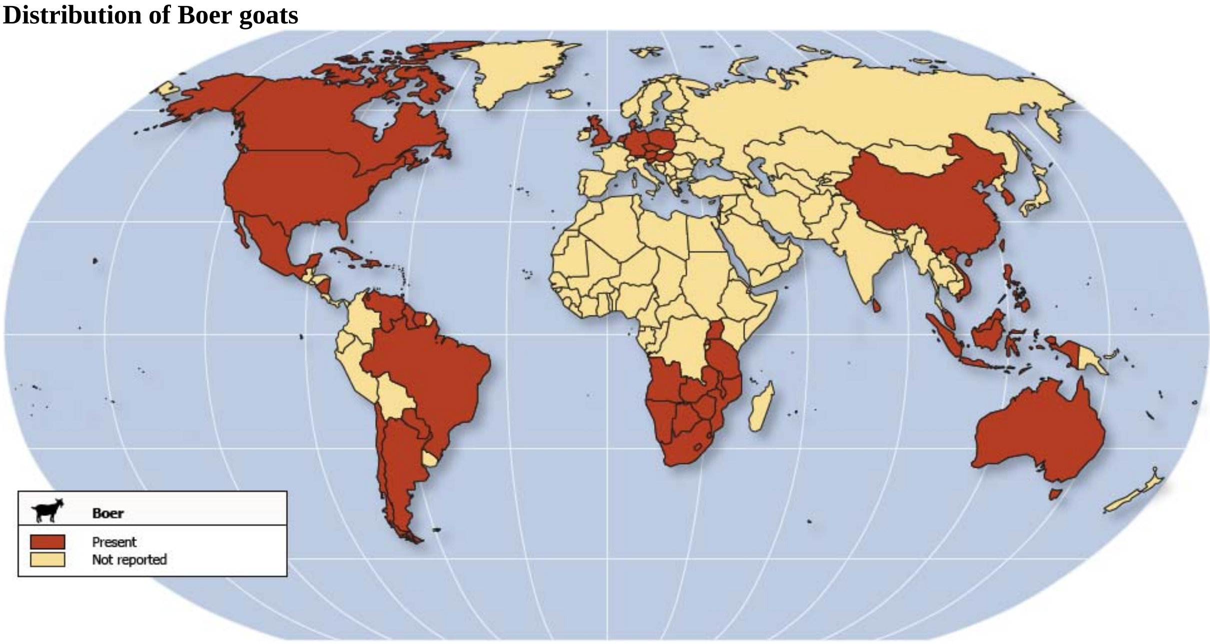


Figure 26
Distribution of Boer goats



African breeds

African breeds make up seven of the 25 most widely distributed goat breeds. They fall into two groups: composites (usually developed through crosses with European breeds), which are widespread outside Africa; and breeds that have remained largely within Africa. In the former category are the Anglo-Nubian (developed in the United Kingdom by crossing British, African and Indian goats, and now reported from 56 countries all over the world), the Boer (bred in South Africa from indigenous, European and Indian animals, and now found in 53 countries), and the Criollo (a Caribbean breed with African and European forebears). Breeds that have remained largely confined to Africa include the West African Dwarf (25 countries), Sahelian, Small East African and Tuareg. Where they have been exported to other countries, these breeds are kept in small numbers as experimental flocks or by hobby breeders.

Breeds from Asia and the Near and Middle East

The mountains of Southwest and Central Asia are the original home of goats. The wild bezoar and markhor are still found there. Other breeds from this region include the Angora (counted as European above), Cashmere, Damascus, Syrian Mountain, Russian Central Asian Local Coarse-Haired and its derivative the Soviet Mohair. The Damascus has recently been improved in Cyprus and has gained international recognition as an outstanding dairy breed for tropical and subtropical regions. While population numbers have remained small, the breed has spread around the Mediterranean basin (Alandia Robles *et al.*, 2006).

