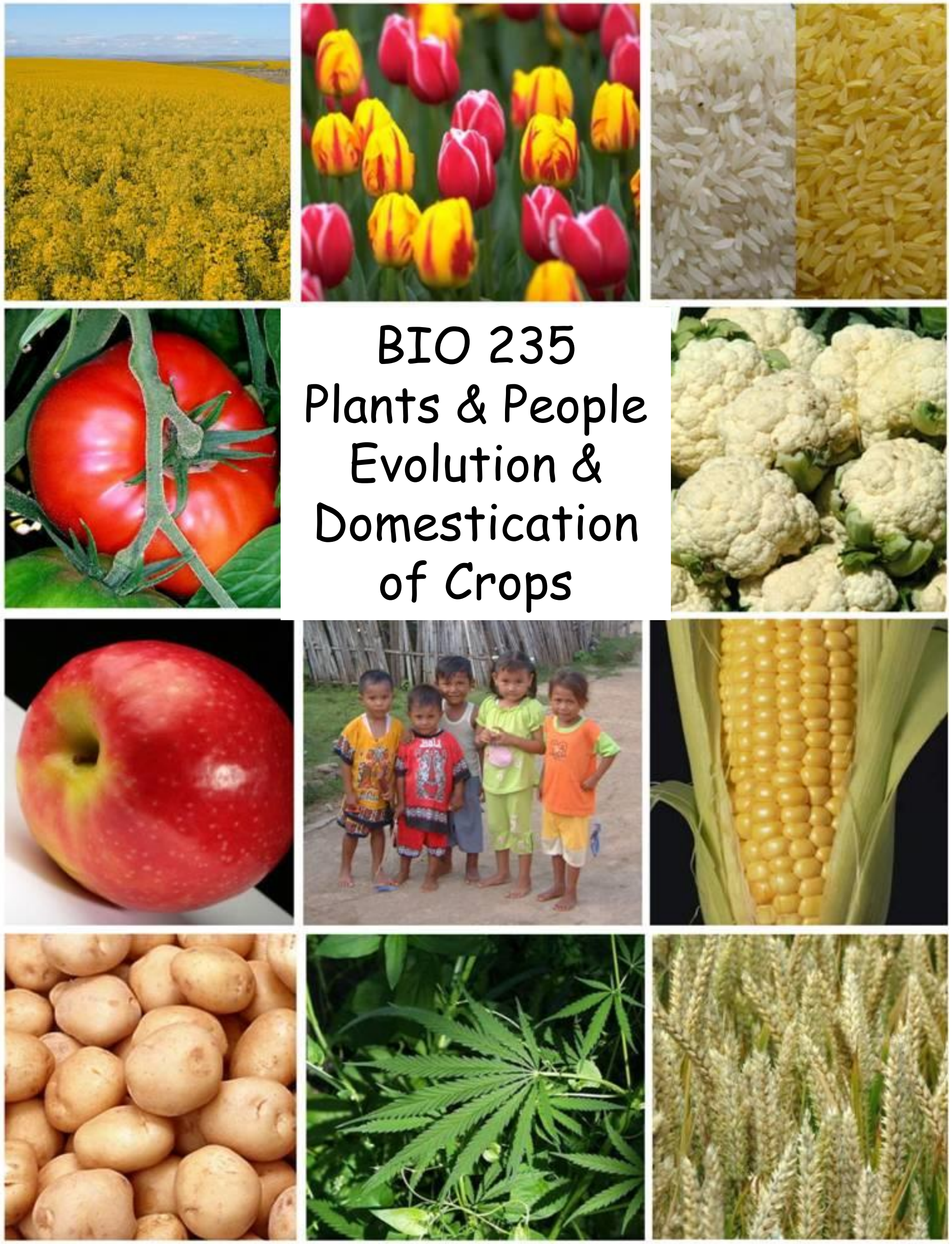
For This Week:

Why did agriculture arise?

Why did it arise more or less simultaneously and independently in different places?

Is there a global explanation?



Lecture 3
Crop Origins - Maize, wheat & rice – the three most important crops.

- Domestication of grasses
- Where, when, how many times and from what progenitors were these cereal crops domesticated?
- Modern genetic & archaeological evidence
- Single vs multiple origins
- Wheat
- Maize
- Rice

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Documenting Domestication

When, where, how many times and from what progenitors?

Biological Data

-taxonomy, morphology, genetics

-DNA sequence data to reveal the identity and geographical ranges of present-day wild progenitors and ancient DNA from archaeological remains

-pinpoint and quantify morphological changes associate with domestication

-Cloning and molecular evolutionary analysis of key domestication genes is providing additional insights into crop origins

-Genome sequencing

Archaeological Data

-identification and dating of plant remains – macro and micro

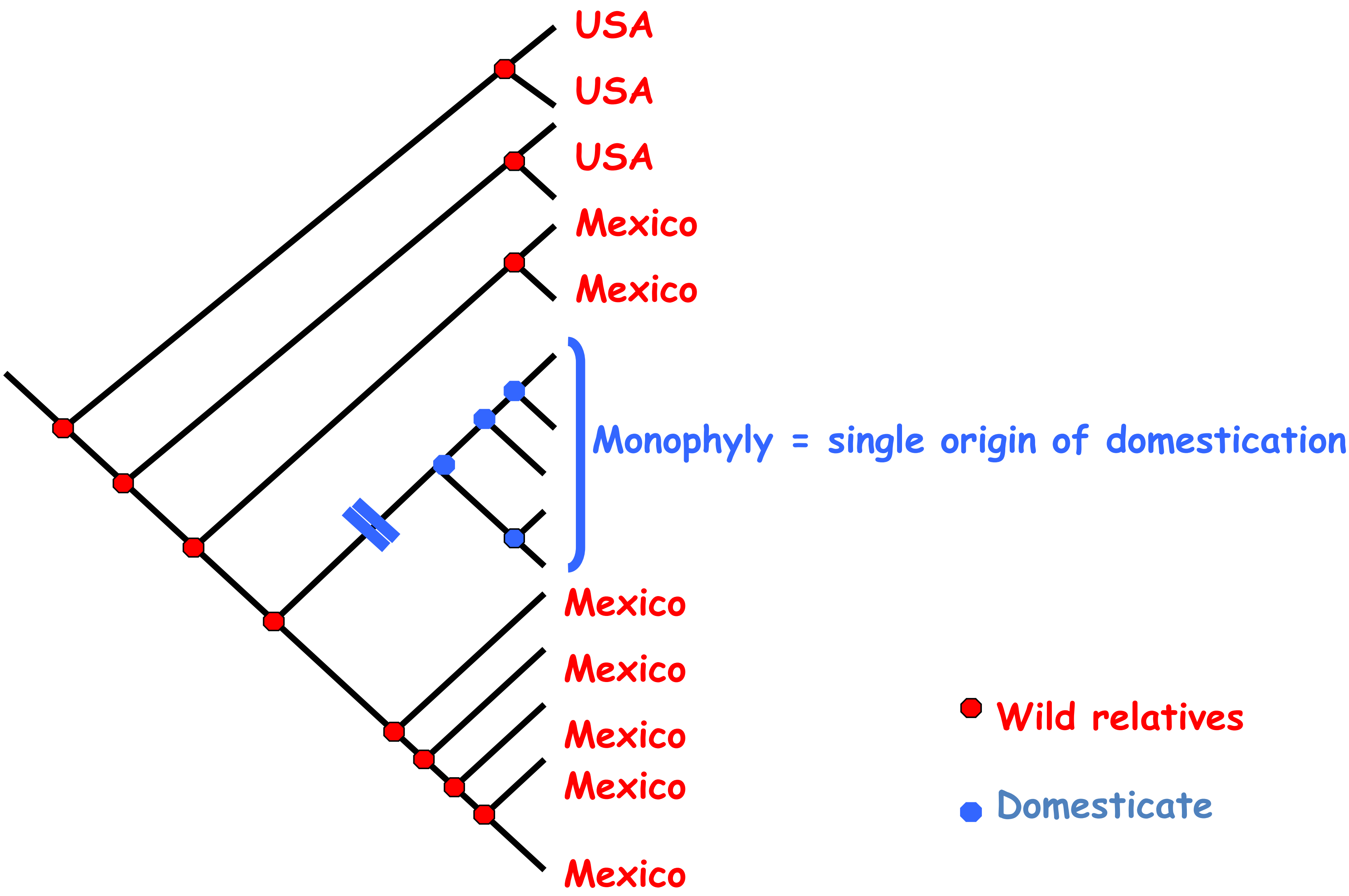
-direct accelerator mass spectrometer (AMS) radiocarbon age determinations provide unequivocal temporal placement of early domesticates

