ANIMAL BREEDING PLANS

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PREFACE

This book has grown out of sixteen years of teaching animal breeding to college students who already have had courses in genetics, embryology, anatomy, and physiology of farm animals, herdbook study, history of breeds, and stock judging. The object of this course is to give the students a clear understanding of the means available for improving the heredity of farm animals, more especially of what each possible method will or will not do well.

No effort of mine could keep the book entirely free from statistical terms. After all, a breed is a population, and any attempt at precision in discussing methods of changing its characteristics must necessarily be phrased in terms of the measurements of populations; that is, in terms of averages and of variability. Complete proofs have been presented only where those were simple and brief. In other cases I have sought to present only enough to outline the argument and to show why it is reasonable. That, of course, involves more facts and formulas than most students will use in actual practice but not, I think, more than are necessary to help the student understand why each breeding method he might use is effective in doing certain things and practically powerless to do other things.

Animal breeding is a business; and, therefore, economic considerations of the value and availability of time and materials loom larger in it than they do in the investigation of a purely scientific problem. The work must go on, and decisions must be made in many cases where there is not yet enough evidence to show with certainty what the result will be. The scientist, faced with the problem of deciding what is the truth in such a case, might retire to his laboratory and design an experiment which in due time would reveal that truth. But the man engaged in the business of animal breeding cannot wait for that. Without being entirely certain of what would result from each of the alternatives open to him, he must decide whether to cull or keep each animal and whether to mate it in this way or that. Knowing that the odds are two to one in favor of one procedure as against another may be highly useful to him as a business man, although the scientist may well demand that the odds be higher than the conventional 19 to 1 before he places much faith in a principle deduced from his experimental data. With

these needs of the practical breeder in mind, I have sought to state the most probable truth concerning questions which may guide his actual decisions, even in cases where genetic knowledge has not yet established the limits of that truth as closely as is desirable. Such statements have been labeled with qualifying phrases so that the students will be prepared to encounter occasional exceptions to them.

The ideas in this book have been drawn freely from the published works of many persons, I wish to acknowledge especially my indebtedness to Sewall Wright for many published and unpublished ideas upon which I have drawn, and for his friendly counsel.

Ames, Iowa
June, 1945

JAY L. LUSH

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CHAPTER 1

The Origin and Domestication of Farm Animals

The story of the origin and domestication of farm animals, although interesting, has little practical usefulness to the animal breeder who is seeking to better his flocks and herds today. Only living animals can be used for breeding; and if those have the inheritance the breeder wants and can produce fertile offspring, it makes little difference how they came by that inheritance or what their ancestors were. Knowledge of how closely two races of animals are related may be of some help in forecasting the outcome of crosses between them; but such predictions, based on degree of relationship, will have many exceptions. Knowledge of the origin of farm animals, therefore, is useful to the practical breeder only in the same way that ancient history may be useful in training modern people for citizenship. The details matter not at all, but here and there the history may show with dispassionate clearness some general principle of human conduct which will repeat itself in present situations. Also, it may give the student a perspective which will be useful in making decisions concerning contemporary affairs. The present chapter, then, is a compilation of facts which may be helpful in forming a historical perspective from which to view the present general problems of animal breeding. The reader seeking only immediately useful information is advised to omit it or merely glance at it.

Domestication of the important farm animals was accomplished long before the beginning of written history, but long after man had become a toolmaker and tool-user of considerable skill. In terms of human culture it seems to have happened mostly very late in the Paleolithic (Old Stone Age) or early in the Neolithic (New Stone Age), although this varied with different peoples in different parts of the world.

The *origin of the species* of animals which were domesticated extends back into vastly greater reaches of time and is only a special aspect of the story of evolution. Figure 1 is intended to show graphically the contrasts in the enormously long time involved in evolution, the comparatively short time which has elapsed since domestication first

took place, and the tiny fraction of time since definite and continuous written history began.

The following comments concerning geologic and cultural time are centered around man and other mammals, since those are the central figures in the story of domestication. There are hundreds of thousands of species in the animal kingdom; but with a few exceptions, such as honeybees and silkworms, all the domesticated animals are included in a few species of mammals and birds. It is an interesting but perhaps an idle speculation to wonder why so few species were domesticated. Did the mental characteristics of the others make domestication impossible? Or did those which were domesticated have among them nearly all the characteristics which man found useful to him? Why did not man domesticate any of the many species of animals which hibernate through

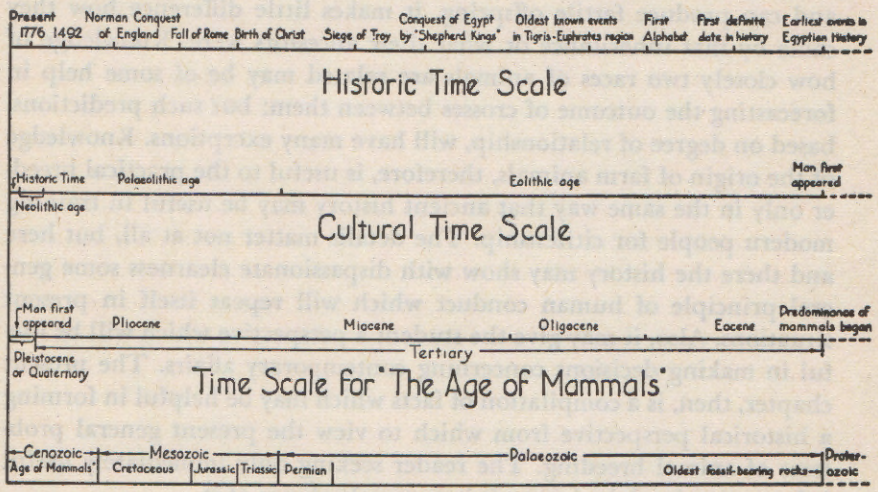

FIG. 1. The comparative lengths of historic, cultural, and geologic time. Each line represents on an expanded scale the small segment at the extreme left end of the line just below it. If the geologic scale were drawn with the same number of years per inch as the historic one, it would need to be more than 20 miles long!

the winter? Those would have had some practical advantages in regions where feed is abundant from spring to fall, but scarce or buried during the winter. Are there perhaps still unrealized possibilities which can be had by domesticating species which are still wild or semi-wild?

Domestication implies several things, no one of which alone is sufficient to define it completely. It usually means tameness, but individual wild animals may be tamed (as trained seals or performing bears are)

without our being willing to call them domesticated, and ranch-raised but nevertheless domesticated cattle or horses may be very wild individuals. Domestication implies bringing the animal's growth and reproduction at least partly under man's control, but we call pigeons and cats domesticated, even though their breeding habits and mating choices usually are not controlled by man. Domestication implies that man converts the animal's products or services to his own advantage or purposes, but he does this also with many wild animals, such as the fur-bearing ones. Some of the domesticated ones, such as canaries, many breeds of dogs, and most "pet and fancy stock," serve him only in an esthetic way. As the word implies, domestic animals usually are kept in or near man's own dwelling places, but usually we do not consider as domesticated the mice and rats which live in man's barns or even in his own houses, while we do consider range-raised cattle and sheep as domestic animals although they may never have seen a human habitation. Some of the domestic animals are dependent on man's care for their very existence, at least in many regions. But horses, dogs, and even cattle, have at times run wild and reproduced for several generations without any control or care by man. Strictly speaking such animals are called "feral" rather than truly wild. Domestication has in most cases produced rather large changes in behavior. Some of these are conditioned by the environmental circumstances under which the domestic animal is reared but many of them are hereditary and presumably have been caused during the process of domestication by selection for those individuals or families which were the gentlest, the most cooperative with man, the best trail-runners (in the case of some breeds of dogs), etc.

In the laboratory animals, or the animals used in fish farming and in fur farming, we may perhaps be witnessing the slow process of domestication. Some of them, like the guinea pig or the white rat, have almost as good a claim to be called domesticated as do swine or reindeer or ducks. Others, such as mink and silver foxes, have advanced little beyond the stage of wild animals being kept in cages as in a menagerie.

GEOLOGIC TIME

The Cenozoic Era (the Age of Mammals) began some 50 to 75 million years ago, although the expression of geologic time in years, particularly in the more remote periods, is very uncertain. The first mammals had come from a reptile group called Cotylosaurs through a premammal group called Cynodonts some time in the enormous interval between the beginning of the Permian and the end of the Triassic, but they did not become the dominant form of animal life until the Cenozoic, being overshadowed earlier by the reptile forms. The Ceno-

zoic is divided into five periods, which, as far as the mammals are concerned, are chiefly noted as follows:

EOCENE. The archaic or generalized mammals were replaced by modern types.