South Asia has over 200 million goats – one-quarter of the world's population. However, South Asian breeds are confined largely to Asia. Only three make it into the top 25 breeds worldwide – the Jamnapari, Beetal and Barbari. East Asia has another quarter of the world's goat population, but none of the world's top 25 breeds (unless the Cashmere, whose range includes part of the subregion, is included).

Other breeds

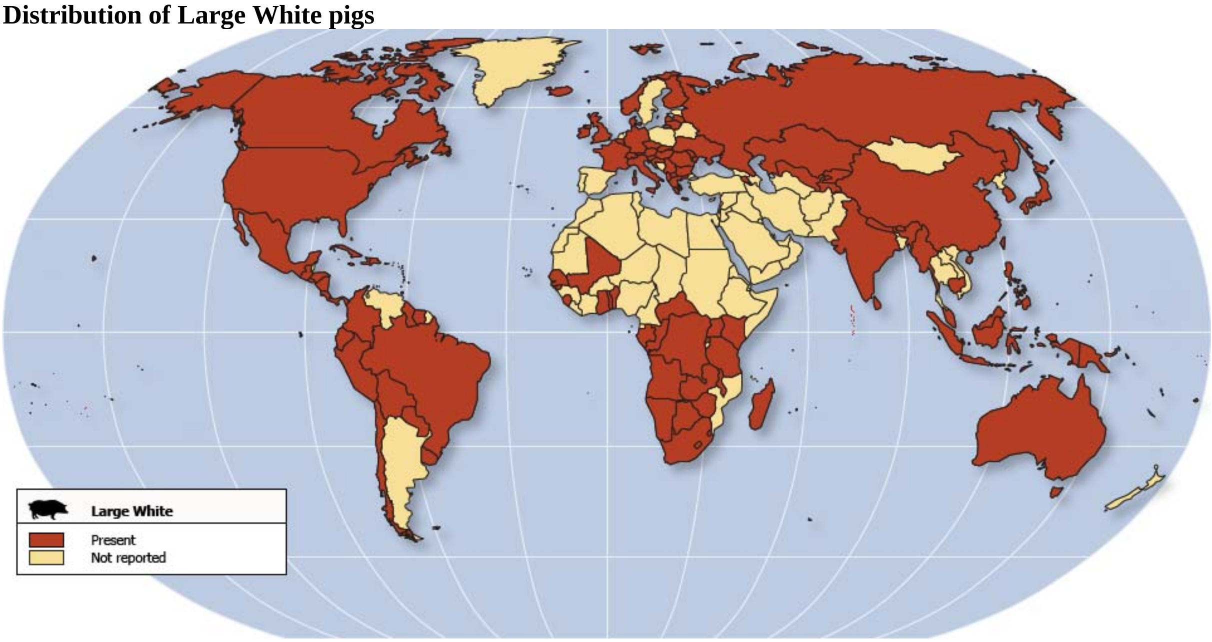
Three breeds developed in the Americas make it into the top 25: the Creole, the Criollo and the La Mancha. All were developed from animals imported by European colonists.

3.4 Pigs

In the eighteenth century, small light-boned pigs from China and Southeast Asia were brought to Europe. The combination of European and Asian genetic material laid the foundation for the creation of modern European pig breeds.

After 1945, national, regional and commercial pig breeding programmes in Europe and North America began to develop. The primary focus was on home markets, but pure-breeds were also exported for cross-breeding: Hampshire, Duroc and Yorkshire from the United States of America to Latin America and Southeast Asia; and Large White (Figure 27) and Swedish Landrace from the United Kingdom to Australia, New Zealand, South Africa, Kenya and Zimbabwe (Musavaya *et al.*, 2006).

Figure 27
Distribution of Large White pigs



In the late 1970s, commercial operations started producing fattening pigs through hybrid breeding programmes (Box 10).

Box 10
Hybrid pigs

Hybrid breeding programmes use crosses between specialized sire and dam lines that have been developed through intense within-line selection of selected breeds including German Landrace, Piétrain, German Large White and Leicoma (Mathias and Mundy 2005). Whole herds of boars and gilts are exported as grandparent and great-grandparent stock for breeding programmes in other countries and regions – a process conducted under the supervision and often the ownership of the exporting company. The firms usually do not sell pure-bred pigs except under contracts that prohibit or control pure-breeding. Furthermore, the local producers have to allow the breeding company to examine their record systems and to pay a "genetic royalty" every time a new breeding animal produced within the multiplication unit is transferred to the breeding unit (Alandia Robles *et al.*, 2006).