- biomolecular analysis & ancient DNA

-determine location of earliest domesticated remains

Pinpoint locations of domestication in time & space

Monophyly = A group that contains all the descendents of a common ancestor



- Archaeology = the excavation and study of past site of human activity/ occupation
- Archaeobotany = recovery and study of plant remains preserved on those sites

Ban Non Wot, Thailand, Jan. 2011

Oswald Heer 1809–1883
1865 *Die Pflanzen der Pfahlbauten*
[Plants of the pile-dwellings]
Summary translation in English, 1866; also, summaries by Darwin & Lubbock

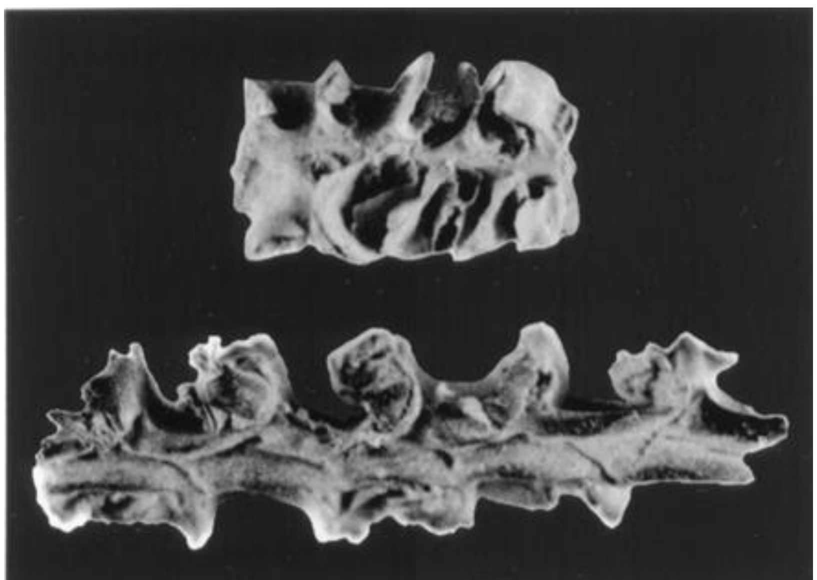
"Altogether 115 species of plants have been determined…Dr. Heer, from whose very interesting memoir the above facts are borrowed, calls particular attention to the fact that, while the remains
Of wild species found in the Pfahlbauten
Agree in the most minute particulars with those still
Living in Switzerland, the cultivated plants, on the contrary, differ from all the existing varieties, and invariably have smaller seeds and fruits. Man has evidently in the course of time effected considerable improvements" (Lubbock *Pre-Historic Times*, 3rd ed, 1872, pp. 212-214)