OLIGOCENE. The mammals differentiated into many of the orders and families known today. An anthropoid (Propliopithecus) is known from early in this period.

MIOCENE. This period saw the greatest variety and abundance of mammalian forms. It was a period of extensive grasslands and restricted forest areas over much of the earth. Corresponding to that, there was a widespread expansion and development of the grazing forms of mammals at the expense of the browsing forms. It is probable that man's line of descent had already diverged from that of the other anthropoids by the middle of the Miocene.

PLIOCENE. Most modern genera and even some modern species of mammals already were present at the beginning of the Pliocene. Man's definitely human ancestors appeared during this period at a time date of something like 600,000 to 1,000,000 years ago.

PLEISTOCENE. There was periodic glaciation and with it the extinction of many of the great mammals, such as the mammoth, the mastodon, the woolly rhinoceros, the saber-toothed tiger, and many others. Man learned the use of tools and fire and began to domesticate animals for his own use. The period ends with the retreat of the last great glaciation about 30,000 years ago.

RECENT (The Age of Man). Civilization began. The historical aspects of what is known about man and his surroundings constitute the subject matter of archaeology, and archaeology in turn gives way to history when the written records become adequate enough to give a connected account of man's activities.

CULTURAL OR ARCHAEOLOGICAL TIME

Archaeological time is measured in stages of human culture. It does not correspond perfectly to chronological time, since human culture did not advance contemporaneously in all parts of the world. The major subdivisions of cultural time are as follows:

PRE-HUMAN PERIOD (the Eolithic or dawn period). This period begins with the time when man's ancestors can first be called definitely human, something like a million years ago, and extends roughly to the coming of pre-Neanderthal man in Europe about 200,000 years ago. The use of tools was advanced but little beyond picking up and using such stones or clubs as happened to be handy. Probably fire was not used.

PALEOLITHIC PERIOD (the Old Stone Age). This period was marked by the use of stone and bone implements which slowly increased in complexity and usefulness. The use of fire was learned at least by the time of Neanderthal man. No agriculture was practiced; and there were no domesticated animals, except perhaps the dog. The Paleolithic culture in Europe slowly developed to Neolithic culture around 25,000 years ago. What was practically Paleolithic culture still prevailed among the aborigines of Australia and Tasmania and the Bushmen of South Africa when the first white explorers came in contact with them.

NEOLITHIC PERIOD (the New Stone Age). This period was marked by the use of ground and polished bone and stone weapons and tools. Neolithic man made pottery and crude textiles and basketwork. He practiced agriculture in a crude way. He had domesticated animals of nearly all the species we have today, whereas Paleolithic man had few or none. Neolithic man lived in huts or even in wooden houses as, for example, the Swiss Lake Dwellings. The art of metal-working was still unknown or was practiced only on soft metals used for ornaments. The American Indians were in a rather advanced stage of Neolithic culture when the first white explorers found them. The cultures of the Aztecs, Mayas, and Peruvian Indians already were more advanced in many ways than the late Neolithic cultures of Europe. They were working copper, silver, and gold, but those metals were too soft to make useful tools. The Neolithic culture of the American Indian was behind that of Europe in the use of domestic animals.

As long ago as 4500–4000 B.C., the city of Tepe Gawra in the Tigris valley included in its culture such things as gold and lapis lazuli beads, temples, landscape painting, and the firing of painted pottery, although the inhabitants had not learned to smelt copper. The earliest bit of copper known is an ornamental pin made in Egypt perhaps as long ago as 5000 B.C. The Egyptians were working the copper mines in the Sinai peninsula regularly for ornaments by 3500 B.C. and were using copper tools by 3000 B.C.

BRONZE AGE. The use of bronze began in Assyria by 3000 B.C. and spread west and northwest like a slow wave. It had certainly reached the Danube basin by 2000 B.C. and perhaps Britain almost that early. Apparently there was no bronze age in Africa, except in Egypt and on the northern coast. The other African races went directly from the stone age into the iron age. In the bronze age in Europe, village life and complex social customs had already developed far.

IRON AGE. Bits of iron have been found in the Great Pyramid at Gizeh (about 2900 B.C.), but apparently these were only rare curiosities. General use of iron for tools or weapons was begun by the Hittites in

Asia Minor about 1300 B.C. and iron supplanted bronze as the commonest metal for weapons among the Assyrians by 1000 B.C. Then its use spread rapidly.

History and archaeology are intertwined in the long period which we describe loosely as the "dawn of history." The earliest definite date in history is 4236 B.C., when the Egyptian calendar began; but fragments of Egyptian history are known from nearly 5000 B.C. Some time between 5000 and 4000 B.C. the Egyptians began to use ox-drawn plows, and by 3500 B.C. they had an alphabet. The beginnings of history were not contemporary in different parts of the world. For example, the definite history of Britain begins about the time of the Roman conquest; and that of the Scandinavian countries begins about five or six hundred years later. Little is known of South Africa or Australia before 1500 A.D. On the other hand, the history of Greece goes back some 2000 years farther than that of Britain; Cretan history is known from nearly 3000 B.C., and a few events among the Sumerians near the Persian Gulf can be dated at about 3500 B.C.

DATE OF DOMESTICATION OF FARM ANIMALS

All the farm animals were domesticated long before historic times. The evidence about when and how that happened is incomplete and consists of such things as the bones and tools found buried in the trash heaps around ancient camp sites or caves, the drawings or carvings on the walls of caves or on ornaments. Rich sources of evidence are the tools, weapons, utensils, and images which so many peoples placed in the graves with their dead.

Often such evidence is fragmentary and may be interpreted with equal plausibility in several different ways. Even where evidence admits only one interpretation, the dates derived from it are necessarily minimum dates. For example, the evidence leaves no doubt that domesticated horses were widely used in the region of the Tigris and Euphrates rivers as long ago as 2000 B.C. and probably the first of them were brought into that region as long ago as 3000 B.C. Even if the earliest date of domesticated horses in this "two-river land" were established with absolute certainty, it still remains possible that horses may have been domesticated and used a thousand years earlier at some other place as yet unexcavated. Doubtless the thoroughly excavated sites of ancient human camps and cities are only a small fraction of the total number which exist and may be discovered in the future.

One who reads the technical evidence and discussions can scarcely avoid the feeling that they give an unduly large emphasis to details of the shape of horns and skull. This is natural since these parts of the

animal are best preserved and best known. It is partly justified because these parts are little affected by ordinary variations in nutrition or other environmental influences. Yet one who surveys the considerable variability in skull and horn shape within comparatively pure breeds today, and who considers the known cases where a single gene substitution can cause large differences in these characteristics, must feel uneasy about placing much faith in genealogies which rest largely on similarities or differences in the size and shape of horns or skulls. Such genealogies are especially questionable when they are based on only a few specimens, perhaps widely separated in time.

It is uncertain that Paleolithic man in Europe actually domesticated any animal, although he may have had the dog. The Paleolithic aborigines who settled in Australia took the dog with them, but no other modern animal. Paleolithic man in Europe used the horse extensively for food, but it is probable that he hunted it as game and had not really domesticated it.

Neolithic man in Europe appears to have had nearly all of our modern domestic animals except the cat and poultry and those animals which were found only in America or in the tropics. Some students of the evidence claim that even in early Neolithic times the bones of the domesticated ox, swine, and sheep were already distinctly different from their wild contemporaries. There is even considerable speculation that the domesticated races of the early Neolithic in Europe were brought from the Caspian region or from Asia Minor in an already domesticated condition by peoples who migrated into Europe then. A considerable amount of care was certainly given to farm animals by the Lake Dwellers and by the men of the bronze age. It is not certain that the horse was really a domesticated animal in Europe before the end of the Neolithic, although the men of the bronze age certainly were riding horses.

The rock-carvings from ancient Egypt and from the pre-Babylonian peoples of Sumer and Akkad, which are among the oldest of what may be called written records, show the goat, sheep, ox, ass, pig, dog, and cat. Caring for these animals was already a well-established part of agricultural practice, even at that remote day.