The largest commercial suppliers of breeding pigs are the British firm PIC (now Genus), which dominates the market in the United States of America, JSR (also based in the United Kingdom), and Topigs and Hyporc of the Netherlands.

For reasons of biosecurity, some companies sustain nucleus breeding herds in Canada. PIC, for example, has such a herd in Saskatchewan. Many international pig transfers originate from this herd, which contains breeds or lines sourced from all over the world (Alandia Robles *et al.*, 2006).

There are no public data on the export of hybrid pigs, but it is likely that they exceed the trade in pure-bred breeding animals reported in export statistics. The transfer of living animals dominates. The use of semen, embryos and other biotechnologies is increasing, but still plays only a small role. The main source-countries of pig breeding materials are the United Kingdom, the Netherlands, Denmark, Sweden, Belgium, Hungary and the United States of America. Strong breeding enterprises also exist in the South, for example in Thailand, the Philippines and China (Alandia Robles *et al.*, 2006).

European breeds

The worldwide distribution of pigs is dominated by just five breeds, all of them from Europe or the United States of America: the Large White (117 countries), Duroc (93 countries), Landrace (91 countries), Hampshire (54 countries) and Piétrain (35 countries). Breeds from Europe and United States of America also completely dominate the list of 21 pig breeds reported in five or more countries

– 15 are European breeds, all from northwest and central Europe: six from the United Kingdom, three from the Netherlands, two each from Belgium and Denmark, one from Germany, and one which originated in the former Austro-Hungarian Empire. Four of the remaining breeds are from the United States of America, and one is a commercial strain supplied by PIC, a large British pig breeder (see Box 10).

North American breeds

The most widespread breed from the United States of America is the Duroc (93 countries, ranked second worldwide). The origins of this reddish breed are unknown, but may include animals from Guinea in West Africa, Spain, Portugal and the United Kingdom. The other breeds from the United States of America in the top 21 worldwide are the Hampshire (developed in New Hampshire from British stock in the 1800s, 54 countries), the Poland China (from various sources, 13 countries), and the Chester White (from British stock, six countries).

Other breeds

The only other breed in the top 21 is the Pelon, a miniature from Central America found in seven countries. Despite the huge numbers of pigs in East Asia (more than half the world's total population), this region contributes none of the top 21 breeds. Asian pigs have, however, contributed to the world's most dominant pig breeds, as many European breeds are reputed to have some Chinese ancestry.

3.5 Chickens

Chickens are the oldest type of poultry. However, the most important breeds developed only in the second half of the nineteenth century, including the White Leghorn, New Hampshire and Plymouth Rock. White Leghorns are based on Italian country chickens that reached the United States of America in the 1820s, where they were selected for egg yield. They were re-imported to Europe after the First World War.

Chicken breeds are divided between layers (used mainly for egg production), broilers (for meat), dual-purpose breeds (meat and eggs), fighting breeds, and ornamental breeds. In the North, commercial strains dominate the production of meat and eggs, while local breeds are restricted to the hobby sector. In the South, however, local breeds continue to play an important role; in some countries they make up 70–80 percent of the chicken population (Guèye, 2005; Pym, 2006). Chickens in the hobby sector look very different from each other, but that does not necessarily mean they are genetically very diverse (Hoffmann *et al.*, 2004). The same may be true for indigenous breeds in developing countries (Pym, 2006).

North American breeds

Chickens were introduced to North America by the Spanish and then other Europeans in the 1500s. These birds gradually developed into distinct breeds. North American breeds now account for three of the top five most widely distributed breeds worldwide, and seven of the 67 breeds reported in five or more countries. The top three are Rhode Island Red, Plymouth Rock and New Hampshire. All three are dual-purpose layers/broilers developed in the northeastern United States of America.