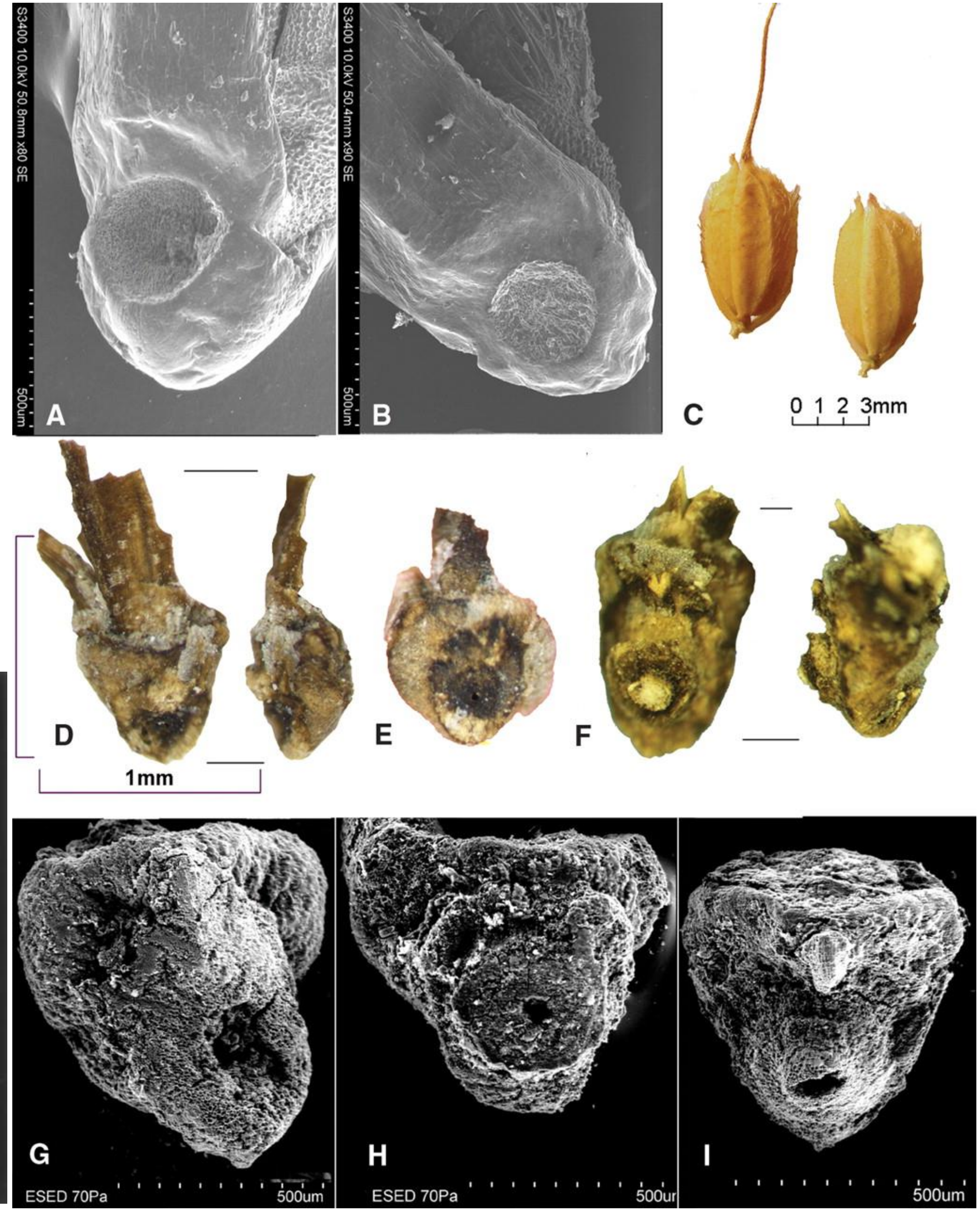
c. 6,000 BP, Neuchatel

Archaeology

Macrobotanical remains preserved in arid or waterlogged environments

Traits that distinguish domesticated from wild forms



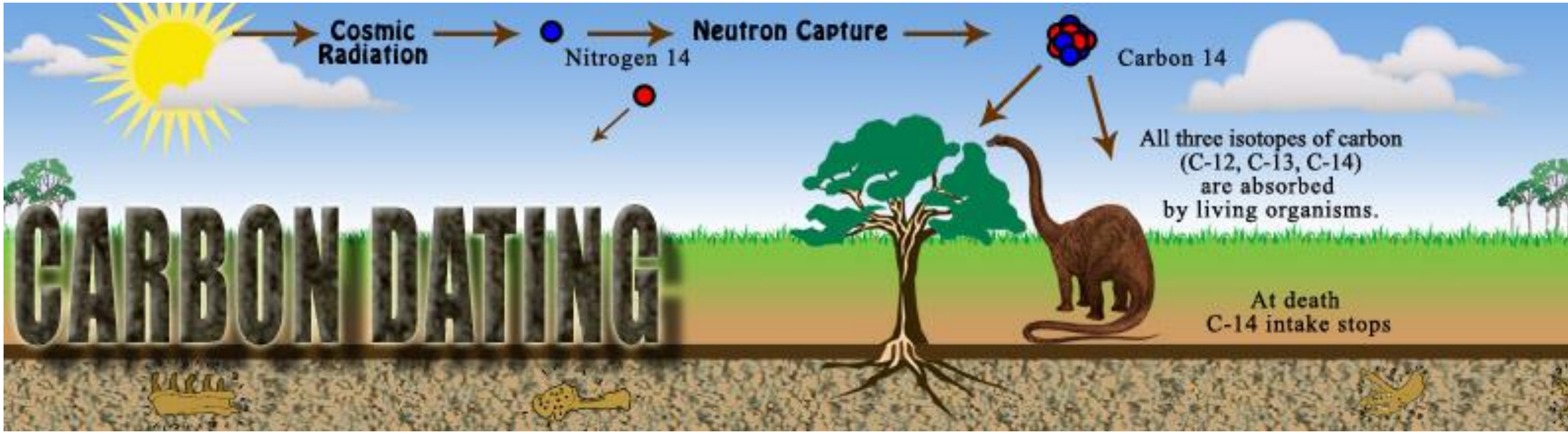


Recovery: FLOTATION of archaeological sediments for macro-remains


Machine flotation


Manual bucket flotation

First flotations in USA: 1962
In Iran: 1963.
Become more widespread from the
End of the 1960s.



Accelerator Mass Spectrometer, AMS radio carbon dating

Half life = 5,730 years

Scanning Electron Microscopy, SEM

Fig. 3. Comparison of an archaeological sunflower achene from eastern North America with the San Andrés specimen. (*Left*) Scanning electron micrograph of a sunflower achene from Cloudsplitter Rockshelter in eastern Kentucky, exhibiting distinctive parallel longitudinal strands or bundles of sclerenchyma fibers (achene length, 9.2 mm). (*Right*) San Andrés achene (achene length, 8.2 mm). (Photograph of San Andrés achene courtesy of David Lentz, Chicago Botanic Garden, Glencoe, IL.)

PNAS

COMMENTARY

Small is big: The microfossil perspective on human–plant interaction

Daniel H. Sandweiss*
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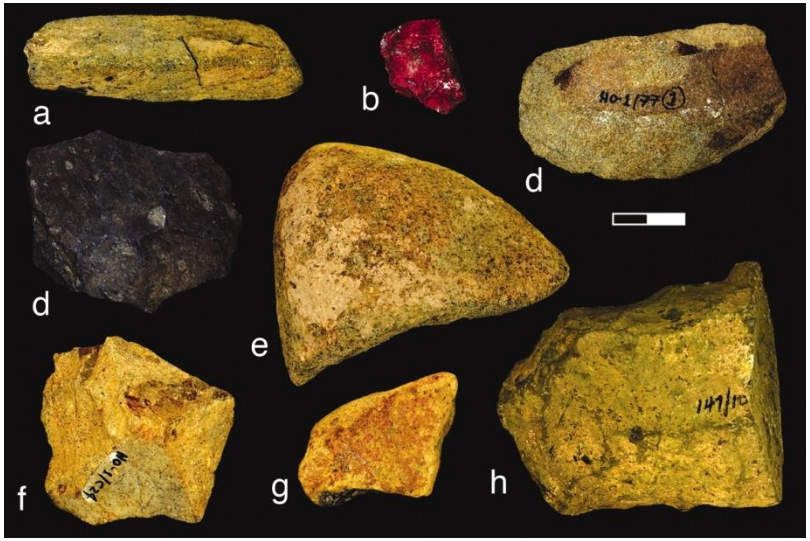
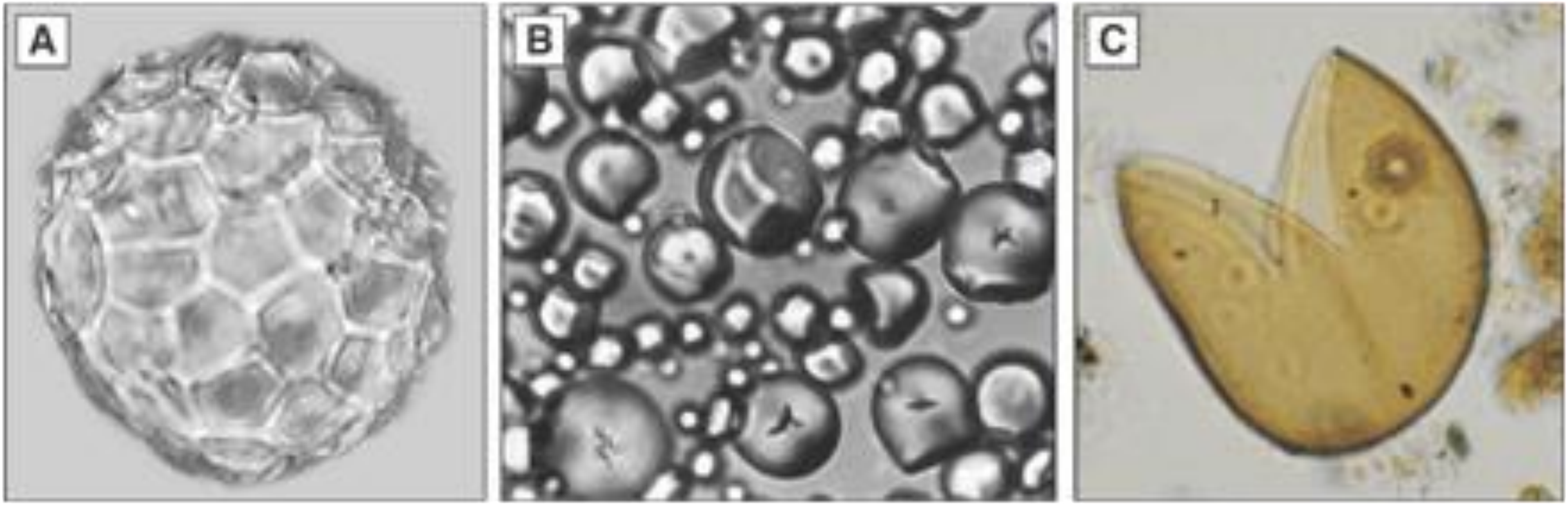
The archaeological record contains only scattered and incomplete clues to the scope and complexity of past human behavior, and archaeologists must develop every possible source of useful information. Although much overused of late, the truism that absence of evidence is not evidence of absence holds particular force in archaeology and nowhere more than in the prehistory of human–plant interaction. Until vated the site to study Terminal Pleistocene [13,000–11,400 calibrated years before present (cal BP)] coast–highland interaction, Waynuna proved to be Late Preceramic (4,000–3,600 cal BP) in age and thus unsuitable to answer the original research questions. Microfossil analyses turned this "failure" into a source of important new information on the history of Andean plant use. Although the excavations recovered no plant parts visible to ing to almost 6,000 years ago. Starch grains indicated both hard and soft endosperm varieties, as at Waynuna a millennium later, whereas phytolith morphology pointed to maize that "combined primitive and derived traits in a way that is not observed in living maize varieties" (ref. 7, p. 438).