PLACE OF DOMESTICATION

Domestication took place in the Old World except in the case of the llama, alpaca, guinea pig, and turkey, which are native to the Americas. In the Old World, domestication seems to have taken place largely in central or western Asia, although the evidence points to some domestication in Egypt and in Europe itself. Chickens and elephants

were domesticated in India, and at least one center of domestication for swine was in China. Domestication may have taken place independently in several regions. This seems certainly to have happened in the case of swine and sheep and may have happened with other animals. Much of the world, especially central Asia, is still incompletely explored from this point of view. There were no modern mammals (except the dog and man) in Australia. Africa south of the Sahara desert had a fauna rich in mammalian species, but none of the domesticated animals, except the South African ostrich and the African elephant, came from there. Upper Egypt or Ethiopia was one of the centers of domestication for the ass.

SPECIES DOMESTICATED

For many animals it is still disputed whether they descended from a single wild species (*monophyletic* origin) or from two or more wild species perhaps domesticated in different regions or at different times and later interbred (*polyphyletic* origin). The main reasons for this dispute are, of course, the scantiness of the evidence and the different biological views which the writers hold. In many cases domestication was completed so long ago that the original wild ancestor has become extinct, or it may still be living but the domesticated form has been changed so much that we are not now certain which contemporary wild species was the ancestor.

Polyphyletic theories are not as widely held now as formerly. The idea of organic evolution was not generally accepted even by naturalists until well into the last half of the nineteenth century. Many of the naturalists who wrote ou the origin of domesticated animals still had in their minds traces of the old Linnean idea of the fixity of the species. Often they had an exaggerated idea of the supposed uniformity of wild species. With this mental background a polyphyletic origin seemed to them the only possible way to explain the tremendous diversity of domesticated forms—for example, the tremendous contrasts between breeds of dogs or of sheep. Modern studies of large samples from wild populations have shown that those populations are not as uniform as many of the older naturalists believed. Some of these modern studies bave shown that enough of this variability in wild populations is hereditary that selection, directed toward diverse goals, and other breeding practices, such as inbreeding, could in a few generations produce distinctly contrasting races from a single wild population if man were to control its breeding as he does that of his domesticated animals. Hence it no longer seems necessary to invoke a polyphyletic origin as an explanation for observed diversity. The possibility remains, how-

ever, that some domesticated animals may really have had in their ancestry crosses of distinct races or even species which were still genetically similar enough for their crosses to be fertile. This seems to have happened in the case of swine and sheep, although there is plenty of room for difference in opinion as to whether the races domesticated were ever different enough and discontinuous enough to justify calling them different species. The whole question of proper taxonomic terms for domesticated animals is in a chaotic condition. Many taxonomists hold (with Linnaeus) that variations among races of domesticated animals are largely man-made and therefore outside the scheme of nature which is the concern of taxonomy.

METHOD OF DOMESTICATION

Literally nothing is known about how domestication was first accomplished. It is only speculation to guess that hunters first brought home a few young as pets or captured cripples from time to time and thus learned how to care for animals. At least one Egyptian rock-picture shows hunters building a fence across the mouth of a little steep-walled valley into which they have driven some wild animals. Wild elephants are captured in India today by carefully planned drives. Tame elephants are then used to help chain the wild ones and to teach them to work. Hunger is the most generally effective method of taming the most unruly among the wild ones. But it is more difficult to tame the African elephant, even by these same methods. This suggests that temperamental aptitude was an important element in the success or failure of early attempts at domestication.

DETAILS ABOUT DIFFERENT KINDS OF DOMESTIC ANIMALS

SWINE. The European wild boar (*Sus scrofa*) still lives in some of the forests of Europe. It crosses freely with domestic swine, and the offspring are fertile. Doubtless it was domesticated somewhere around the Baltic sea in Neolithic times. A swine race or species (generally known as *S. vittatus,* although some divide it into two groups and give the name *S. cristatus* to one) native to the middle and eastern Asian mainland from western India around to central China, and found also in nearby island lands like Japan, Formosa, Sumatra, Java and Borneo, was separately domesticated in China, perhaps as long ago as 3000 B.C. At least one more center of domestication in Neolithic times was south or southeast of the Alps, where some of the Mediterranean local wild races were domesticated. *S. scrofa* grades into *S. vittatus* by a gradual but continuous series of local races to such an extent that modern writers (such as Kelm, 1938) are inclined to consider them all as one highly

variable species—a *"Formenkreis"*; i.e., a chain or circle of local groups or races, each differing only a little from the ones next to it but considerably from those farther away.

Nomadic peoples could not move swine with them easily. They generally regarded with contempt the farmers and settled valley-dwellers who did keep swine. This may have been the origin of the Hebrew and Moslem dislike of swine, which was later fortified by religious precept. Because nomads could do so little spreading of swine and because wild swine by themselves do not usually migrate far, there has been in swine more than in most species a differentiation into local races which vary from one place to another. It may be more accurate to speak of the practice of domestication spreading from tribe to neighboring tribe rather than to speak of an actual spread of one or of a few domesticated forms of swine.

Some of the early navigators report finding native swine on some of the islands in the southern Pacific; but the Polynesians who settled those islands were expert navigators who had come from the general Malaysian region only a few centuries earlier, and probably they brought swine with them. The peccaries, which belong to a different genus, are the nearest American relatives of swine. They had not been tamed by the Indians nor, from their behavior in captivity, does it seem likely that they can be domesticated. The breeds of swine common in the United States probably get most of their ancestry from the European wild swine, but there may have been a considerable amount from the Mediterranean races, and there is clear historical evidence of the introduction of at least a little blood from Chinese swine.

Cattle. The family Bovidae are the most specialized of the hollow-horned ruminants. They are connected with the other ruminants by way of antelope-like ancestors from which they diverged in the Pliocene or Miocene. Living forms of the Bovidae include the true buffalo, the bison, musk-ox, banteng, gaur, gayal, yak, and zebu, besides what we commonly call cattle. The musk-ox is intermediate in some respects between oxen and sheep or goats. The musk-ox has not been domesticated, although Stefansson reports that it is well suited for domestication. The Asiatic buffalo was in Syria in Neolithic times, but may not have been domesticated until near Christian times. It is an important dairy and work animal of India and lands farther east and is used a little as far west as Bulgaria. It existed in the Atlas region of northwestern Africa even after Neolithic times. The African buffalo has never been domesticated. The banteng, gaur, and gayal are all restricted to southeastern Asia and the nearby islands. The banteng is the common work ox of Java, Bali, and Borneo. It is often crossed with common cattle,

but the crosses thus produced are fertile. The gayal may be only the domesticated form of the gaur. The European bison, or wisent, and the American bison have never been really domesticated, despite a few sporadic attempts to do so. The American bison can be crossed with common cattle, but there is much mortality and sterility among the crossbreds. The yak is the bovine species best adapted to cold mountain lands. It is native to the highlands of Asia north of the Himalayas and, although an important domestic animal there, has not found practical use outside that region. Nothing very certain is known about its date of domestication. The yak can be crossed with common cattle and with zebus and with bison, but there seems to be some sterility among the males from such crosses.[1]

There are in the whole world between six and seven hundred million cattle which are commonly grouped under the one species name of *Bos taurus,* although some prefer to give a separate species name, *B. indicus,* to the zebu group. In the Balkans, Asia Minor, central Asia, Korea, Formosa, and in eastern and southern Africa, there is a wide variety of forms intermediate in many respects to the extreme zebu types and the cattle of western Europe. The more extreme types have been separate in their ancestry for thousands of years. Carvings from the Indus valley region show bulls with extreme zebu characteristics from as long ago as the third millenium B.C. The cattle of the United States are of purely European origin, except some in the region bordering the Gulf of Mexico, which have considerable zebu ancestry. Concerning the ancestry of European cattle, the most commonly mentioned species or subspecies are: (1) *B. taurus brachyceros* (or *longifrons*), which was in Europe as a domesticated animal early in the Neolithic and presumably was domesticated somewhere north of the Alps or in northwestern Asia; (2) *B. taurus primigenius,* the urus or aurochs, known in Caesar's time as the wild ox of Europe[2] but domesticated long before (perhaps early in the Neolithic), probably south of the Alps or in the Balkans or in Asia Minor; and (3) *B. namadicus,* which was contemporary with man in India in the early Pleistocene. Other names, common in the early writing but not seen so often now, include *B. taurus frontosus,* the Swiss spotted cattle; *B. taurus brachycephalus,* the short-headed cattle such as the Dexter, Eringer and Zillertaler breeds; and *B. taurus akeratos,* the hornless cattle of northern Europe.

HORSES. Horses were plentiful in Europe in Paleolithic times. That

[1] Deakin, Alan, Muir, G. W., and Smith, A. G. 1935. *Hybridization of Domestic Cattle, Bison, and Yak.* Publication 479, Department of Agriculture, Dominion of Canada.