European breeds

Breeds that definitively originated in Europe account for 26 of the 67 chicken breeds reported in five or more countries. The Leghorn mentioned above is the most widespread; it is found in 51 countries, and ranks second overall. It also is an important contributor to commercial strains. The second most common European breed is the Sussex from the United Kingdom, which is found in 17 countries (tenth overall).

Commercial strains

Commercial strains dominate the worldwide distribution of chickens, accounting for 19 of the top 67 breeds. Because the companies involved keep their breeding information secret, there is no information on the provenance of these strains. However, most appear to be derived from White Leghorn, Plymouth Rock, New Hampshire and White Cornish (Campbell and Lasley, 1985). Commercial strains are controlled by a small number of multinational companies based in northwestern Europe and the United States of America. There has been further consolidation in the industry in recent years. Today, only two primary breeding companies (Erich Wesjohann, based in Germany, and Hendrix Genetics from the Netherlands) dominate the international layer market, and three primary breeders (Erich Wesjohann, Hendrix Genetics and Tyson, a company from the United States of America) dominate the market for broilers. The companies maintain many separate breeding lines (Box 11), and different units within a company may even compete with one another for market share (Flock and Preisinger, 2002; company websites).

Box 11
The chicken breeding industry

Breeding companies have developed a series of lines, each with a set of desirable characteristics, such as egg-laying ability or high growth rate. These lines are then crossed with each other, and then with still more lines, to produce hybrid birds that lay the eggs or produce the broilers that end up on consumers' tables. The companies closely guard their pure-line breeding stock. The structure of the industry is illustrated in Figure 48 in Part 4 – Section D. Developing pure-lines with desirable characteristics is costly and time-consuming; new entrants to the breeding industry would have to invest large sums to break into the market, so it is cheaper to rely on existing suppliers of breeding stock. The large breeding companies lack the local presence and expertise to penetrate new markets, and so often license local companies to act as distributors of their breeding stock to outgrowers.

Source: Mathias and Mundy (2005)

Breeds from other areas

The most widespread breed not included in the categories above is the Aseel, which hails from India, and is reported from 11 countries, ranking only 17th in the world. It is followed by several Chinese breeds: the Brahma and Cochin (which were developed further in the United States of America), and the Silkie (a breed with fur-like feathers). Other Asian breeds are considered as "ornamental" in the West: Sumatra (from Indonesia, eight countries), Malay Game and Onagadori (a long-tailed breed from Japan). Also worth mentioning is the Jungle Fowl (5 countries) from Southeast Asia, which is the ancestor of modern chickens.

The only Australian breed in the top 67 breeds is the Australorp, derived from the Black Orpington, a British breed. Reported from 16 countries, this breed ranks 12th overall in terms of distribution. Its claim to fame is that it holds the world record for egg-laying – a hen once laid 364 eggs in 365 days.

3.6 Other species

Gene flow has also been significant in other livestock species. Among horses, for example, the Arabian breed is the most successful on a world scale. It has had unique influence on horse breeds throughout Europe and has spread to 52 countries. The Pekin Duck breed originated in the 1870s in the United States of America, based on a founder population from China. It is now the most widespread duck breed, reported in 35 countries worldwide. In the nineteenth century, dromedaries were exported to Australia, North America, South Africa, Brazil, and even Java. While they immediately died of disease in Java, the Australian deserts were such a suitable environment that large feral herds established themselves. From their original home in Asia, yaks have been introduced to the Caucasus, North America (3 000 animals) and many countries in Europe. They were imported to Europe mainly as a curiosity, but have shown to have certain advantages for mountain husbandry systems since they require next to no inputs. Their meat can be marketed and they have tourist value. From the United States of America they were further disseminated to Argentina. Domesticated reindeer from Siberia were brought to Alaska in 1891, and from there were introduced to Canada. The species was introduced to Iceland between 1771 and 1787, and subsequently turned feral. In 1952 they were introduced from Norway into Greenland (Benecke, 1994).

