center of origin

A **center of origin** (or **center of diversity**) is a geographical area where a group of organisms, either domesticated or wild, first developed its distinctive properties. They are also considered centers of diversity. Centers of origin were first identified in 1924 by Nikolai Vavilov.

A Vavilov Center (of Diversity) is a region of the world first indicated by Nikolai Vavilov to be an original center for the domestication of plants. For crop plants, Nikolai Vavilov identified differing numbers of centers: three in 1924, five in 1926, six in 1929, seven in 1931, eight in 1935 and reduced to seven again in 1940.

Vavilov argued that plants were not domesticated somewhere in the world at random, but that there were regions where domestication started. The center of origin is also considered the center of diversity.

Vavilov centers are regions where a high diversity of crop wild relatives can be found, representing the natural relatives of domesticated crop plants. Later in 1935 Vavilov divided the centers into 12, giving the following list:

1. Chinese center
2. Indian center
3. Indo-Malayan center
4. Central Asiatic center
5. Persian center
6. Mediterranean center
7. Abyssinian center
8. South American center
9. Central American center
10. Chilean center
11. Brazilian-Paraguayan center
12. North American center

World centers of origin of cultivated plants

Center	Plants
1) South Mexican and Central American Center	Includes southern sections of Mexico, Guatemala, Honduras and Costa Rica. • **Grains and Legumes:** maize, common bean, lima bean, tepary bean, jack bean, grain amaranth • **Melon Plants:** malabar gourd, winter pumpkin, chayote • **Fiber Plants:** upland cotton, bourbon cotton, henequen (sisal) • **Miscellaneous:** sweetpotato, arrowroot, pepper, papaya, guava, cashew, wild black cherry, chochenial, cherry tomato, cacao.
2) South American Center	62 plants listed; three subcenters

	2) Peruvian, Ecuadorean, Bolivian Center: • **Root Tubers:** Andean potato, Other endemic cultivated potato species. Fourteen or more species with chromosome numbers varying from 24 to 60, Edible nasturtium • **Grains and Legumes:** starchy maize, lima bean, common bean • **Root Tubers:** edible canna, potato • **Vegetable Crops:** pepino, tomato, ground cherry, pumpkin, pepper • **Fiber Plants:** Egyptian cotton • **Fruit and Miscellaneous:** cocoa, passion flower, guava, heilborn, quinine tree, tobacco, cherimoya, coca ***2A) Chiloe Center*** (Island near the coast of southern Chile) • Common potato (48 chromosomes), Chilean strawberry ***2B) Brazilian-Paraguayan Center*** • manioc, peanut, rubber tree, pineapple, Brazil nut, cashew, Erva-mate, purple granadilla.
3) Mediterranean Center	Includes the borders of the Mediterranean Sea. 84 listed plants • **Cereals and Legumes:** durum wheat, emmer, Polish wheat, spelt, Mediterranean oats, sand oats, canarygrass, grass pea, pea, lupine • **Forage Plants:** Egyptian clover, white clover, crimson clover, serradella • **Oil and Fiber Plants:** flax, rape, black mustard, olive • **Vegetables:** garden beet, cabbage, turnip, lettuce, asparagus, celery, chicory, parsnip, rhubarb, • **Ethereal Oil and Spice Plants:** caraway, anise, thyme, peppermint, sage, hop.
4) Middle East	Includes interior of Asia Minor, all of Transcaucasia, Iran, and the highlands of Turkmenistan. 83 species • **Grains and Legumes:** einkorn wheat, durum wheat, poulard wheat, common wheat, oriental wheat, Persian wheat, two-row barley, rye, Mediterranean oats, common oats, lentil, lupine • **Forage Plants:** alfalfa, Persian clover, fenugreek, vetch, hairy vetch • **Fruits:** fig, pomegranate, apple, pear, quince, cherry, hawthorn.
5) Ethiopia	Includes Abyssinia, Eritrea, and part of Somalia. 38 species listed; rich in wheat and barley. • **Grains and Legumes:** Abyssinian hard wheat, poulard wheat, emmer, Polish wheat, barley, grain sorghum, pearl millet, African millet, cowpea, flax, teff • **Miscellaneous:** sesame, castor bean, garden cress, coffee, okra, myrrh, indigo, enset.
6) Central Asiatic Center	Includes Northwest India (Punjab, Northwest Frontier Provinces and Kashmir), Afghanistan, Tadjikistan, Uzbekistan, and western Tian-Shan. 43 plants