[2] Keller says the last wild aurochs cow in Poland was killed in 1627.

they were used for food is attested by the cracked and dismembered bones, mostly of young horses, around old camp sites like that of Solutre near Lyons. They were probably not domesticated at that time but were hunted for food. The horse is primarily adapted to open grassland country and apparently became rare in Europe during Neolithic times with the increasing forest growth. Formerly it was thought that a distinct type of forest horse remained in western Europe through the Neolithic and was the principal ancestor of the heavy or "cold-blooded" draft breeds. More recent studies (Antonius, 1936) indicate that the heavy horse was developed between 1000 and 1200 A.D. in or near Friesland out of the existing domesticated horses of Tarpan origin. Prawochenski, however, disagrees with this interpretation. Horse bones are rare in Neolithic deposits, but bronze age deposits include bridle bits and other accoutrements thus proving its domestication by that time.

Probably all domesticated horses of Europe and western Asia descend from the tarpan which still existed wild in eastern Europe in the region from East Prussia southward as recently as 1700 A.D. and perhaps in the 1800's. Some writers distinguish between a "forest tarpan" in the more westerly region and a "steppe tarpan" farther south and east, but others think (Antonius, 1936) there was no real distinction. In eastern Asia the wild horse of Przewalskii was reported about 50 years ago and perhaps still exists in the Mongolian desert region. It may have been domesticated separately there. The use of the horse had reached China before historic times, but that is of uncertain date.

The horse first appears definitely in western history before 2500 B.C. when the Neolithic Indo-Europeans from the Caspian basin brought it into Anatolia and later to Babylonia. Presumably the Indo-Europeans from west of the Caspian took domesticated horses westward with them north of the Black Sea at more or less the same time. Certainly horses were in Spain and northwest Africa before any could have reached there from Egypt. The horse first reached Egypt about 1800 B.C. when the Shepherd Kings conquered Egypt from the northeast.

The *evolution* of the horse is especially well known compared with that of other mammals and is used as a classic illustration in many books on evolution and zoology. Most of this evolution took place in the Americas, but horses later became extinct there after some of them had migrated to Asia. There were no horses in the Americas when the white men came. Why they died out is one of the unexplained mysteries of evolution. Conditions were favorable for them at the time of the discovery of America by white men, as is shown by the way the horses which escaped from the early settlers or explorers multiplied. The wild horses of the present western ranges are descendants of these escaped

horses and are often used to illustrate the difference between "feral" animals and truly wild ones whose ancestors never have been domesticated.

The early use of horses was for human transport and for pulling chariots in time of war. Their use for pulling loads and for tilling the soil is a comparatively modern development.

Asses. The ass was in common use in Egypt and Babylonia many centuries before the horse was introduced into those lands. Probably it was originally domesticated in Egypt or on the east coast of Africa or in southern Arabia or around the Persian gulf. Its nearest wild relatives are found in Africa and in Asia Minor. The main (perhaps the only) ancestor is thought to have been the Nubian wild ass, although another variety of wild ass in Somaliland may have contributed something.

It is generally stated that the other Equidae, such as the zebra, the kiang, and the onager, have not been domesticated. However, Antonius concludes that the ancient Sumerians had domesticated the onager and used it extensively, even for crossing with horses to produce mules. Also it is stated[3] that Burchell's zebras were formerly used on stage lines in the Transvaal.

Sheep and Goats. The subfamily Ovinae are all highland or mountain dwellers. Perhaps because of this and the resulting isolation they are mightily given to breaking up into many species, subspecies, varieties, and local races. There is no single trait which distinguishes all goats from all sheep, although there are some things which are characteristic of most sheep and few goats or vice versa. Besides the true sheep and the true goats, there are, according to Antonius, the following groups of Ovinae: (1) The Hemitragus group of primitive or short-horned goats with four teats. Three living species are found in the mountains of India and southern Arabia. (2) The ibexes or steinbocks, which resemble the true goats rather closely and are fertile with them but have contributed nothing to their ancestry. They are all mountain dwellers, and Antonius lists seven species in the mountains from the Himalayas to the Pyrenees and another from the mountains of southern Abyssinia. (3) The burrhel or blue sheep of Tibet. (4) The maned sheep or aoudad, now restricted to the Atlas mountains but extending as far east as Egypt even in historic times. (5) The argali group, which are rather sheep-like and include an enormous number of local races besides the argali itself and Marco Polo's sheep. The argali group probably did not contribute anything to the ancestry of domesticated sheep, unless perhaps something to the fat-rumped races. This is disputed by some investigators (Gromova, 1936) who believe the argali group was

[3] *The Horse Lover.* 7:9. 1943.

important in the ancestry of domesticated sheep. (6) The thick-horned sheep, of which there are an enormous number of local races extending from the northern Himalayas northeastward over Kamchatka and Alaska to California. The Big Horn Sheep of the Rocky Mountain region is an example. Probably this group played no part in the ancestry of domestic sheep. There have been a few accounts of crosses between domestic sheep and Big Horn Sheep in western United States.[4]

Domesticated goats are believed to descend mostly from *Capra prisca,* which is known from Pleistocene fossils from Greece northward, or from *C. aegagrus,* the Bezoar goat or Psaang, which still exists through the mountainous regions of Asia Minor and Persia and in the past has extended from Sind to as far west as Crete. Also mentioned among the true goats are *C. dorcas* (which some think only a form of *C. prisca*) from the Jura mountains, and *C. falconeri,* which is extraordinarily given to the development of distinct local races and lives in the region around Afghanistan. Some of the tame Egyptian goats resemble *C. falconeri* rather closely, but it is not certain that they descend from it in any part. Nothing is known about the place of domestication of the goat, nor about the date of domestication, except that it must have been very remote.

Domestic sheep are thought to descend mainly from the mouflon, *Ovis musimon,* which is still found wild in Sardinia and Corsica and interbreeds freely with domesticated sheep, and from *O. vignei,* the urial, which is found from Turkestan to Asia Minor. Some writers think that a part of the ancestry of domesticated sheep came from *O. orientalis,* the mouflon of Asia Minor and Armenia, or from *O. arkal,* which is found east of the Caspian Sea. There is more confusion and disagreement about the ancestry and classification of sheep than of any other farm animal.

Domestication of the sheep took place so long ago that taxonomic names have even been given to the forms found in deposits from various stages of human culture. Thus, there is talk of a "turbary sheep, *Ovis aries palustris*" and of a "copper-age sheep, *Ovis aries studeri.*" Early Neolithic man in Europe certainly had domesticated sheep with him, but where or when he got them can only be conjectured from what is known about their geographical distribution.

There is an enormous variety of breeds and races of domesticated sheep. The classifications proposed for convenience in referring to these are generally based on the nature of their wool and the length and fatness of their tails. Antonius classifies them for that purpose as follows:

1. Long-tailed sheep

[4] *Jour. Wildlife Management* 9:82–83. 1945.

A. The wool sheep of Europe. These include all the breeds which are prominent in the United States.
B. Hairy sheep originally prevalent all over Africa. The black-headed Persian sheep of South Africa is an example.

2. Fat-tailed sheep, usually with a long tail, fat at the upper end but slender at the tip. Karakuls are an example.
3. Short-tailed sheep, such as the Heidschnucke of Germany and other marsh or moorland sheep of northern Europe.
4. Fat-rumped sheep, which were originally native to high Asia east of where the fat-tailed sheep developed.

DOG. Zoologically the dog is essentially the same as the common wolf of the northern hemisphere.[5] The dog was the only domesticated animal found in both the New and the Old Worlds. The polyphyletic origin of the dog, involving the jackal as well as the wolf, was once widely believed, but that belief has almost disappeared now. The dog may very well have been the first animal domesticated. Chaldean and Egyptian monuments show several distinct breeds in existence four or five thousand years ago. The Incas in Peru had bulldogs as well as their ordinary breed (Hilzheimer, 1936).

CAT. The Egyptians domesticated the African wild cat. Thence it was probably introduced to Italy by Phoenician traders some centuries before the Christian era. A European wild cat and perhaps also a Chinese wild cat may have contributed to the ancestry of modern domestic cats.

CAMEL. The single-humped camel, *Camelus dromedarius,* was domesticated probably in Arabia or northeastern Africa, perhaps near the very beginning of Egyptian civilization or perhaps not until near 1000 B.C. The two-humped camel, *C. bactrianus,* was domesticated in Asia somewhere between Iran and the Gobi desert. It had reached Syria at least by 1000 B.C. and perhaps a thousand years earlier. It is now the common camel in China and the regions just northwest, although the other occurs also.