Recent microfossil studies at either extreme of the American continents have shed light on different human–plant inter-

Phytolith (plant crystal and opal silica bodies) and starch grains on stone tools that indicated movement and adoption of maize, arrowroot, manioc and yam in central Panama 7,800 BP



Invisible Clues to Plant Domestication

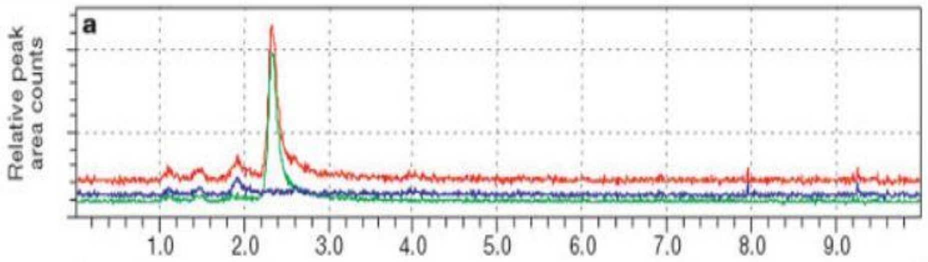


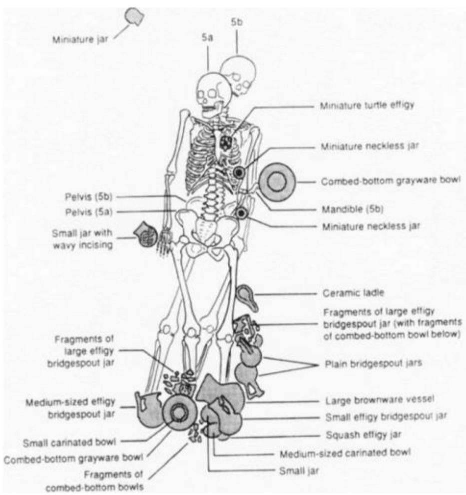
Phytoliths – (plant crystals) & starch grains from sediments, milling stones, stone tools and pottery shards

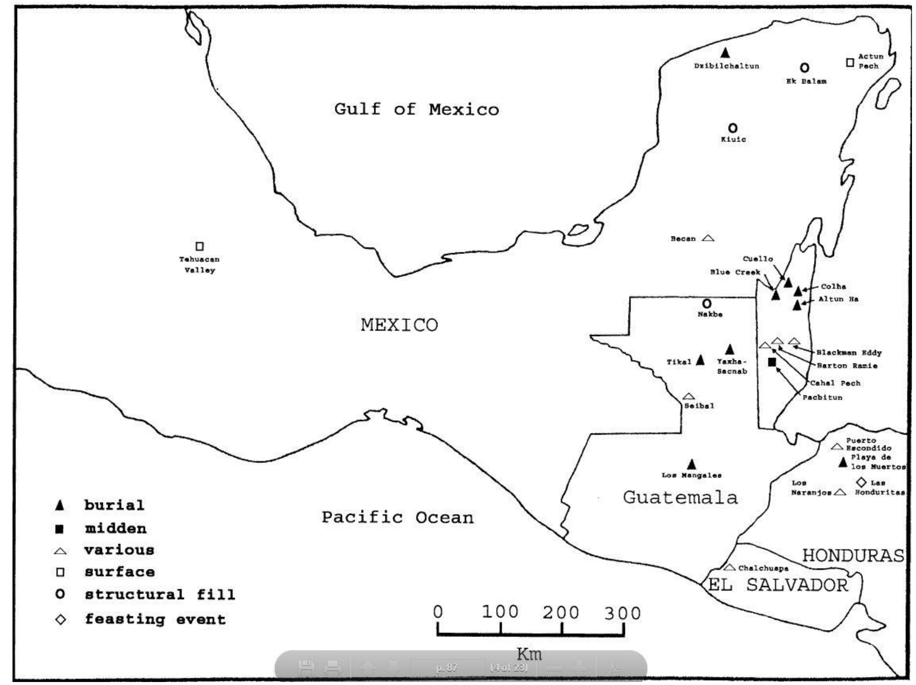
Potent new evidence in revealing early root crop agriculture in lowland wet tropical forests e.g. in Panama and Ecuador, and in New Guinea

Bryant 2003 Science; Piperno et al. 2000 Nature; Sandwiess 2007 PNAS.