	• **Grains and Legumes:** common wheat, club wheat, shot wheat, peas, lentil, horse bean, chickpea, mung bean, mustard, flax, sesame • **Fiber Plants:** hemp, cotton • **Vegetables:** onion, garlic, spinach, carrot • **Fruits:** pistacio, pear, almond, grape, apple.
7) Indian Center	Two subcenters ***7) Indo-Burma:*** Main Center (India): Includes Assam, Bangladesh and Burma, but not Northwest India, Punjab, nor Northwest Frontier Provinces, 117 plants • Cereals and Legumes: chickpea, pigeon pea, urd bean, mung bean, rice bean, cowpea, • Vegetables and Tubers: eggplant, cucumber, radish, taro, yam • Fruits: mango, tangerine, citron, tamarind • Sugar, Oil, and Fiber Plants: sugar cane, coconut palm, sesame, safflower, tree cotton, oriental cotton, jute, crotalaria, kenaf • Spices, Stimulants, Dyes, and Miscellaneous: hemp, black pepper, gum arabic, sandalwood, indigo, cinnamon tree, croton, bamboo, turmeric, ***7A) Siam-Malaya-Java:*** statt Indo-Malayan Center: Includes Indo-China and the Malay Archipelago, 55 plants • Cereals and Legumes: Job's tears, velvet bean • Fruits: pummelo, banana, breadfruit, mangosteen • Oil, Sugar, Spice, and Fiber Plants: candlenut, coconut palm, sugarcane, clove, nutmeg, black pepper, manila hemp.
8) Chinese Center	A total of 136 endemic plants are listed in the largest independent center • **Cereals and Legumes:** e.g. rice[9] broomcorn millet, Italian millet, Japanese barnyard millet, sorghum, buckwheat, hull-less barley, soybean, Adzuki bean, velvet bean • **Roots, Tubers, and Vegetables:** e.g. Chinese yam, radish, Chinese cabbage, onion, cucumber • **Fruits and Nuts:** e.g. pear, Chinese apple, peach, apricot, cherry, walnut, litchi, orange • **Sugar, Drug, and Fiber Plants:** e.g.sugar cane, opium poppy, ginseng camphor, hemp.

Importance

In 2016, researchers linked the origins and primary regions of diversity ("areas typically including the locations of the initial domestication of crops, encompassing the primary geographical zones of crop variation generated since that time, and containing relatively high species richness in crop wild relatives") of food and agricultural crops with their current importance around the world in modern national food supplies and agricultural production. The results indicated that foreign crops were 68.7% of national food supplies as a global mean, and their usage has greatly increased in the last fifty years.

Methods used by Vavilov for determining the centers of type-formation (centers of origin) of cultivated plants

For the purpose of establishing the centers of type-formation or the centers of diversity the 'differential phyto-geographical method' was applied (Vavilov 1935). It can be described by the following steps:

1. A strict differentiation of the plants studied into Linnaean species and intraspecific groups by all available means of various disciplines beginning with morphology, agrobotany, phytopathology, cytology and recently by molecular methods.

2. Delimitation of the distribution areas of these plants and, if possible, also of the distribution areas in the remote past when communication and seed exchange were more difficult than at present.

3. A detailed determination of the composition of the varieties and races of each species, and a general system of the genetic variability within the different species.

4. Establishment of the distribution of the genetic variability of the forms of a given species as far as regions and areas are concerned, and the establishment of the geographical centers where these varieties are now accumulated. Regions of maximum diversity, usually also including a number of endemic types and characteristics, can also be centers of type-formation.

5. For a more exact definition of the center of origin and type-formation it is necessary to establish the geographical centers of concentrations of species that are botanically closely related as well.

6. Finally, the establishment of the areas of diversity of wild subspecies and species that are closely related to the cultivated species in question should be used for amendment and addition to the area defined as area of origin, when the differential method for studying races is applied to them.

Vavilov's original concepts

In 1940 Vavilov stated that the method of differential taxonomy offers an opportunity to trace the dispersal of many cultivated plants. It demonstrates their stages of evolution with respect to both the initial origin and their introduction into cultivation within different areas. It shows their relation to wild subspecies and species, but also demonstrates the subsequent evolution under domestication of these plants when dispersed from the basic centers and undergoing changes under new conditions and the further effects of natural and artificial selection.

The studies of the origin of different cultivated plants led Vavilov to the establishment of new concepts, i.e. primary and more ancient crops in contrast to secondary ones, allowing him to characterize with good precision the centers where agriculture originated and the pathways along which it was dispersed.