The llama and alpaca are the only living American representatives of the camel family, although that family went through most of its evolution in North America. They were domesticated by the ancient Peruvians from the wild guanaco, *Lama huanachus,* long before the Spanish conquest. The wild vicuna, *L. vicugna,* is a close relative. In the Incan agriculture the alpaca occupied somewhat the place of the sheep in ours, but the llama was used extensively as a beast of burden, as well as for its meat and wool. Llamas sometimes are used for dairy purposes, too.

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[5] Crosses between dogs and wolves are frequent (*Jour. of Genetics* 43:359–414. 1941).

REINDEER. *Rangifer tarandus* is the Scandinavian wild form which was domesticated by the Lapps and later introduced to Alaska and arctic Canada. *R. caribou,* the caribou of Canada, has not been domesticated. One report has it that reindeer were domesticated in the Yenisei River basin about the time of Christ.

ELEPHANTS. Elephants were domesticated at least as long ago as in ancient Carthage. Presumably they were used in India much earlier. Alexander used them in his battle with Darius in 331 B.C.[6] in Mesopotamia.

CHICKENS. Chickens came from southeastern Asia and are generally believed to have descended from *Gallus bankiva,* the jungle fowl of India. It is not certain that more than one species was involved. Domesticated chickens were kept in China at least as early as 1400 B.C., and from India had arrived in Babylon by 600 B.C., in Greece by 500 B.C., and in Rome well before the Christian era. The actual introductions may have been centuries earlier.

GEESE. These came from the grey laggose,*Anser anser,* and perhaps also the Chinese goose, *Cygnopsis cygnoides.* The date is uncertain, but geese were kept by the ancient Romans several centuries before the Christian era, as witness the legend about the cackling of the geese which on one occasion saved Rome from invaders. There may have been several independent domestications.

DUCKS. Probably these all come from the mallard duck, *Anas boschas,* although there are many other species of wild ducks. Ducks probably were not domesticated before Roman times.

GUINEA. The guinea comes from the Guinea coast of western Africa. The wild species is *Numida meleagris.* The guinea was known to the Romans as a domestic fowl but later ceased to be kept in Europe and was reintroduced by the Portugese in the sixteenth century.

PEACOCK. *Pavo cristatus* is found in India and Ceylon. *P. muticus* is found in Burma and Java. Either or both may have contributed to the origin of domestic races. The peacock was a relatively late arrival in European agriculture. It was first domesticated in Persia, or at least first knowledge of it came to Europe from Persia.

TURKEY. The peoples of ancient Mexico and Peru had domesticated the turkey long before the discovery of America by white men. The wild Mexican turkey, *Meleagris mexicana,* is thought to have furnished most of the ancestry, but *M. gallopavo* from the Atlantic coast of the United States and *M. ocellata* from Central America are sometimes mentioned in that connection.

FUR-BEARING ANIMALS. Such animals as the *fox, mink, marten, ferret, skunk, muskrat,* etc., are extensively reared in captivity but prob-

[6] See Armandi's *"Histoire militaire des elephants."* Paris. 1843.

ably should not yet be called truly domesticated. They may represent stages in domestication through which our farm animals passed far back in Neolithic times.

LABORATORY ANIMALS. Among the laboratory animals, the *guinea pig* probably should be called domesticated. South American Indians were breeding it in captivity for food before the white man came. The *white rat* is an albinotic strain of the common Norway rat, *Mus norvegicus*. Probably the albino rat was domesticated before the beginning of the nineteenth century. An albino rat colony in England in 1822 is reported. Fancy races of *mice* were known in ancient Troy perhaps as long ago as 1200 B.C. and probably in China as far back as 1100 B.C., since a Chinese dictionary of that date had a special word for the spotted mouse. Domestic *rabbits* are descended from the European rabbit, *Oryctolagus cuniculus*. It was probably domesticated in the Spanish peninsula or southern France, perhaps as early as 1000 A.D.

BEES. Honeybees are mentioned frequently in the Old Testament and in early Roman writings on agriculture. They were brought to America from Europe. Bumblebees were already in America when the first white explorers came.

SILKWORM CULTURE developed in China, possibly longer ago than 2000 B.C. It did not spread to other countries until the Christian era.

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CHAPTER 2

Consequences of Domestication

The fundamental laws of heredity and the mechanics and physiology of reproduction are the same among domesticated animals as among their wild relatives. The change from the wild to the domesticated condition did not alter these laws nor create any new inheritance. The changes which domestication did bring about were an increased amount of inbreeding and outbreeding and assortive mating and the addition of artificial selection to the forces of natural selection. The changes in environment which accompanied domestication doubtless permitted many differences in heredity to show themselves more clearly than they could in the environment of wild animals, and thus to be more readily and accurately selected. For example, when feed is so scarce that no animal gets all it wants, hereditary differences in ability to fatten could hardly show themselves as clearly as they can in a well-managed feedlot. But there is no direct evidence to indicate that the changed environment directly *created* any new genes or hereditary differences.

Increased inbreeding happened because domesticated animals were more narrowly restricted (by tethering, herding, or fencing) to growing up, remaining, and reproducing in the same region in which they were born. Soon the animals around one community or village would all become related to each other. Most breeders, even among primitive peoples, intentionally avoided the very closest inbreeding; but often the pedigrees were known only for a generation or two, or only in the female line. Under such circumstances, attempts to avoid inbreeding merely made the inbreeding less intense so that more time was required to produce the same amount of fixation and uniformity in the stock. That gave more opportunity for the accompanying selection to discard undesired results of the inbreeding than if the inbreeding had been extremely close. Even when obstacles to exchange between tribes were greatest, some introduction of outside blood went on either by trade or by war. Doubtless these exchanges usually involved stock from only the closest neighboring tribes. Such animals, as a result of previous

exchanges, would already be more closely related to those among which they were introduced than animals which might have been chosen at random from the whole species. There would have had to be a large amount of such interchange to prevent this inbreeding from bringing about a situation where almost every tribe or community would have its own type of each kind of animal. Doubtless the intensity of this inbreeding varied greatly from region to region according to the nomadic habits of the people, geographic barriers, or social customs which may have prevented extensive trade with neighboring tribes, and the extent to which their beliefs about breeding led them to try deliberately to prevent this inbreeding by taking special pains to get sires from unrelated or remotely related stocks. This extra inbreeding resulting from restricting the movements, and also from limiting the number of breeding males, may well have been one of the most potent forces leading to the production of diverse races among domestic animals. It does not seem possible now to measure its past importance accurately, since so little is known about actual breeding customs until very modern times. The geographic or physiologic isolation, which in nature divides so many species into small sub-groups between which crosses occur only at rare intervals, is the very same kind of a process in principle, but probably is rarely as extreme in nature as it is under domestication where man has added so many artificial barriers to the natural ones.

Increased outbreeding has certainly resulted now and then from domestication. By the agency of man, breeding animals could be transported far beyond the area in which they were born or over which they could have wandered before they were domesticated. Thus they could be crossed on races more diverse than they would have encountered if they had remained in the wild state. Knights returning from the Crusades brought with them stallions from Arabia. Cattle were brought from Holland to England across water which would have been impassable to wild cattle. In a later day Merino sheep were taken from Spain to many lands, Angora goats came from Turkey to the United States and to South Africa, zebu cattle came from India to Brazil and to the Gulf Coast of the United States, and Shorthorn cattle went from England to the Argentine and Australia. Many other examples could be cited to show how this process went on in historic times. The diverse races of swine from which the Poland-China breed was formed could hardly by any conceivable circumstances have come together anywhere on earth without the intervention of man to transport them.

Presumably this process has gone on more rapidly in the last three or four centuries of exploration and widespread trade than it did for-

merly, but Phoenician traders were traveling the length of the Mediterranean and skirting the western shores of Europe as far as Britain nearly three thousand years ago and doubtless helped exchange some of the smaller animals at least. Invading armies or migrating peoples usually carried with them much livestock from their native lands; some of these were mingled with the breeding stock of the countries through which they passed. Two thousand years ago Hannibal and Hasdrubal took their armies and livestock, including such large and unwieldy animals as elephants, from Carthage along the northern coast of Africa to Spain and over such mountains as the Pyrenees and Alps almost to Rome itself. Also, Alexander the Great took large numbers of livestock with his armies on the road from Greece to India and had with him men who made careful notes about the strange livestock they saw in the new lands. In the early thirteenth century the armies of Genghis Khan and his sons, with their enormous reserves of cavalry horses, ranged all the way from eastern China to central Europe. The passing of that band of horses (with the inevitably large amount of straying and robbing) must have changed greatly the genetic composition of the local races in the regions through which they passed. With such cases known from definite history, it is only reasonable to suppose that similar exchanges by migrations or wars had been taking place almost since the beginnings of domestication. Here again, as in the case of geographic isolation, there must have been much more of such exchanges in some parts of the world than in others.