Biomolecular Archaeology





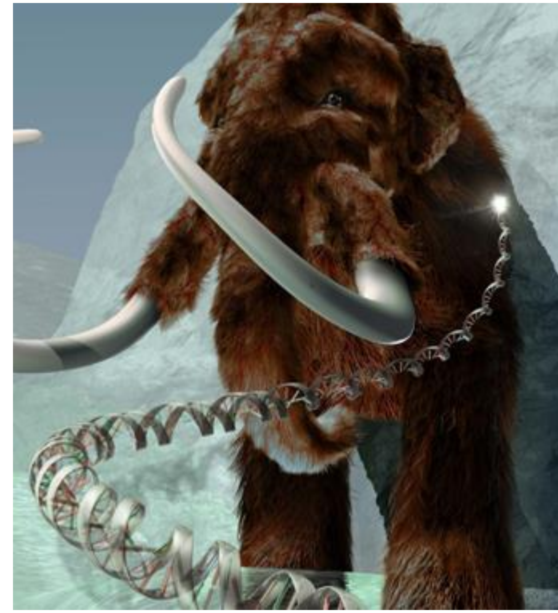


High performance liquid chromoatography & chemical ionization mass spectrometry

For example, detection of theobromine, a chemical distinctive to cacao from spouted vessels from Central America used to infer the earliest use of chocolate (Teobroma cacao) by PreClassic Maya 2,600 BP

Ancient DNA

Small quantities & low quality DNA
1 Myr upper limit
Post-mortem mutations
Contamination
Neandertal draft genome sequence in 2010
10,000 year-old bottle gourd remains from Peru
Archaeogenomics / paleogenomics – hominids, horse, mammoth, polar bear, cotton, plague, Irish potato blight, leprosy



Shapiro & Hofreiter (2014)

Grasses – Poaceae

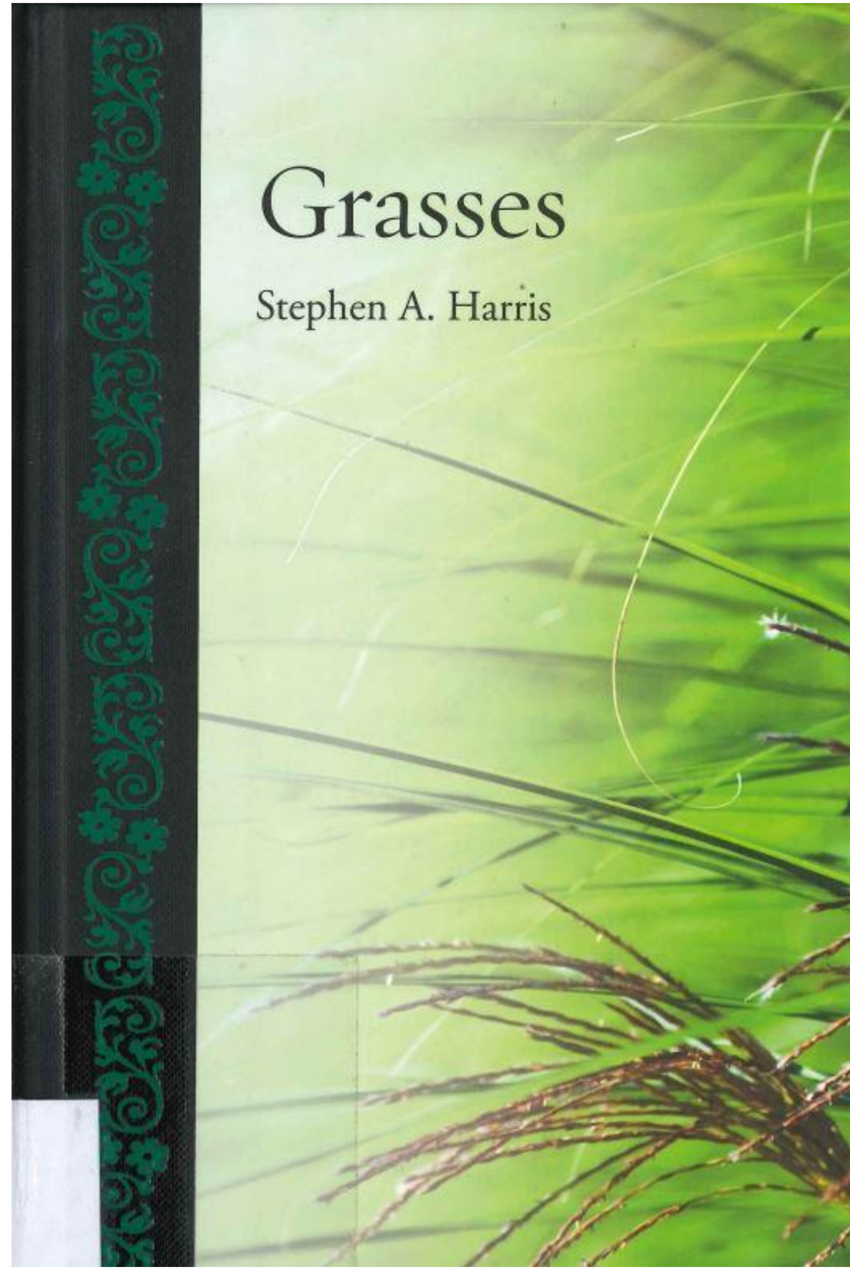
11,000 species
Global distribution in many biomes
Grasslands: tropical savannas; temperate prairies, alpine meadows

Natural grasslands dominate the planet

Fostered the evolution of large herbivores

Man-made grasslands dominate the planet: fields of food crops, fields of livestock, lawns, sports fields

Grasses form the granaries of the world and the cradle of agrculture - The biggest crops – maize, wheat, rice and sugar cane are all grasses