The study of the laws of the geographical distribution of plant resources on earth and the establishment of the enormous infraspecific diversity of the majority of crops allowed not only a determination of their localization but also offered an opportunity to ascertain the period of origin of the plants most important for cultivation. In 1924 Vavilov wrote: "The history and origin of human civilizations and agriculture are, no doubt, much older than what any ancient documentation in the form of objects, inscriptions and bas-reliefs reveals to us. A more intimate knowledge of cultivated plants and their differentiation into geographical groups helps us attribute their origin to very remote epochs, where 5000 to 10,000 years represent but a short moment" (Vavilov 1992).

The number of centers listed in Vavilov's papers increased dramatically during a comparatively short period from three in 1924 to five during 1926, six in 1929, seven in 1931 and eight in 1935, but was again reduced to seven in 1940. Each publication appeared to be the result of consideration of additional data (Vavilov 1924, 1929, 1931, 1932, 1935, 1938, 1940).

In 1932, Vavilov wrote: "Many historical problems can be understood only because of the interaction between man, animals and plants." Centers differ with respect to the concentration of specific variation. Vavilov attached great importance to data indicating regions of major concentration of specific and generic variation. During the arrangement of these regions according to the richness of cultivated floras, the Chinese center was put in first place and the Hindustani one in second (Vavilov 1934). More recent data (1940) led to the necessity for changing these places: 33% of all cultivated plant species are to be found concentrated in the southern Asiatic tropical center, which at Vavilov's time nourished up to one-fourth (now one-third) of the population of the world. In eastern Asia, the second most important center, 20% of the number of species of cultivated plants are grown. As far as the number of species introduced into cultivation is concerned, southwestern Asia follows with 14%. However, Vavilov attached a particular importance to that center since the composition of what is cultivated in the territory of Russia is a consequence of the influence from Asia in general and specifically from Asia Minor in a wide sense and Inner Asia. He determined the boundaries of that center.

In the papers published in 1934 and 1935, the division of southwestern Asia into two centers is suggested: the Middle Asian one and one covering Asia Minor. In 1937, the Middle Asian center was renamed the Inner Asian one. It belongs to one of the five major regions where cultivated plants originated in Asia and includes northwestern India, Afghanistan and the mountainous parts of Turkistan (Uzbekistan, Tajikstan and a part of Turkmenistan). This name, however, does not agree with the centers of origin or with their subdivision in Vavilov's later papers. Its appearance is explained by the fact that during that period and until recently, the exact spatial-geographical borders of Inner Asia had not been clearly outlined (Grach 1984).

After rejecting the division of the southwestern Asiatic center, Vavilov (1938, 1940) discussed the composition of the complex of species formed by cultivated plants within the territory in question. He refers to the close relationship between Cis-Caucasus and Asia Minor: "An enormous potential of species and even of genera is concentrated there, constituting genetically distinct units" (Vavilov 1938). In addition to quantitative characteristics, Vavilov concentrated his attention on the specific composition of cultivated plants for each of which endemic genera, species and even forms occurred.

Vavilov used equally the terms 'center', 'focus' and also 'area' of origin. Their definition is important: the geographical centers are basic and independent foci where agricultural crops originated but are also geographic areas where cultivated plants are grown. Passing from one of Vavilov's papers to another concerning the problem of the origin of cultivated plants, it is possible to conclude that the terms 'center' and 'focus' are mainly associated with large territories. In his last papers, he writes about 'areas of basic origin of cultivated plants' and about the conventional concept of 'center of origin' such as suggested by Darwin.

Summing up the data concerning the hundreds of cultivated plants from all over the world resulting from the systematic collection by the All-Union Institute of Plant Industry (VIR), Vavilov wrote in 1935: "We can now speak with a considerably greater accuracy than dreamed of ten years ago about the eight ancient and basic centers of agriculture in the world, or, more accurately about the eight independent areas where plants were initially taken into cultivation."

The domestication of the plant was man's crowning achievement. It allowed us to develop into the complex global society that we are today. We are arguably more dependent on those same crop species domesticated by early man up to 10,000 years ago than we ever have been. Whether early man joyfully embraced the new technology of agriculture is debatable, but once it caught on it spread quickly across continents. The hunter-gatherer systems of old were notoriously land inefficient. It took large acreages to support these early humans, and so agriculture arose from necessity and allowed more people to survive on fewer acres.

The process of man's conversion to agricultural systems was spurred along by the warming of the earth and the scarcity of large land mammals previously hunted for food and clothing. The plants used to fill the void were less selected than they were chanced upon. Traits that made domestication possible were controlled by few genes. These traits were fixed quickly and we are left with those same original domesticated crops from antiquity. The crops have certainly evolved, but not as much as they did during those first centuries.