A combination of moderate inbreeding alternating with occasional wide outbreeding is an effective plan for producing many distinct families which are moderately uniform within themselves. A population being thus bred is in a more favorable condition for selection to be effective than if matings within the group selected to be parents were entirely at random. In this way domestication made conditions more favorable for the formation of distinct races than exist among wild animals.

Selection means differences in reproductive rates within a population, whereby animals with some characteristics tend to have more offspring than animals without those characteristics. Thereby the genes of the favored animals tend to become more abundant in the population and those of the less favored animals less abundant. Artificial selection differs from natural selection only in the kind or degree of the characteristics which are thus favored. Also, in many cases artificial selection may be more intense, less of the decision being left to chance or to accidental circumstances than in the case of natural selection.

Natural selection did not wholly cease with domestication. More of

the weak and sickly than of the strong and vigorous are still doomed to die before they reach breeding age. This will happen whether the breeder consciously aids in this selection or not. Indeed, some of it will happen in spite of the breeder's efforts if he tries to breed a type which is rather frail or susceptible to disease. Among domesticated animals natural selection is merely supplemented by man's selections. In making his decisions as to which animals should leave few and which should leave many offspring, man often strongly emphasizes characteristics which were of little worth in a state of nature. Other qualities valuable in the wild state became useless or nearly so when man began to protect his animals against their enemies, against cold and against starvation. Thus, man's selection may differ from natural selection both in *intensity* and in *direction*.

The practice of favoring for breeding purposes those animals which in their owner's opinion were the most desirable ones must have begun with domestication itself. The recognition that offspring tend to resemble their parents and other near relatives occurred at so early a cultural stage that proverbs embodying this idea are found in practically all languages, even those of extremely primitive people. Primitive man was doubtless quite shrewd enough to put this knowledge into practice on his domesticated animals. Castration is one of the most ancient of surgical practices. Medical literature traces it back at least as far as 700 B.C., and in the Bible there is frequent reference to eunuchs in the time of Solomon or earlier. Eunuchs are mentioned in the Code of Hamurabi; ca. 2000 B.C. Castrated bullocks (balivarda), as distinct from bulls, are mentioned in the Puranas of the Hindus, which deal with the events of the Aryan migrations into northwestern India probably as long ago as 2400–1500 B.C. (Since the Puranas were not put into writing until much later, the words may have been changed during the interval). The general practice of castration must have intensified the selection which was practiced among males.

The Roman agricultural literature of about two thousands years ago[1] contains many bits of advice about the kinds of animals to select for different purposes. Much of this they had copied from still older writings, such as those of Mago the Carthaginian. It is certain that artificial selection has been practiced by man for thousands of years, although there seems to be no way of measuring the intensity with which it was practiced.

Another aspect of selection which was intensified by domestication was that the characteristics favored for one set of conditions might not

[1] Harrison, Fairfax. 1917. *Roman Farm Management.* 365 pp. New York: The Macmillan Company.

be the same as those favored under other conditions. This, of course, was true in nature also, contrasting characteristics sometimes being favored for life on the open grasslands or for life in the forest, for mountain or lowland, for tropics or temperate climates, etc. In nature these would often—perhaps usually—be characteristic of wide areas with broad transitional zones between them. Under domestication one man might prefer a certain type of horse or cattle, and his next-door neighbor or the people of the very next village might prefer and select for a distinctly different type. Indeed, as agriculture became more complex the same man might keep two or more types of the same species, each being preferred for some special purpose. For instance, the ancient Egyptians had several breeds of dogs, and modern farmers keep different breeds of cattle for beef and for dairy purposes. So far as one breed or type is concerned, this is nothing but selection directed toward that particular ideal; but, from the standpoint of the whole species, this is assortive mating, which is a powerful tool for producing diversity within a species. This seems certain to have been more intensified under domestication than it was in nature.

SUMMARY

Domestication merely intensified forces or processes which already existed in nature. Increased inbreeding alternating with wider outcrossing, more intense selection devoted toward a wider variety of goals, and mating like to like wherever one man or tribe was breeding the same species for two or more different goals, all had the net effect of tremendously speeding up the slow process of evolution as it occurs in nature, until remarkably large changes were made in animals under domestication during what was a very short period in terms of geologic time. That the changes thus brought about were at the maximum rate possible seems highly unlikely. If further changes are desired, it is probable that the possibilities in most directions are by no means exhausted and that intelligent use of these same processes can result in much faster progress than has been averaged during the long (in terms of human lifetimes) history of domestication.

CHAPTER 3

The Beginnings of Pedigree Breeding and the Formation of Breed Registry Societies

"The virtues of their fathers live on in bulls and in stallions." Horace
"Who would grow spirited stallions for the Olympic prizes or strong bulls for the plow, let him choose carefully the females who will be their dams." Virgil

Emphasis on ancestry in human genealogies is older than history, although human pedigrees may have been used more for social purposes, such as to determine the inheritance of property or of rank in a caste system of society, than because of definite beliefs about the inheritance of physical and mental qualities. Often these pedigrees recorded only the male or only the female line of descent. The genealogies in the early chapters of Genesis are examples of this.

Pure breeding is also an ancient idea as applied to man, not only in those peoples which had a pronounced caste system of society but also in many others where a tribe was warring on neighboring tribes, or a conquering race was trying to live with but keep itself "pure" from a conquered or slave race. Also, many tribes or races with a simpler social structure cherished myths about their racial origins which implied that they alone were the chosen people descended from the sun or the moon or some other deity, while other peoples were of inferior or mixed descent. In most (but not all) human societies there has been a heavy social prejudice against the "half-breed," which in general has meant that the half-breed and its descendants must come up to higher standards of individual excellence than the average "purebred" before they would have an equal chance to contribute to the inheritance of the future race.

The Arabs in their horse breeding more than a thousand years ago were memorizing the genealogies of their horses, but we have no detailed knowledge of how these genealogies were used—if at all—to guide them in making the matings. Probably, like the modern Arabs, they traced the pedigrees only in the female line and used the family name only as an aid to selection,[1] also taking some care to avoid close

[1] Nurettin, Aral, and Selahattin, E. 1935. *Der heutige Stand der Pferdezucht in Arabien.* Zeit. f. Züchtung. (Reihe B), 33:13–38.

inbreeding. The Romans of the time of Varro and Cato made many comments about the kinds and types of animals which should be selected for breeding purposes but apparently made no attempt to memorize or record long pedigrees for their livestock. Varro's comments on the importance of judging the breeding worth of a sire by the quality of his get show that in a general way they were aware of the importance of the progeny test and the use of pedigrees, traced at least to the parents and grandparents, to help them to a more correct estimate of an animal's breeding worth.

"Throughout the Middle Ages the authority of the written word almost completely displaced firsthand observation and experiment in the search for truth."[2] Largely because of this, knowledge of the mechanics and laws of heredity advanced but little. Most of the learning was preserved in the monasteries and what little is known about agriculture in the middle ages comes mostly from the account books, inventories, and fragmentary notes kept in connection with the farming operations of the monasteries. It was not until 1700 that enough was written and preserved to give us a connected account of agricultural practices.

The use of pedigrees in the modern manner began in rural England late in the eighteenth century, and the general formation of breed registry societies began around the middle of the nineteenth century. Robert Bakewell is generally given credit for setting the pattern of modern animal breeding and is sometimes called the founder of animal breeding. Perhaps this is giving too much credit to one man, but at any rate pedigree breeding was established in his time, and his own outstanding success had more to do with making it popular than the efforts of any other one man did.

Robert Bakewell was an English farmer or country gentleman who lived from 1725 to 1795.[3] We first hear of his agricultural efforts when he began to manage the estate at Dishley in 1760. He wrote little or nothing about himself. He was a good farmer in other things besides his stock breeding, having taken a prominent part in the introduction of turnips and other root crops into English agriculture. He was a good observer, a keen student of anatomy and probably a good judge of livestock. According to some accounts he even kept for future reference specimens of the bones or pickled joints of animals which he had bred and which he regarded as nearly ideal. He told so little about his opera-

[2] Mees, C. E. Kenneth. 1934. Scientific Thought and Social Reconstruction. *Sigma Xi Quarterly*, 22 (No. 1) :17.

