

Plant domestication: Wheat and Corn

- I. Review of Terms:
 - a. Wild plants: plants that grow in nature without the aid of humans
 - b. Cultivated plants/crop plants: plants that are planted/cared for by humans
 - c. Agriculture: the practice of caring for/cultivating plants
 - d. Domesticated plants

- II. What is domestication?
 - a. Domus = house or dwelling (e.g., domestic servant, a servant that lives in your house) – a completely domesticated plant is completely dependent upon man for survival
 - b. Domestication is an **evolutionary process** that occurs over time as humans select plants from wild populations and begin cultivating them. (selection process for adaptation to the human (cultivated) environment (farmers and consumers). Domesticated plants are those that are genetically distinct from their wild progenitors
 - c. Darwin's use of domestication as evidence for his theory of Evolution by Natural Selection: (Chapter 1: Evolution Under Domestication)
 - i. **Evidence of selection:** over time, humans have selected and cultivated varieties that are of use to us
 - ii. **Evidence for genetic variation:** Cultivated plants show higher levels of phenotypic variation than wild progenitors – a nearly infinite amount of variation is possible

- III. Where does domestication take place?
 - a. All of our domesticated plants come from what were once wild populations
 - b. Domestication happens somewhere in plants' native range (example corn)
 - c. How do we know where a domesticated plant originated?
 - i. Vavilov: origin = center of crop genetic diversity
 - ii. Where wild relatives occur
 - iii. Fossil remains of domesticated plants
 - d. How do we know what the crops' wild relatives are?
 - i. Morphological comparisons
 - ii. Genetic analyses
 - e. We depend on < 1% of living species; in the course of history, people have used ~7000 plant species for food (there are at least 75,000 species of edible plants in existence. 90% of the world's food comes from 15 species (wheat, corn, and rice supply 2/3s this amount

Although there are 10,000 species of cereals, no new ones have been brought into cultivation during the past 2000 years

Darwinian Evolution:

Charles Darwin. great observer

Observed. Variation in nature.

Observed Variation in many directions-- some good, some bad. seemed random

Deduced that there must be a struggle for existence -- based on T. Malthus essay on human population growth

Deduced that some variants more fit than others in this "struggle"

The most fit let their genes in population, therefore population changed over generations.

Domestication--- evolutionary process --is artificial selection

Evolutionary processes affect domestication: drift and bottleneck

Drift --random changes in populations due to small sample size

Bottleneck: loss of genetic variation due to small population size

What happens during domestication?

- f. Basic scenario: people find plants in growing in the wild. They pick the plants that have desirable traits (e.g., the fruits are bigger, sweeter, lower to the ground, more nutritious, etc.) They begin cultivating these plants, presumably near their homes. They use the seeds from the original plantings to establish future generations.
- g. This selection leads to changes on two basic levels in the cultivated plant species:
 - i. Changes in morphology associated with domestication
 - ii. Changes in amount and distribution of genetic diversity

IV. What morphological changes do plants undergo during domestication? The domestication syndrome:

- a. More plants germinating
 - i. larger seeds (more storage room for bigger, healthier seedlings)
 - ii. non-dormant seeds (seeds germinate instead of laying dormant)
- b. Increase in the number of seeds harvested:
 - i. elimination of seed dispersal (non-shattering cereals, fruits that don't open)
 - ii. reduction of the number of branches (more fruit on one branch)
 - iii. seeds maturing at the same time
- c. Plants that are easier to grow:
 - i. outcrossing – selfing
 - ii. vegetatively reproducing plants (instant domestication?)
- d. Tastier, safer plants

1. Growth habit for easy farming
2. Color, flavor, texture, storage quality, cooking time
3. Reduction in toxic or unpleasant compounds (e.g., in the almond). Wild almond seeds contain amygdalin, a bitter chemical which breaks down to yield poison cyanide – a handful of wild almonds can kill a person. Well, it turns out that the occasional individual almond trees have a mutation in a single gene that prevents the almond trees from making amygdalin. One theory: kids try almonds – eventually they find a tree that makes non-bitter almonds. They take the seeds, eat and/or plant them, etc. They only plant the non-bitter ones, so eventually, all the cultivated almonds are non-bitter.