With domestication came some negative aspects such as reduced genetic diversity. The genetic bottle neck effect seen in modern crops is a product of man's selection for desirable agronomic traits. Unfortunately modern crops are often susceptible to disease, insects, and abiotic stresses. To find resistance genes it is often necessary to go back to their wild ancestors and close relatives. This is can be problematic due to the setback in yields attained when crossing to wild relatives, but it necessary for advancement of the crop. An understanding of crop domestication can help the plant breeder in her pursuit of the next best plant.

Early humans lived as hunter gatherers, victims of the wax and wane of the ecosystem in which they inhabited. For those that lived in grassland systems, a nomadic existence, following the plants and animals they fed upon was necessary. Tropical forest dwellers or those that lived in ecosystems where food was available year-round could build more permanent homes. They all depended on that which sprang forth from the ground naturally for their sustenance however, which meant that their fates were not necessarily their own to choose. Food availability depended on what the ecosystem could provide, and searching for that food required a great deal of early man's time and energies. Survival was a full-time job. This inherent lack of control over their fates changed roughly 5,000 to 10,000 years ago with the domestication of the plant species that would become the first agricultural crops (Smith and Pluciennik, 1995). The change did not occur abruptly (Anderson, 1956), and certainly did not resemble what we today would call agriculture for quite some time.

The domestication of the plant was arguably the single most important technological advance in our history, and allowed us to develop into the highly complex civilization we have become. As technologically advanced as we might be, we are still as dependent on plants as we have ever been. It could be argued, that with the current population and rate of growth, we are more dependent on these crops than ever. There were 6.1 billion humans on earth in 2000, and current population estimates for 2050 range from 7.4 billion to 10.6 billion (UN, 2004). Not only is that a lot of mouths to feed, but homes for 7 to 10 billion people covers large amounts of land. Much of that same land will be needed for food and fiber production.

It is interesting that the crops we grow globally today, to feed an ever growing society, in most cases were the same species our ancestors originally domesticated thousands of years ago. The beginnings of agriculture and plant domestication occurred at different times and places, with different plant species, for different societies around the globe (Flannery, 1973). It appears that some societies did this independently of each other, and for other societies the technology was introduced. An in-depth review of the archaeological evidence is beyond the scope of this chapter however, a discussion of plant domestication is impossible without an archaeological perspective.

MAN'S DOMESTICATION OF THE PLANT

The most likely model of man's transition to food production from hunting and gathering is one that includes several explanatory variables and probably occurred gradually in several stages (Ford, 1985; Harris, 1989; Redding, 1988). The exact mode of action is contentiously debated; however, Redding (1988) provides a useful generalized method. The proposed model involves the hunter-gatherer population for a given environment reaching the carrying capacity of the land and using methods to side-step the carrying capacity, either by avoidance or by directly increasing the capacity. The inhabitants of the over-populated environment would have dealt with the lack of resources by 1) emigration, 2) reducing reproductive rate, 3) diversification, or 4) storage (Redding, 1988).

It is necessary to explain these methods clarified by Redding (1988), as they are tantamount to the evolution of agriculture. Emigration to a new environment with more available plants and animals to hunt is probably the easiest and most common method ancestral man used to escape the limited carrying capacity of a given environ. Reducing the reproductive rate would have held the population level at the environment's carrying capacity for a longer period. Diversification involved finding new sources of nutrition like a novel food plant or devising new technology to process an available resource not yet utilized for food, such as a mortar and pestle. To decrease the uncertainty of the food supply, humans would have had to broaden their food choices and devise new methods to exploit novel sources (Flannery et al., 1969; Stiner et al., 2000).

Storage could be considered a form of diversification, as it in many cases involves development of technology. It is most likely the source from which agriculture evolved. Food storage could include capturing more animals than a group could consume immediately, and tying them up for later consumption. It could also include the storage and carrying of edible seeds to eat later. The storage and transport of seeds could have easily led to planting the seeds for later harvest the next time the hunting-gathering group camped in the same area (Redding, 1988).

Any number of likely scenarios exists for the small leap from simply carrying around a few extra seeds for a later snack, to the conscious effort of saving some seeds to plant in a favorite tribal camping ground. The small leap might have been spurred along by the rapidly changing climactic conditions of the late Pleistocene and early Holocene (Richerson et al., 2001). As the earth warmed and glaciers receded the large land mammals became less numerous. As the preferred nutrition of our hunter-gatherer forebears declined in numbers, human populations simultaneously increased. This increase in human population and decrease of such a vital resource caused the early humans to search for new resources and develop new behaviors (Binford and Binford, 1968; Flannery et al., 1969).