[3] A more complete account of Bakewell's work and of the conditions of animal breeding then is given on pages 176–189 of Lord Ernle's ***English Farming, Past and Present.*** 1936.

tions that many of his contemporaries thought there was something mysterious about them. Some writers hint that this was done deliberately to avoid competition or censure. This latter point is made because an important element in his procedure was the deliberate and intense use of inbreeding. At that time there was even more prejudice against inbreeding than there is today, and many people thought it almost sacrilegious. Perhaps Bakewell thought it no use to invite criticism by proclaiming openly what he was doing. There is also more than a hint that he kept his operations secret because of certain extreme outbreeding he was practicing which, if known, might have injured the commercial reputation of his stock. Thus, there were rumors of a mysterious black ram used in his sheep breeding which visitors were never permitted to see and whose existence he would never admit.

Bakewell's own breeding work was with the old Longhorn cattle, Leicester sheep and Shire horses. He was so successful with these that his animals came into great demand as breeding stock. He inaugurated the practice of ram-letting. That is, he did not sell his best males outright, but rented the use of them a year at a time. His annual auctions, or ram-lettings, attracted great attention and were a distinct financial success. He is said to have received as much as 1,200 guineas for one year's use of a ram. By this practice of ram-letting, the best sires came back to him each year and any whose progeny had proved them much better than the others could be kept for use in his own flocks or herds. There seems to be no record of how many times he took back for his own use a sire which originally he had thought not quite good enough for that, but no doubt such instances occurred.

Bakewell's success attracted many imitators. From many parts of England ambitious stockmen went to Dishley to work with Bakewell and study his methods. Some of them stayed for as much as six months. Returning home they applied his methods to stock secured from him or to what they thought were the best of their own local animals. The details about these students and what they did are poorly known, but it is certain that the Collings who laid the foundations of the Shorthorn breed were in close touch with Bakewell and that men from Herefordshire were students with him. Enough of Bakewell's followers won distinct success that here and there all over England there soon began to be groups of animals closely related to each other and similar in type. These were the groups from which came the modern breeds, most of which were not formally organized as such until later.

The *principles* which Bakewell used included such things as: "Like produces like or the likeness of some ancestor; inbreeding produces prepotency and refinement; breed the best to the best." His greatest

contribution to breeding methods lay in his appreciation of the fact that inbreeding was the most effective tool for producing refinement and fixing type. He was reluctant to make any outcrosses at all when his own stock seemed to him better than that of his neighbors. With his willingness to inbreed was coupled a good knowledge of anatomy and a keen interest in the subject of what types of animals were best suited to his agriculture and should be set up as goals.

The economic setting of the times, of course, had much to do with the increased interest in breeding improved animals. The enclosures of the "common lands" had given the individual farmer opportunity to breed his own stock as he pleased and to reap the rewards of anything he might do to improve them or to build up the fertility of his own lands. The introduction of clovers and root crops to English agriculture had made more intensive animal husbandry possible and had supplied a store of roughages suitable for winter feeding. The times were ripe for commercial appreciation of animals which could utilize the crops of the new agriculture better than their contemporaries and which would produce a quality of product well suited to contemporary market demands. The warfare through the latter half of the eighteenth century, finally coming to a climax in the Napoleonic wars, often made prices high for farm products. Afterward, the industrial revolution and the steadily expanding urban population of Britain made a rising market for agricultural products, more particularly for those like meat which, in the days before refrigeration, could not be imported in the fresh state from the New World. When the improvement which Bakewell and his followers had made in their breeding stock began to be known in other lands, the export of breeding stock to those lands became a considerable source of income to British stockmen. Appreciation of the importance of this was a spur to further improvement in order to keep the foreign customers coming back for fresh breeding stock and had much to do with guiding the policies of breed registry societies.

BREED REGISTRY SOCIETIES

As long as each breed was local the private records of each breeder were adequate for his own purposes. He usually knew at least the sires used by his fellow breeders and knew the integrity of those breeders well enough to have some idea of how much he could depend on their statements or records when purchasing breeding animals from them. But in time the number of breeders increased until many of them were utter strangers to each other, and the number of animal generations in the pedigrees increased until no man could remember all of the foundation animals far back in the pedigrees. To supply this knowledge

and to prevent (as far as other breeders could) unscrupulous traders from exporting grades or common stock as purebreds, herdbooks were formed. The latter motive was very important[4] and generally the herdbook was established soon after there began to be a considerable export demand.

The first herdbook was "An Introduction to the General Stud Book" for the Thoroughbred horse and appeared in 1791. In it were recorded the pedigrees of the horses winning important races. It was aimed, therefore, at recording the pedigrees of performers rather than of all members of the pure breed. The Shorthorn herdbook, which first appeared in 1822, was the next one formed and may be taken as an example of the modern type of herdbook which aims at including the pedigrees of all animals of the pure breed. The Shorthorn herdbook, however, like the one for the Thoroughbred horse, would accept for entry outstanding individuals or performers which would be called high grades in the United States. Later herdbooks were largely modeled after the more successful of the early ones. An English Hereford herdbook was published in 1846 and a Polled Herd Book (for Aberdeen-Angus) in 1862. The first swine herdbook in the world was that of the American Berkshire Association, which appeared in 1876. The Berkshire Society in England was established first in 1883. The first herdbooks in the continental countries of Europe appeared at a later date than in Britain. Studbooks for horses were founded in France in 1826, in Germany in 1827, and in Austria in 1847. The first cattle herdbook in France was established in 1855, the first German one in 1864, the first Dutch one in 1874 and the first Danish one in 1881.

The Shorthorn herdbook was undertaken as a private venture by George Coates, who had been a Shorthorn breeder in a small way. A number of the Shorthorn breeders helped finance him and each was to receive a copy of the book. The other copies were to be his personal property to sell for whatever profit he could. He was already acquainted with many breeders, and from each of them he secured such information as he could about the animals which that man regarded as genuine Shorthorns. No doubt there was plenty of dispute about that. That is, some breeders would say that certain animals should be included in the records while others would think that those animals were not sufficiently desirable to be included as genuine Shorthorns. Coates was criticized, of course, for many of these decisions; and it was even charged[5] (perhaps unjustly) that his favoritism to his personal friends went to the extent

[4] For example, many events in Bates' book (1871) illustrate the incentive which the American demand for Shorthorns gave to the formation of the Coates herdbook.

[5] *See* p. 38 in Bates' *History of Improved Shorthorn or Durham Cattle.*

of printing for their cattle false pedigrees which would make them sell well to the American trade, then becoming important. Where Coates included animals which the majority of the breeders thought were not really pure, the breeders themselves could remedy the situation by having nothing to do with those animals or their descendants—a course of action which is still open today and which is still used freely wherever falsification of pedigrees is suspected but evidence is not complete enough to justify canceling the registration. Wherever Coates omitted from the first volume of his herdbooks animals which the majority of breeders thought should have been included, such mistakes could be corrected by including these pedigrees in succeeding volumes of the herdbook—a process no longer available wherever herdbooks are entirely closed to all but the offspring of registered parents.

Some of the very early breeders objected to furnishing pedigrees of the animals they sold, believing that they would thus give away valuable trade secrets. The demand for full information about pedigrees, however, finally prevailed over the "trade-secret" idea; and it became accepted as a matter of course that anyone selling breeding stock should furnish full identification of their immediate ancestors.

Doubtless many of the contemporary breeders felt that this herdbook of Coates was only a hobby of his which would disappear with his death; but, as the breed became more popular and the number of breeders increased and the number of generations to be remembered in the pedigrees grew larger, the difficulties which first prompted Coates to the formation of the herdbook became greater. Eventually every breeder admitted the necessity of the herdbook, in view of the customer demand for pedigrees, and depended upon it in his purchases and sales of breeding stock. When this stage was reached, those who owned the herdbooks had the power to charge exorbitant fees for registration and transfer or to use their influence to favor the business of certain breeders and to harm that of others. While there was rarely any widespread complaint of this kind, yet it generally seemed wiser or even necessary for the breeders to organize breed associations in order to manage the herdbook, conduct breed promotion, and attend to any other matters which could be handled best by co-operative action.