VI. Direction of selection in grain

Process of artificial selection (first a by product, then on purpose)

Two major modifications vegetative and reproductive

Tillering grasses (tiller, multiple stems)

Select for erect habit and synchrony of tiller formation

Each tiller terminated by inflorescence

Simultaneous flowering and harvest

Or , eliminate lateral stems so all seeds mature at the same time

Secondary modification recently has been for short stature

To prevent lodging (stems fall over and mat)

Is a particular problem in wet cultivation

Native grasses seed **shatter**—seed become brittle at mature and shatter when jostled by wind

Retention of seed is a single gene trait that would be immediately selected for—found now in all major grains

separation of seed from fruit—primitive grasses encased in fruit and bracts. Threshing—separate seed from other structure is difficult work

modern grains have seed loosely encased in the fruit and bract

Ployploidy in plant evolution

Doubling of chromosome number is a common theme in plant evolution

Several mechanisms—unreduced gametes

Why is it so common

Larger size, vigor not clear why this is so

Hybridization in plant evolution

Theme in plants, uncommon in animals

Allo-polyploidy---hybridization between two species and then
Increase in ploidy level

One of the most common mechanisms of speciation in plants

Seldom observed in animals due to sex chromosome

Can't have multiple sex chromosomes without causing

Phenotypic problems

What is evidence for polyploid evolution?

Chromosome counts

Secondary compounds

DNA sequence information

Direction of cross determined by chloroplast DNA vs nuclear DNA

(cp DNA is maternally inherited in angiosperms)

recent work on Arabidopsis and corn by gene mapping suggests ancient
polyploid events and chromosome fusions and reshuffling of large chromosome segments

VII Wheat

Domesticated in the fertile crescent (go to this region today, see wild relatives of barley
and wheat)

Barley was domesticated first, and most used. Wheat then replaced barley, by the time of
the Bible

Wild and early wheat are diploid ($2n = 14$) **Triticum monococcum**.

Early mutation prevented shattering. This was known as einkorn wheat (one grain)

Are cultivated for historical interest and in a very few areas

By 8000 bp independently of humans, an einkorn wheat and another species of wild grass
(*Triticum speltoides* or *longissima* or *searsii*) hybridized

Hard to tell which species because many changes since this happened

Hybrid was sterile but tetraploid event occurred. The fertile tetraploid is **T. turgidum**
var. *dicoccum* which is called emmer wheat

This underwent a mutation which caused the basis of the glumes to collapse at maturity. Which made the separation of the fruit from the chaff easy.

This is free –threshing wheat known as durum.

Before this mutation, wheat was heated to separate the bacts. Made it unsuitable for flour because heat denatured the proteins

Advantage of gluten was not apparent—emmer wheat had lots of gluten so good for flour

Durum wheats are hard, have lots of gluten, grown in dry Mediterranean region for pasta

Shortly after the appearance of agriculture a hexaploid species arose ($2n = 42$)

3 sets of chromosomes, two from a tetraploid emmer wheat and another set from a diploid species *T. tauschii*.

Is called **T. aestivum** Hexaploid wheat has an endosperm that is especially high in protein and surpasses other wheats in making bread.

There are over 20,000 cultivars of hexaploid wheat

Summary:

Triticum monococcum wild wheat and early domesticated wheat

Einkorn wheat *T. monococcum* wheat that has mutation to prevent shattering

Emmer Wheat (*Triticum turgidum*): tetraploid hybrid of einkorn and the wild grass, *Triticum speltoides*

Durum Wheat Emmer wheat that has a mutation which made it easy to thresh

T. aestivum is hexaploid wheat, made from a cross of *T. turgidum* and *T. tauschii*
This is modern bread wheat

Wheat in the New World

Spanish brought wheat as did English colonist. Didn't grow well

Mennonites were one of few that were successful

1870 immigrants from Russia brought "Turkey" wheat which grew well in hot dry continental climate

Triticale

Is a cross between wheat and rye. Is first man made cereal
Has good characters of rye and wheat and surpasses in yield

VIII. Corn

Old World has given several major cereal crops
New world—only major grain is corn

Corn was the basis for all of the major new world civilizations Maya, Aztec, and Inca

Also basis for Indian civilization here in mid west Cahokia (very large village based on corn)

At the time of the Spanish invasion Amaranthus was important in some regions, but the Spanish forbade its cultivation because it was used in religious services and as food.

Cultivation of corn—in combination with beans—very efficient due to N fixation
Also cultivation with squash.

Origin of Corn

Origin of corn has been very actively speculated and remained undetermined until relatively recently—there are no clear wild relatives based on morphology

Morphology of corn has been so modified large stalks, male flowers on top
Female flowers packed on cob, silks are long style

The ear of domesticated corn is larger than any potential relative and has features very different from any potential relative.