THE SPREAD OF AGRICULTURE

It is commonly held that agriculture arose at as many as nine different locations scattered around the globe, independently of each other. These agricultural origins essentially mirror Vavilov's originally proposed "centers of origin." These centers of origin are the places where Vavilov suggested the currently cultivated crop species were originally domesticated from the wild type (Vavilov, 1926). It is from these centers that domesticated plants and agriculture first spread. The spread of this new technology would have been a slow process. It is unlikely that wholly nomadic peoples converted to sedentary agricultural systems over-night. It is more likely that the transition was a slow one, involving both methods together for quite some time before finally settling down into a wholly agrarian existence (Smith, 2001a; Smith, 2001b).

These new methods and new plants would have spread faster going east or west across the globe from their origin. This east/west spread was easier due largely to plant adaptability to climate (Diamond, 1997). As was found to be the case in Africa, the spread north or south was more difficult due to climate adaptation (Marshall and Hildebrand, 2002). Cohen et al. (1984) suggest that the beginnings of agriculture would have resulted in decreased fitness for adherents to the new method. This could very well be the case for groups who were forced to switch from an entirely hunter-gatherer existence to an entirely agricultural existence due to lack of prey animals or some catastrophe. The agricultural outputs would have struggled to catch up with necessity. In an experiment to test the difficulty of harvesting wild grains by hand, one researcher went to a naturally occurring stand of wild wheat in Turkey. He demonstrated that a person could easily harvest a year's supply of grain in just a couple of weeks using nothing but their hands, and considerably more grain with a hand-held sickle made of flint (Harlan, 1967). So, given a shortfall in the productivity of a certain environ, it would have been quite easy to harvest sufficient food from the plant-scape of one's environment. The limiting factor would be knowledge of which plants to taste or eat. Once the knowledge hurdle was crossed, the idea would have spread quickly within and without camps.

IMPORTANCE

The domestication of the plant and the subsequent development of agriculture allowed people to set down permanent roots and develop the rich cultures that led to our existence. With agriculture came the production of excess food and sedentary villages that were hitherto unobtainable. The excess of food, and the decrease in time required to spend foraging, lead to a division of labor, the development of such things as art and science, and gave birth to modern civilization (Diamond, 2002). Population growth, thought to be a contributing factor to the development of agriculture, was also a consequence of agriculture's increased sedentism (Lee, 1980). Fortunately, more people could be sustained by a smaller land area with agriculture than before.

CONSEQUENCES OF DOMESTICATION

Few plant species, of the thousands of possibilities, were ever domesticated for food, fiber, or other human use. In the immensely popular book, "Guns, Germs and Steel: The Fates of Human Societies", Diamond (1997) cites a simple explanation for the domestication of this small percentage of available species. His basic hypothesis is that these species were used for their ease of breeding for those traits that made them useful plants. That is, the traits which made some plants desirable to the early plant breeders/domesticators were controlled by few genes (Diamond, 1997). This idea is supported by a great deal of molecular work discussed later in this paper. This is interesting, and answers some very important questions. An example of this simple inheritance of important agricultural traits is the shattering system in wheat and barley. The mechanism by which wheat and barley scatter their seeds at maturity is controlled by a single gene. When man selected for the non-shattering type wheat, the trait was fixed quickly and easily, making the crop preferable to others that might have been candidates (Zohary and Hopf, 1988). It is obvious that our early ancestors would have preferred these cereals to all others simply because the grain stayed on the plant longer, and so the harvest window was longer than others.

It seems that crop species were not necessarily selected, but serendipitously discovered because they did not need much tinkering to become valuable food sources and agricultural models. The leap from useless weed to valuable food source was short and relatively easy. Almonds provide another example of simple inheritance of beneficial traits. The wild progenitors of almonds contained bitter chemicals to fend off predators, however, the mutation that makes the distasteful compounds absent is a single gene system and as such was easy to select. Oak tree acorns, on the other hand, have similar distasteful compounds within them, but the trait is a polygenic trait, making selection difficult, especially for the unwitting plant breeders of antiquity, which might explain why oak trees have never been domesticated (Diamond, 1997).