4 Impacts of gene flows on diversity

Gene flow can both enhance and reduce diversity. The type of impact depends on a number of factors which include the environmental suitability in the receiving country, and the organizational structures on both the receiving and the providing side (Mathias and Mundy, 2005). Importantly, the amount of material transferred is not indicative of its impact. There are cases where the import of a handful of animals had an enormous effect on breed development. In other cases, large numbers of animals were imported without much effect.

During the first two phases of gene flow described above, which spanned the period from the beginning of animal husbandry in prehistory to the mid-twentieth century, gene flow generally enhanced diversity. However, during the past four to five decades the development and expansion of intensive livestock production and the export of entire production systems have led to a reduction in diversity through the large-scale replacement of local breeds with a small number of globally successful breeds.

This process has already run its course in North America and Europe, where 50 percent of documented breeds are classified as extinct, critical or endangered. It is now being replicated in those developing countries, such as China, that have the resources for and give priority to intensive production systems.

4.1 Diversity-enhancing gene flow

Throughout history, gene flow has been crucial to the development of diversity, which in turn enabled livestock keepers to adapt to new situations and requirements.

Gene flow enhances diversity in the following situations:

- **Imported animals or breeds adapt to the local environment, and a local variety of the imported breed develops**. One example was the introduction of Spanish and Portuguese breeds to South America, which eventually resulted in the hardy Criollo breeds. Another is the spread of Merino sheep through much of Europe and to many countries elsewhere in the world.
- **Imported animals or breeds are crossed with the local livestock, and synthetic breeds are developed which have characteristics of both parent breeds**. For example, the cross-breeding of Chinese and Southeast Asian pigs with European stock led to the development of fast-growing, precocious pig breeds in the 1880s. In South America, the beef industry developed after breeds such as Ongole and Gir were imported and cross-bred with the local Criollo. Structured cross-breeding programmes can also serve to reduce the loss of diversity if they create a justification for the maintenance of pure-bred populations of local breeds that would otherwise decline.
- **Selective use of "fresh blood" in herd book breeds**. Judicious infusion of "fresh blood" by discriminate use of sires from different breeds has often been used by breeders to maintain the vitality of otherwise closed gene pools. An example is the occasional introduction of English or Arabian thoroughbred sires into local German horse breeds.
- **Targeted transfer of gene(s) for specific characteristics**. This has become possible with advances in statistics and biotechnology. An example is the introduction of the Booroola gene encoding litter size into improved Awassi sheep in Israel to create the Afec Awassi. The gene can be traced to a flock of Indian Bengal sheep imported to Australia at the end of the eighteenth century. In 1993, the discovery of a genetic marker for the gene made it possible to identify carriers. The gene and its marker have since been patented (Mathias and Mundy, 2005; Rummel *et al.*, 2006).

The following quotation taken from Cemal and Karaca (2005) provides several other examples of such "major genes" (along with relevant references for further reading) "[in sheep, the] Inverdale gene affecting ovulation rate (Piper and Bindon, 1982; Davis *et al.*, 1988) and the callipyge gene affecting meat production (Cockett *et al.*, 1993); in cattle, the double muscling gene affecting meat production

(Hanset and Michaux, 1985a,b); in pigs, the halothane sensitivity and the RN genes affecting meat quality (Archibald and Imlah, 1985), and the oestrogen receptor locus affecting litter size (Rothschild *et al.*, 1996); and in poultry, the naked-neck gene affecting heat tolerance and the dwarf gene affecting body size (Merat, 1990)."

Markers for genes responsible for desirable traits make it possible to select carriers of the trait in question and use these animals for breeding in marker assisted introgression programmes. Experiences from the few existing programmes indicate that the method could bring economic benefits in developing countries. However, use of this technology should be decided on a case by case basis, and will work only against the background of a sound existing breeding programme and intensive data recording (van der Werf 2007).