General conclusion is that corn was domesticated in southern Mexico

Oldest record of cobs 5,500 pb from a cave E of Mexico City
Is a variety like popcorn that is still grown in Mexico today

When Columbus arrived there were an estimated 300 local land races
Some survived till relatively recently kept as part of tribal cultural heritage

Two possible origins for corn:

Wild ancestor—either Teosinte (4 species of wild annual and perennial grasses of Mexico and Guatemala) in genus *Zea*

Or *Tripsacum* also involved in corn—12 perennial grass species.

One theory—Teosinte is the ancestor

Other theory there was a wild ancestor of corn in the lowlands of South America. Teosinte is the result of this species crossing with *Tripsacum* after cultivated maize had been introduced into Central America. Varieties of corn are the result of crosses with *Tripsacum*

Hugh Iltis—found and described perennial species of teosinte in 1979

Modern Corn is a direct result of human selection from an annual species of Mexican teosinte

Based on cytology, biochemistry, and DNA one of the annual teosintes *Z. mays* subsp. *parviglumis* is wild ancestor

But, it is still not known how ancestor was turned into corn

There are 5 major characters that differential teosinte from corn –cob characters

Lack of shattering

Seed is naked (outside of a cupule)

Each corn cupule produces 2 seeds rather than one

Cupules of corn in ranks of 4-10, teosinte in 2

Teosinte long primary branches each which terminates in a male tassel. Corn has short primary branches each which ends in a single ear—male tassel only at the top of the primary stem

There are major genes that are responsible for all of these changes

And have been identified by crosses and mapping

Developmental mutations and modifier genes can result in very large changes in the appearance of a plant.

History of Corn

Selection

Lack of dormancy

Large glumes (shucks)

Flint length of the individual kernel stalks to protrude from cupule SW US

Dent elongation of kernel to protrude from cupule Eastern US
Photoperiod were short day plants needed to be day length neutral
This allowed corn to spread north

Hybrid Corn

Cross between flint and dent -- ancestor to our modern corn in US

Pellagra

Nutritional deficiency disease due to tryptophan deficiency

Corn low in tryptophan

Was a common disease in rural American south. Diet was molasses, corn bread and salt pork –overcome by adding yeast supplements to food

Southern corn blight fungus

1970 warm moist weather encouraged fungal growth crop losses over 4 billion.
Illustrated the vulnerability of modern agricultural practices to disease and pests
Lead to interest in crop genetic resources.

Domestication in chocolate

- e. Cacao biology:
- f. Cacao use by Native peoples in Central America
 - i. cultivated by Mayans for fruits. Seeds were used in making chocolate drink called “xocolatl”
 - ii. Legend surrounding cacao: first beans came out of Paradise and lent wisdom and power to whoever ate them.
 - iii. The scientific name of the plant literally means “food of the Gods”
- g. Cacao discovered by the Europeans
 - i. Christopher Columbus (1502) – beans were used as money and also to make a spicy beverage. He didn’t like it
 - ii. Hernan Cortés (1519) – found Montezuma, the Aztec Emperor, drinking chocolatl from a golden goblet (roasted and ground beans, various species including chili peppers and vanilla beans). Boiling water was added, it was whipped to a foamy consistency
- h. Cacao taken to Europe
 - i. Cortés took the beverage to Spain in 1528 – the Spanish added sugar to make it more palatable
 - ii. The Spanish guarded the recipe for several years, by 1650 it had spread through Europe.
- i. Making chocolate
 - i. ripe cacao pods are harvested (Ivory Coast in Africa, Brazil, Costa Rica); pulpy seeds are removed, allowed to ferment; beans are

dried mechanically in the sun and shipped to Europe and North America for processing.

- ii. Beans are roasted at ~250 - 280° F for 20-50 minutes (this develops color and flavor of chocolate)
- iii. Seeds are cracked open; cotyledons (nibs) are crushed to produce chocolate liquor. Liquor can be solidified into baking chocolate, or the cocoa butter can be removed with heat and pressure to make cocoa powder.
- iv. Chocolate = chocolate liquor, sugar, cocoa butter, vanilla, and milk (usually).

Coca-cola

- v. Cola: relative of the cacao tree; seeds are removed and allowed to ferment before they are dried and pulverized (in Africa the seeds are used as a stimulant and as an appetite depressant because of high caffeine content)
- vi. Coca: relative of cocaine, leaf extract used in making coca-cola.