Among the cultivated species, a certain set of traits exist that are common to nearly all of them. It was originally postulated by Charles Darwin that differences seen in cultivated plants from their wild relatives was due to selection pressures by early man (Darwin, 1859; Darwin, 1868). These are the traits that make the plants productive and beneficial to human society. This group of traits is commonly referred to as "domestication syndrome," first proposed by Hammer (1984) and later expounded upon by Harlan (1992). The domestication syndrome traits imbued the crop plants with uniformity, predictability, and high productivity (Table 1). There are several traits involved or contributing that include short stature (rice, wheat), large fruit with tasty flesh (tomatoes, apples), non-shattering (rice, wheat, sorghum), reduced seed dormancy (common beans), and reduced feeding deterrents (virtually all). These traits are summarized by Frary and Doganlar (2003), and in the summary there is included a discussion on how few genes control each of these critical traits.

There is no better example of how these traits can come together to produce something truly nutritive, than corn and its progenitor teosinte. Teosinte is a weedy looking grass with a small seed head made up of only two rows of several small, hard seeds. It looks as though it came out of a gardener's nightmare. But somehow this wild and bushy bunch grass became the robust, single stalked behemoth we now know as field corn, whose constituents are used as ingredients in a plethora of food products consumed heartily by Americans daily.

Table 1. Traits associated with plant domestication (Murphy 2007)

Trait	Wild Plant	Domesticated Crop
Height	Tall	Short/dwarf
Growth Habit	Branched/Bushy	Compact
Ripening	Asynchronous	Synchronous
Seed Dormancy	Present	Absent
Seed Shattering	Shattering heads	Non-shattering heads
Fruit/Seed Size	Small	Large
Ease of dispersal	Highly dispersible	Loss of dispersal
Threshing	Hard	Easy
Reproduction	Out-breeding	Self-fertilizing
Germination	Asynchronous	Synchronous
Hairs/spines	Present	Absent/reduced
Toxins	Present	Absent/reduced

The domestication traits would have been immensely important to the early agriculturalist, and rapidly fixed within their germplasm. It has also been shown by several researchers that many of these domestication traits are clustered near each other on the chromosome, and so are often closely linked (Cai and Morishima, 2002; Khavkin and Coe, 1997; Koinange et al., 1996; Poncet et al., 2000; Xiong et al., 1999). This clustering of domestication traits along the genome, and the small number of genes controlling these traits, suggest that the jump from wild, weedy progenitor might have occurred quite quickly, perhaps in as little as 100 years (Frary and Doganlar, 2003). This is of course hard to prove without archaeological evidence.

THE BOTTLENECK CONCEPT

It is evident that genetic diversity of our crops is much lower than that of their wild relatives. Early farmers would have noticed these few mutants or deviants that exhibited a beneficial trait, kept them and planted them over and over again. This reduction of genetic diversity gave rise to what is known as the genetic bottleneck due to domestication. The bottleneck effect of domestication on the genetic diversity of crops was most likely due to small founder populations of the plants and strong selection pressures imposed upon these populations (Iqbal et al., 2001; Tanksley and McCouch, 1997).

CONCLUSION

Plant domestication was arguably the single most important advancement in the history of mankind. Once developed, agriculture spread across the globe like wild-fire. Our early ancestors unwittingly selected for traits that were easily fixed within the crop species, and as a product of their selection pressures, we now have reduced genetic diversity within our crops. Genetic bottlenecks have reduced the base of breeding materials available to the modern-day plant breeder. Fortunately, however, we know of this short-coming, and have tools to combat it. We know the centers of origin for most crops and have the wild relatives to use as sources of diversity. There is much that can still be achieved through plant breeding of the crops and genetic resources we have. As easy as it may be to complain and dwell on the lack of genetic diversity within our crops due to domestication. A discussion of plant domestication would be insufficient if it was not mentioned that our ancestors did an amazing job as amateur plant breeders. For people who never had the opportunity to attend a plant breeding class, much less learn how to tie a shoe, they did quite a service for us. It is truly amazing that the crops domesticated thousands of years ago are still with us today feeding 6 billion individuals.

Differences from wild plants

Domesticated plants may differ from their wild relatives in many ways, including

- the way they spread to a more diverse environment and have a wider geographic range
- different ecological preference (sun, water, temperature, nutrients, etc. requirements), different disease susceptibility;
- conversion from a perennial to annual;
- loss of seed dormancy and photoperiodic controls;
- simultaneous flower and fruit, double flowers;
- a lack of shattering or scattering of seeds, or even loss of their dispersal mechanisms completely;

- less efficient breeding system (e.g. lack normal pollinating organs, making human intervention a requirement), smaller seeds with lower success in the wild, or even complete sexual sterility (e.g. seedless fruits) and therefore only vegetative reproduction;
- less defensive adaptations such as hairs, thorns, spines, and prickles, poison, protective coverings and sturdiness, rendering them more likely to be eaten by animals and pests unless cared by humans;
- chemical composition, giving them better palatability (e.g. sugar content), better smell, and lower toxicity;
- edible part larger, and easier separated from non-edible part (e.g. freestone fruit).