The typical history of the formation of the British breeds (the breeding practices in the United States are patterned closely after the British ones) was about as follows: First, came the existence of a type which was more useful and desirable than the ordinary type, but which was not yet distinctly different in pedigree from the other animals in the community. Second, some of the best animals of that type were gathered into one or a few herds which then ceased to introduce much

outside blood. Then followed some rather intense inbreeding among these animals and their descendants until the animals of those herds became distinct from the other animals in the community, not only in type but also in inheritance; that is, until they were really welded into a breed. Third, if this process had been moderately successful in producing a desirable kind of animal, the breed became more and more popular and more and more herds were established. Fourth, necessity for a central herdbook arose when the breed became so numerous and the breeders so many that no man could remember all the information needed for the proper use of pedigrees. Fifth, a breed society was formed to safeguard the purity of the breed, conduct the herdbook, and promote the general interests of the breeders. From the very beginning many of these breeders emphasized that the males they produced were especially valuable for crossing on other races or on common stock. An important function of these pure breeds was to produce sires for commercial use on unrelated stock, even for crossbreeding.

In not all breeds did the breed history develop in just exactly these steps. Sometimes there was a breed society before there was a herdbook. Thus, even in Bakewell's time a Dishley Society was founded, with the primary object of protecting the pure breeding of the animals descended from those bred by Bakewell and the commercial promotion of the interests of those who were breeding animals of the Bakewell strains. Often there was no intervening stage of private ownership of the herdbook, but the breed society established the first herdbook itself. In practically every case the breed was a well-established fact before any herdbook was considered. People did not say to each other: "Let's establish a breed." Rather they said: "Here we already have a useful and profitable breed. We should protect its purity and our own interests as possessors of this valuable breeding stock and the interests of the purchasers who want genuine animals of this breed."

In the continental countries of Europe pure breeding and registration were generally organized at a later date than in Britain. In Germany and adjoining lands (Engeler, 1936), extensive efforts at improvement developed first in sheep breeding,[6] then in horse breeding, and then in cattle breeding. In the period about 1800 it was common practice to cross extensively, even for producing seedstock, in accordance with the idea expressed by Buffon (1780) that perfection could be attained only through widespread crossing and mixing of all individuals which had any of the desired points, regardless of race or regional

[6] As long ago as 1779 Daubenton was measuring wool fineness with a micrometer and in 1802 Abilgaard wrote in detail about the reasons for marking sheep individually so that their production could be recorded and used as a basis for selections.

origin. Then for a half century the trend changed toward following the successful English example of pure breeding, that is, of improving a breed from within itself.[7] Some of the writers (but perhaps not many of the breeders themselves?) carried this to an extreme form in what became known as the theory of "racial constancy." This held that each animal transmitted according to its race and not according to its own characteristics. The latter were unimportant except as they indicated the animal's purity of race. Under the influence of that doctrine, herdbooks were only records of genealogy, and official attention was focused almost wholly on purity of breeding.

Sharp reaction to the theory of "racial constancy" developed about 1860, and the pendulum swung far the other way, at least among the writers. Thenceforth attention was devoted more to the individual. They sought more and more to make the herdbooks contain full information about each animal's characteristics, productivity, conformation, reproductive performance, longevity, etc. To collect this information the herdbook societies were organized around semi-official local records which might be either the private herdbook which the breeder was required to keep himself or the records kept by a local breeding association organized somewhat like a dairy herd improvement association in the United States. In either case the records to be kept were definitely prescribed and were inspected more or less regularly by officials of the herdbook society or of the government. From those local records the central herdbook society collected regularly the information thought useful there.

Because of this background, the continental breed associations make more use of formal scoring or other inspections or production requirements as a prerequisite to registry than is done in Britain, where the responsibility of deciding whether a purebred animal is good enough for registry is still left almost entirely with the individual breeder. In Britain it is thought that the reputation of his herd and the resultant prices which the cusomers will pay will more or less automatically reward or penalize the breeder if his efforts have been above or below average.

Often the continental associations have only tentative registry at birth; final registry in a printed herdbook is postponed until an animal is mature or even until it is dead and all of the data on its lifetime performance, prizes won, scores for type, etc., can be printed, too.

At the Strickhof agricultural school at Zurich, Switzerland, the pro-

[7] Thus Krünitz wrote in 1815 with surprise: "The English improve a race from within itself. They choose carefully the best individuals they can find within the same race and mate these together. In this way they keep the stock unmixed and produce a race in which the desired qualities are retained permanently."

duction of all cows has been recorded continuously since 1871. The first cow-testing association in the world was established in 1892 at Vejen in Denmark. For the last two decades about 40 per cent of the cows in Denmark have had their milk weighed and tested. Those thought to be best among these are admitted to registry each year. Often the continental associations were built around some such plan for recording production. At the beginning of 1938, 67 per cent of all cows in Germany were on test but the figure had only very recently risen that high.

In the lands of their origin the breeds usually continued for a long time to register what would be called high grades in the United States. A common rule—which still holds there for many breeds—was that females with four top-crosses of registered sires were eligible to registry themselves if they came up to certain standards of individual excellence. In importing lands, such as the United States and Argentina, the herdbooks have usually been closed from the very beginning, and fashions in pedigrees have often gone to greater extremes in waves of speculation than has been the case in the native lands of the breeds. The greater emphasis which the importing countries placed on strict purity of breeding is illustrated by the fact that for some breeds, e.g., Berkshire swine, Holstein-Friesian and Ayrshire cattle, and Hampshire sheep, herdbooks were established in the United States before they were in the native land of the breed.

Breeders of poultry have never attempted general registration of all eligible individuals. The short life and comparatively small value of the individual birds have made that uneconomical. There have, however, been a number of attempts to register individuals in connection with a scheme of advanced registry for outstanding producers, e.g., Lancashire (England) Poultry Society, Record of Performance in Canada, the Record of Performance in the United States.

As an illustration of the difficulties encountered in assembling the first herdbooks, we may take the pedigree of the first bull in the Coates herdbook and wonder how Mr. Coates collected and verified the information printed for it. That pedigree is as follows:

> "(1) Abelard, Calved in 1812, bred by Major Bower; got by Cecil (120), d. (Easby) by Mr. Booth's Lame Bull (359), g.d. by Mr. Booth's Old White Bull (89), gr. g.d. bought at Darlington."

For a more specific account of some of the kinds of mistakes later found in those first herdbooks, consult the second edition of "The Polled Herd Book" (Aberdeen-Angus in Scotland) and read the preface and the notes in brackets under the pedigrees of bulls numbers 1, 2, 3, 4, 12, 17, 29, 35, 49 and 51.

As an example of the controversies which arose over the purity or non-purity of certain animals may be cited the long controversy in early American Shorthorn history over the "seventeens"[8] which were imported in 1817 and hence were not recorded in the Coates Herdbook since it did not appear until five years later. Also, Bates makes many references to the long controversy over the "Galloway alloy," which one of the early Shorthorn breeders was thought by some of his fellows to have introduced into his Shorthorns.

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[8] *See* pp. 165–72 of "Shorthorn Cattle," by Alvin H. Sanders. Sanders Publishing Company. 1918.

CHAPTER 4

The History of Animal Breeding Methods in the United States

The first settlers in the New World brought with them such animals as they thought would be most useful. In most cases those came from the same communities as the immigrants themselves. Little detail is known about the animals they brought; but that is not surprising, since most of the pioneering period was ended in the region east of the Mississippi River before the period of herdbooks and pedigree breeding began in Britain. Then, too, during pioneering times the problems of defense against marauding men and wild animals and the problems of learning to raise the new crops and of adapting the old crops to the new climate overshadowed in importance any question of animal breeding methods.

Where the new conditions demanded a new type of animal, the pioneers or the first generations of settlers which followed them, seem to have been ready to produce that type. Thus, there were developed the Vermont Merino, the cornbelt breeds of swine, and horses like the Narragansett pacer, the Conestoga, the Morgan and the Standardbred, the American Saddle Horse, the Quarter horse, and many another race of less fame, each of which fitted some local need well enough to become known, but many of which never reached the stage of having an organized herdbook. Many of them have ceased to exist, either because they were engulfed in the flood of undiscriminating enthusiasm which came later for registered stock or because the economic and physical conditions for which they were adapted had ceased to exist.

It is an interesting but perhaps an idle speculation to wonder whether animal industry in the United States would have been more efficient today if in more cases the good local races, already well adapted to local conditions, had been preserved, either as pure breeds or as foundations for breeds combining some of the good traits of the local stock and of the imported breeds used for improving them. Examples of the latter process are such widely separated cases as the American Saddle Horse