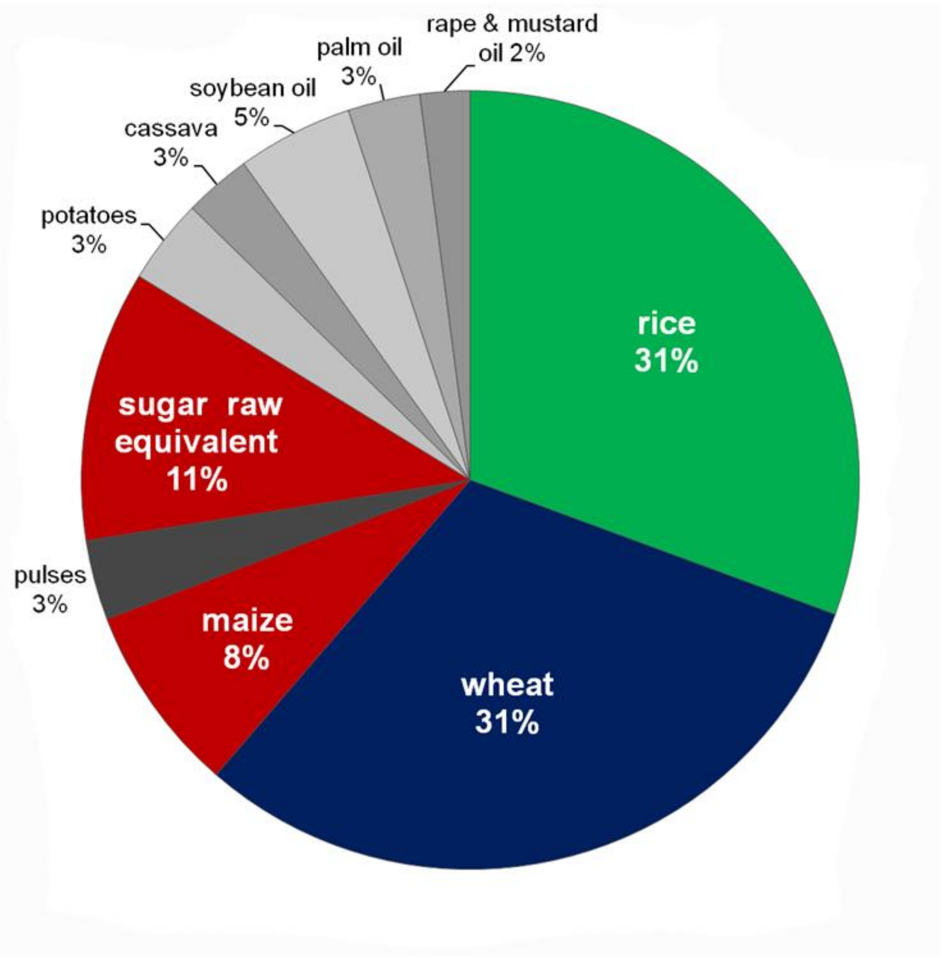
Cereals = Grasses

Grass domestication of unique importance in the history of human civilizations, providing the main staple foods for the majority of the world's population. > 50% of all calories consumed by humans come from the three species of grasses – the world's three top food crops:

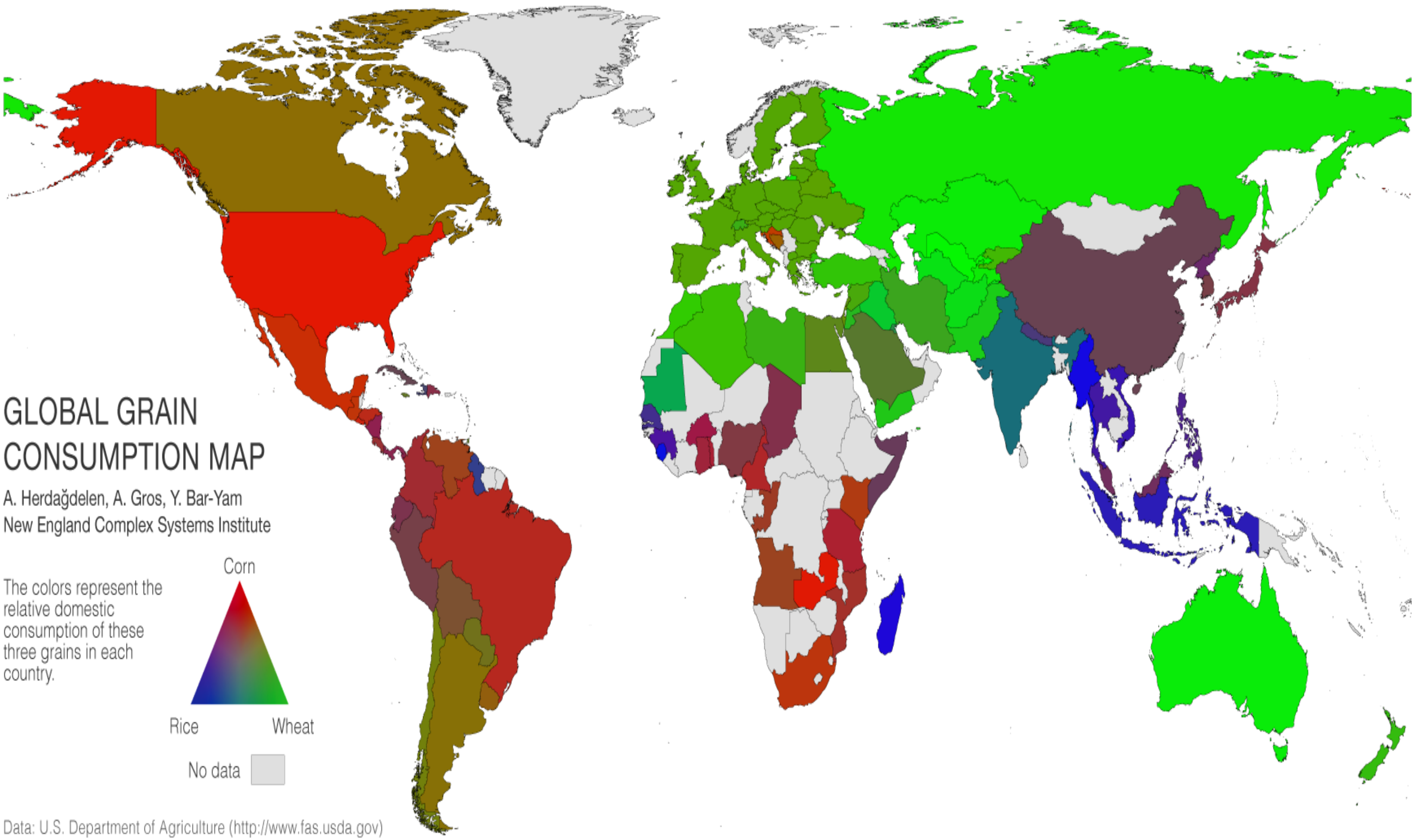
Maize, *Zea mays*
Mesoamerica

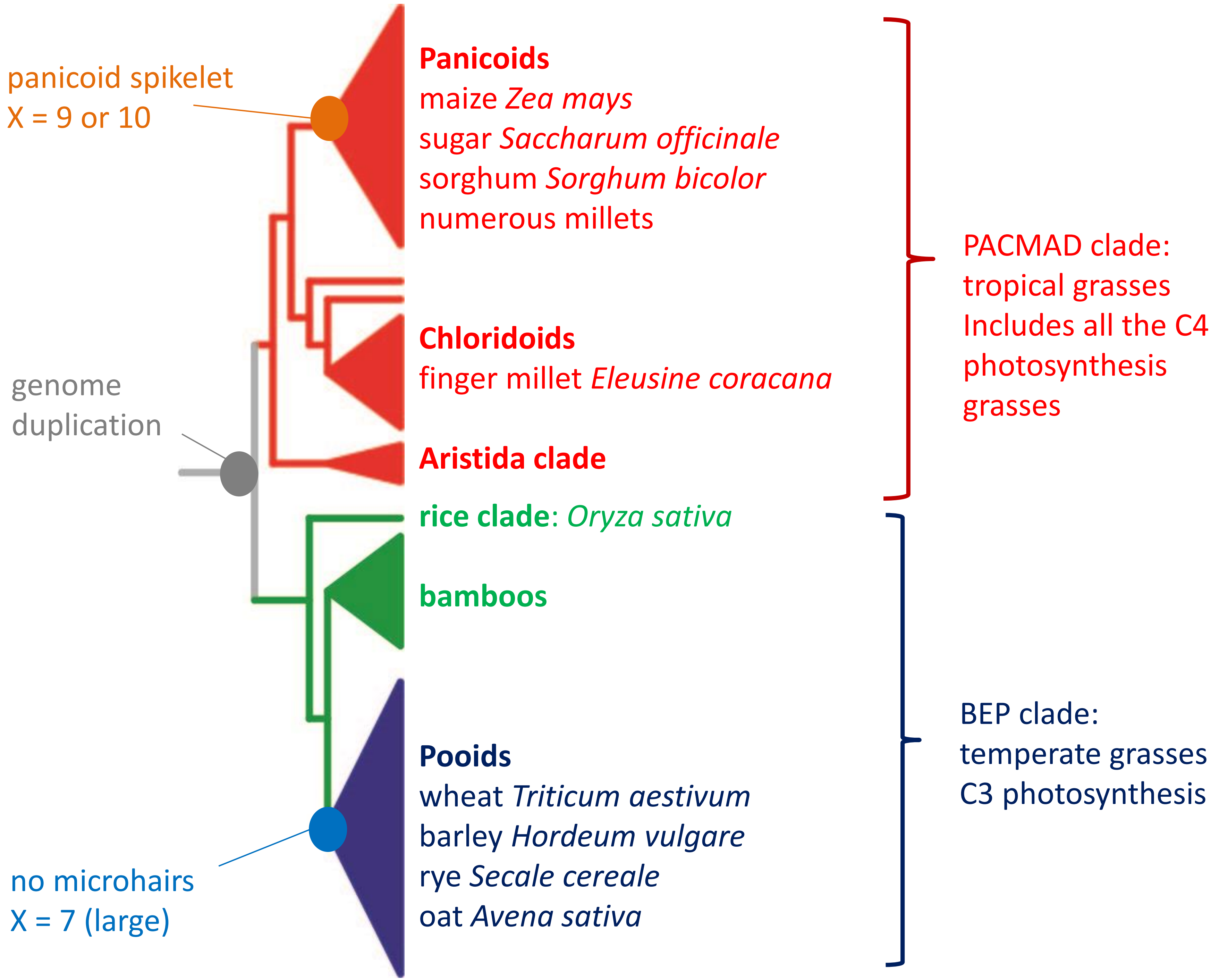
Wheat, *Triticum spp.*
Fertile Crescent

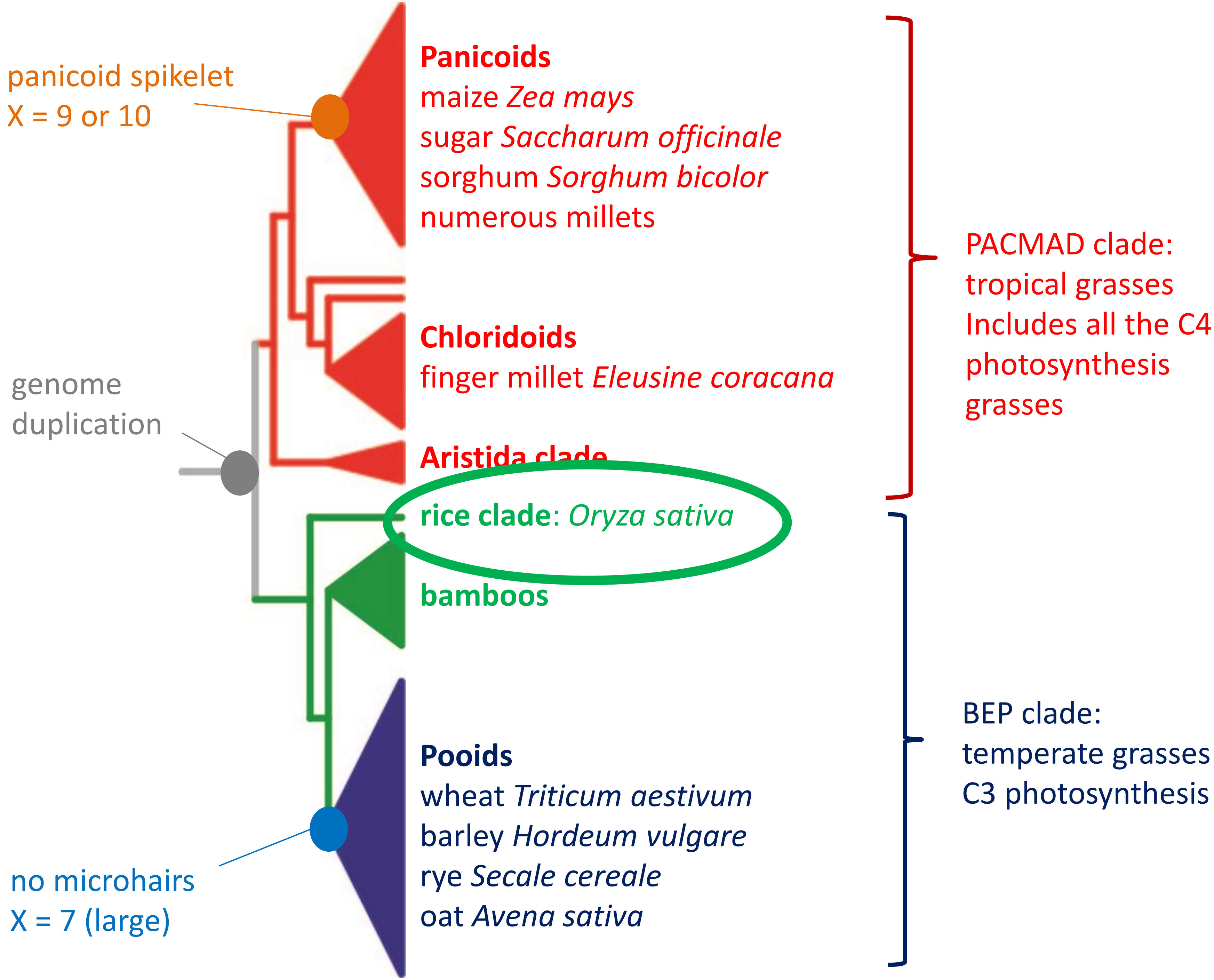
Rice, *Oryza sativa*
S.E. Asia



FAO 2009: *global consumption of 10 major vegetal foods (2003-2005)*


GLOBAL GRAIN
CONSUMPTION MAP
A. Herdağdelen, A. Gros, Y. Bar-Yam
New England Complex Systems Institute
The colors represent the relative domestic consumption of these three grains in each country.
Corn
Rice
Wheat
No data
Data: U.S. Department of Agriculture (http://www.fas.usda.gov)


panicoid spikelet
X = 9 or 10
genome
duplication
no microhairs
X = 7 (large)
Panicoids
maize *Zea mays*
sugar *Saccharum officinale*
sorghum *Sorghum bicolor*
numerous millets
Chloridoids
finger millet *Eleusine coracana*
Aristida clade
rice clade: *Oryza sativa*
bamboos
Pooids
wheat *Triticum aestivum*
barley *Hordeum vulgare*
rye *Secale cereale*
oat *Avena sativa*
PACMAD clade:
tropical grasses
Includes all the C4
photosynthesis
grasses
BEP clade:
temperate grasses
C3 photosynthesis