Traits that are being genetically improved

There are many challenges facing modern farmers, including climate change, pests, soil salinity, drought, and periods with limited sunlight.

Drought is one of the most serious challenges facing farmers today. With shifting climates comes shifting weather patterns, meaning that regions that could traditionally rely on a substantial amount of precipitation were, quite literally, left out to dry. In light of these conditions, drought resistance in major crop plants has become a clear priority.One method is to identify the genetic basis of drought resistance in naturally drought resistant plants, i.e. the Bambara groundnut. Next, transferring these advantages to otherwise vulnerable crop plants. Rice, which is one of the most vulnerable crops in terms of drought, has been successfully improved by the addition of the Barley hva1 gene into the genome using transgenetics. Drought resistance can also be improved through changes in a plant's root system architecture,such as a root orientation that maximizes water retention and nutrient uptake. There must be a continued focus on the efficient usage of available water on a planet that is expected to have a population in excess of nine-billion people by 2050.

Another specific area of genetic improvement for domesticated crops is the crop plant's uptake and utilization of soil potassium, an essential element for crop plants yield and overall quality. A plant's ability to effectively uptake potassium and utilize it efficiently is known as its potassium utilization efficiency. It has been suggested that first optimizing plant root architecture and then root potassium uptake activity may effectively improve plant potassium utilization efficiency.

Crop plants that are being genetically improved

Cereals, rice, wheat, corn, sorghum and barley, make up a huge amount of the global diet across all demographic and social scales. These cereal crop plants are all autogamous, i.e. self-fertilizing, which limits overall diversity in allelic combinations, and therefore adaptability to novel environments.To combat this issue the researchers suggest an "Island Model of Genomic Selection". By breaking a single large population of cereal crop plants into several smaller sub-populations which can receive "migrants" from the other subpopulations, new genetic combinations can be generated.

The Bambara groundnut is a durable crop plant that, like many underutilized crops, has received little attention in an agricultural sense. The Bambara Groundnut is drought resistant and is known to be able to grow in almost any soil conditions, no matter how impoverished an area may be. New genomic and transcriptomic approaches are allowing researchers to improve this relatively small-scale crop, as well as other large-scale crop plants. The reduction in cost, and wide availability of both microarray technology and Next Generation Sequencing have made it possible to analyze underutilized crops, like the groundnut, at genome-wide level. Not overlooking particular crops that don't appear to hold any value outside of the developing world will be key to not only overall crop improvement, but also to reducing the global dependency on only a few crop plants, which holds many intrinsic dangers to the global population's food supply.

Working with wild plants to improve domestics

Work has also has been focusing on improving domestic crops through the use of crop wild relatives.The amount and depth of genetic material available in crop wild relatives is larger than originally believed, and the range of plants involved, both wild and domestic, is ever expanding.Through the use of new biotechnological tools such as genome editing, cisgenesis/intragenesis, the transfer of genes between crossable donor species including hybrids, and other omic approaches.

Wild plants can be hybridized with crop plants to form perennial crops from annuals, increase yield, growth rate, and resistance to outside pressures like disease and drought. It is important to remember that these changes take significant lengths of time to achieve, sometimes even decades. However, the outcome can be extremely successful as is the case with a hybrid grass variant known as *Kernza*. Over the course of nearly three decades, work was done on an attempted hybridization between an already domesticated grass strain, and several of its wild relatives. The domesticated strain as was more uniform in its orientation, but the wild strains were larger and propagated faster. The resulting *Kernza* crop has traits from both progenitors: uniform orientation and a linearly vertical root system from the domesticated crop, along with increased size and rate of propagation from the wild relatives.

Effects

On domestic animals

Selection of animals for visible "desirable" traits may have undesired consequences. Captive and domesticated animals often have smaller size, piebald color, shorter faces with smaller and fewer teeth, diminished horns, weak muscle ridges, and less genetic variability. Poor joint definition, late fusion of the limb bone epiphyses with the diaphyses, hair changes, greater fat accumulation, smaller brains, simplified behavior patterns, extended immaturity, and more pathology are among the defects of domestic animals. All of these changes have been documented by archaeological evidence, and confirmed by animal breeders in the 20th century. In 2014, a study proposed the theory that under selection, docility in mammals and birds results partly from a slowed pace of neural crest development, that would in turn cause a reduced fear–startle response due to mild neurocristopathy that causes domestication syndrome. The theory was unable to explain curly tails nor domestication syndrome exhibited by plants.