4.2 Diversity-reducing gene flow

Replacement of local breeds. Gene flow reduces diversity when high-performance breeds and intensive production systems replace local breeds and production systems. Since the mid-twentieth century, a few high-performance breeds, usually of European descent and including Holstein-Friesian and Jersey cattle, Large White, Duroc and Landrace pigs, Saanen goats, and Rhode Island Red and Leghorn chickens, have spread throughout the world, and have often crowded out the traditional breeds. This process is largely complete in Europe and North America, but is now being repeated in many developing countries that have so far retained a large number of indigenous breeds. It is difficult to quantify this effect, because the necessary data have not been compiled, and because other factors have also contributed to the erosion of diversity. However, it is no exaggeration to say that the South will be the hotspot of breed diversity loss in the twenty-first century (Mathias and Mundy, 2005).

- In Viet Nam, the percentage of indigenous sows declined from 72 percent of the total population in 1994 to only 26 percent in 2002. Of its 14 local breeds, five breeds are vulnerable, two in a critical state and three are facing extinction (Huyen *et al.*, 2006).
- In Kenya, introduction of the Dorper sheep breed has caused the almost complete disappearance of pure-bred Red Maasai sheep.

Dilution and disintegration of local breeds. Local breeds have often been diluted by indiscriminate cross-breeding with imported stock, often without significant gains in productivity or other desirable characteristics. In India, for example, the government has supported cross-breeding with Holstein-Friesian, Danish Red, Jersey, and Brown Swiss for many decades. This has led to dilution of local breeds, but often it has not had much effect on production levels. The increased milk production in India can be largely attributed to the greater use of buffaloes and structural changes in the dairy sector (Mathias and Mundy, 2005). Indiscriminate promotion of cross-breeding with exotic breeds can result in the total disintegration of local breeds. Upgrading of *Bos indicus* cattle breeds with Northern *Bos taurus* breeds often has negative effects on fertility.

4.3 Diversity-neutral gene flow

The flow of breeds and genes has often had no sustained effect on local biodiversity in the receiving country. Many efforts to introduce breeds into a new country have failed. This has been most apparent with the import of European breeds into the humid tropics – large sums have been spent on shipping animals around the globe, but they have failed to become established in their new homes.

4.4 The future

How gene flow will impact diversity in the future will depend primarily on the policy and legislative frameworks that are now in the process of being developed. In the context of the on-going "livestock revolution", it seems likely that the transfer of pig and cattle breeding systems will continue and even increase in pace in the rapidly developing countries of the South. The crowding out of local breeds is, thus, set to accelerate in many developing countries, unless special provisions are made for their *in situ* conservation by providing livestock keepers with appropriate support.

However, countries are becoming increasingly concerned about the effect of indiscriminate imports on their indigenous breeds. For example, Japan recently announced its intention to protect its Wagyu cattle breeds by according “geographic indications” (similar to trademarks) for products from pure-bred Wagyu animals. While for decades, governments of developing countries gave preference to exotic breeds, a move in the opposite direction can now be observed, with calls to prohibit farmers from using exotics (potentially resulting in negative impacts on the livelihoods of those who would benefit from using these breeds).

Possible dangers to the free exchange of genetic resources lie in the widespread adoption of the Access and Benefit Sharing (ABS) concept, since this would necessitate bi-lateral negotiations at government level, in order to work out the details of possible benefit-sharing arrangements, every time breeding stock moves across national borders. It can be expected that this will increase bureaucratic red tape, making it more difficult or in some cases even impossible to exchange genetic material. The (still limited) experience from plant genetic resources has shown that governments rather than farmers benefit from ABS regimes.

Implementation of such concepts would mean that governments would have to give permission for all transfers of genetic material across national borders and set the conditions under which these take place. This could reduce the ability to form new breeds, damage the business of livestock breeders, as well as harm agricultural economies. Because of fears of biopiracy, countries might be hesitant to give official access to their genetic resources.

The greater use of intellectual property rights regulations also has the potential to restrict the exchange of AnGR. Trade secrets and licensing agreements are already the rule in commercial poultry and pig breeding, leading to the control over genes in a concentrated private sector. Use of the patent system to obtain control over breeding processes could further concentrate animal breeding in a few hands.

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