A side effect of domestication has been zoonotic diseases. For example, cattle have given humanity various viral poxes, measles, and tuberculosis; pigs and ducks have given influenza; and horses have given the rhinoviruses. Many parasites have their origins in domestic animals. The advent of domestication resulted in denser human populations which provided ripe conditions for pathogens to reproduce, mutate, spread, and eventually find a new host in humans.

Paul Shepard writes "Man substitutes controlled breeding for natural selection; animals are selected for special traits like milk production or passivity, at the expense of overall fitness and nature-wide relationships...Though domestication broadens the diversity of forms – that is, increases visible polymorphism – it undermines the crisp demarcations that separate wild species and cripples our recognition of the species as a group. Knowing only domestic animals dulls our understanding of the way in which unity and discontinuity occur as patterns in nature, and substitutes an attention to individuals and breeds. The wide variety of size, color, shape, and form of domestic horses, for example, blurs the distinction among different species of *Equus* that once were constant and meaningful.

On society

Some anarcho-primitivist authors describe domestication as the process by which previously nomadic human populations shifted towards a sedentary or settled existence through agriculture and animal husbandry. They claim that this kind of domestication demands a totalitarian relationship with both the land and the plants and animals being domesticated.

On diversity

Sustainable agriculture:

In 2016, a study found that humans have had a major impact on global genetic diversity as well as extinction rates, including a contribution to megafaunal extinctions. Pristine landscapes no longer exist and have not existed for millennia, and humans have concentrated the planet's biomass into human-favored plants and animals. Domesticated ecosystems provide food, reduce predator and natural dangers, and promote commerce, but have also resulted in habitat loss and extinctions commencing in the Late Pleistocene. Ecologists and other researchers are advised to make better use of the archaeological and paleoecological data available for gaining an understanding the history of human impacts before proposing solutions.[

Genetic Diverity:

Genetic diversity is the total number of genetic characteristics in the genetic makeup of a species. It is distinguished from genetic variability, which describes the tendency of genetic characteristics to vary.

Genetic diversity serves as a way for populations to adapt to changing environments. With more variation, it is more likely that some individuals in a population will possess variations of alleles that are suited for the environment. Those individuals are more likely to survive to produce offspring bearing that allele. The population will continue for more generations because of the success of these individuals.

What is genetic diversity?

Genetic diversity refers to the diversity (or genetic variability) within species.

Each individual species possesses genes which are the source of its own unique features: In human beings, for example, the huge variety of people's faces reflects each person's genetic individuality. The term genetic diversity also covers distinct populations of a single species, such as the thousands of breeds of different dogs or the numerous variety of roses.

What is the significance of genetic diversity?

The huge variety of different gene sets also define an individual or a whole population's ability to tolerate stress from any given environmental factor.

While some individuals might be able to tolerate an increased load of pollutants in their environment, others, carrying different genes, might suffer from infertility or even die under the exact same environmental conditions. Whilst the former will continue to live in the environment the latter will either have to leave it or die. This process is called natural selection and it leads to the loss of genetic diversity in certain habitats. However, the individuals that are no longer present might have carried genes for faster growth or for the ability to cope better with other stress factors.

How do human activities affect genetic diversity?

Any change in the environment - natural or human induced causes a selection of events that only the fittest survive.

Anthropogenic impact is particularly apparent in the coastal zone and increases the number of changes occurring to individual and populations. Such pressure is exerted by

- artificial selection (harvesting, aquaculture)
- degradation of habitats (leading to a reduction of total stocks and thus increasing the likeliness of inbreeding) and
- the release of farmed fish into the wild. These activities reduce the sum of genes available, thus leaving behind a population that is less capable of tolerating any further natural or anthropogenically caused changes in environment.

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Why prevent the loss of genetic diversity?

The loss of genetic diversity is difficult to see or measure. In contrast, the reduction and extinction of populations is far easier to see. Extinction is not only the loss of whole species, but is also preceded by a loss of genetic diversity within the species.

This loss reduces the species ability to perform its inherent role in the whole ecosystem.

Furthermore, the loss of genetic diversity within a species can result in the loss of useful and desirable traits (e.g. resistance to parasites). Reduced diversity may eliminate options to use untapped resources for food production, industry and medicine.