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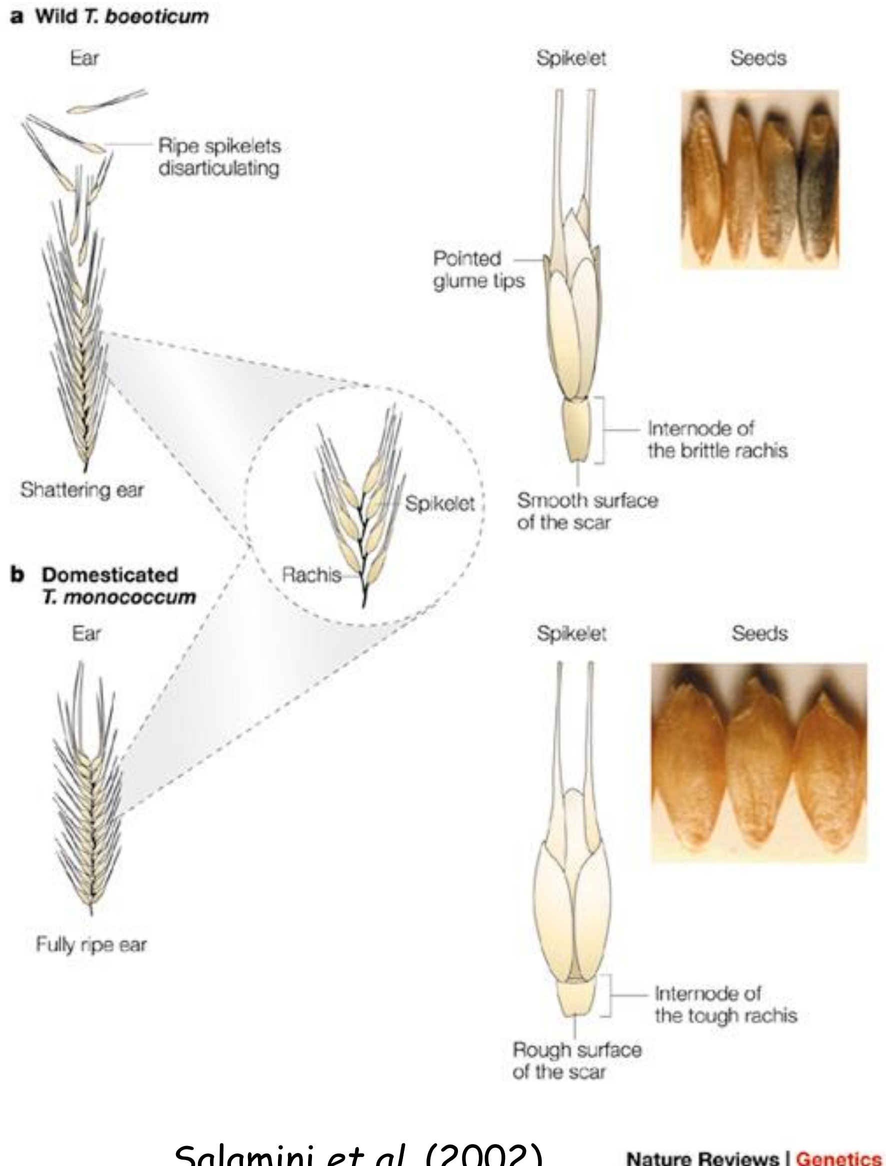
no microhairs
X = 7 (large)

Phenotype of wild vs domesticated cereals

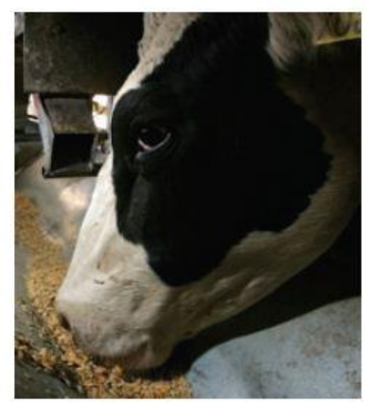


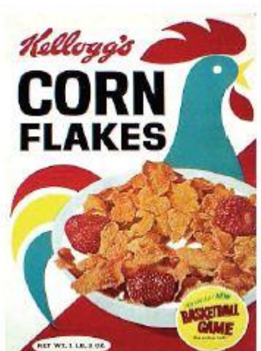
Salamini *et al.* (2002)

Einkorn wheat spikelets, or ears, with two rows of seeds:

- Seed size increase in domesticated forms
- Non-shattering spiklets due to a tough rachis that holds the seeds together in a harvestable and threshable ear
- Leaf-like structures that protect the seed – called glumes – are attached tightly to the seed or fused to it in wild forms whereas they release the seed in the more advanced domesticated forms, which are therefore termed 'free-threshing' or naked.

<u>Maize</u> - the most widely grown crop in the Americas; 332 million metric tonnes /yr in the U.S.A., 800 worldwide; transgenic maize comprised 85% of maize planted in the U.S.A. in 2009; a greater weight of maize is produced each year than any other grain; > 150 million ha worldwide

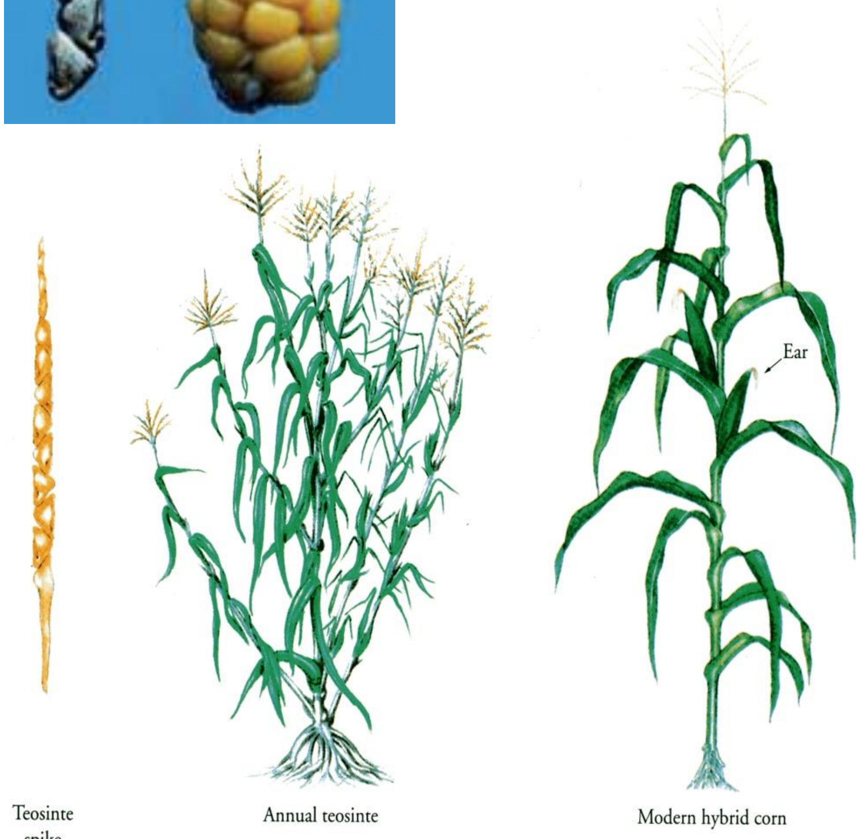




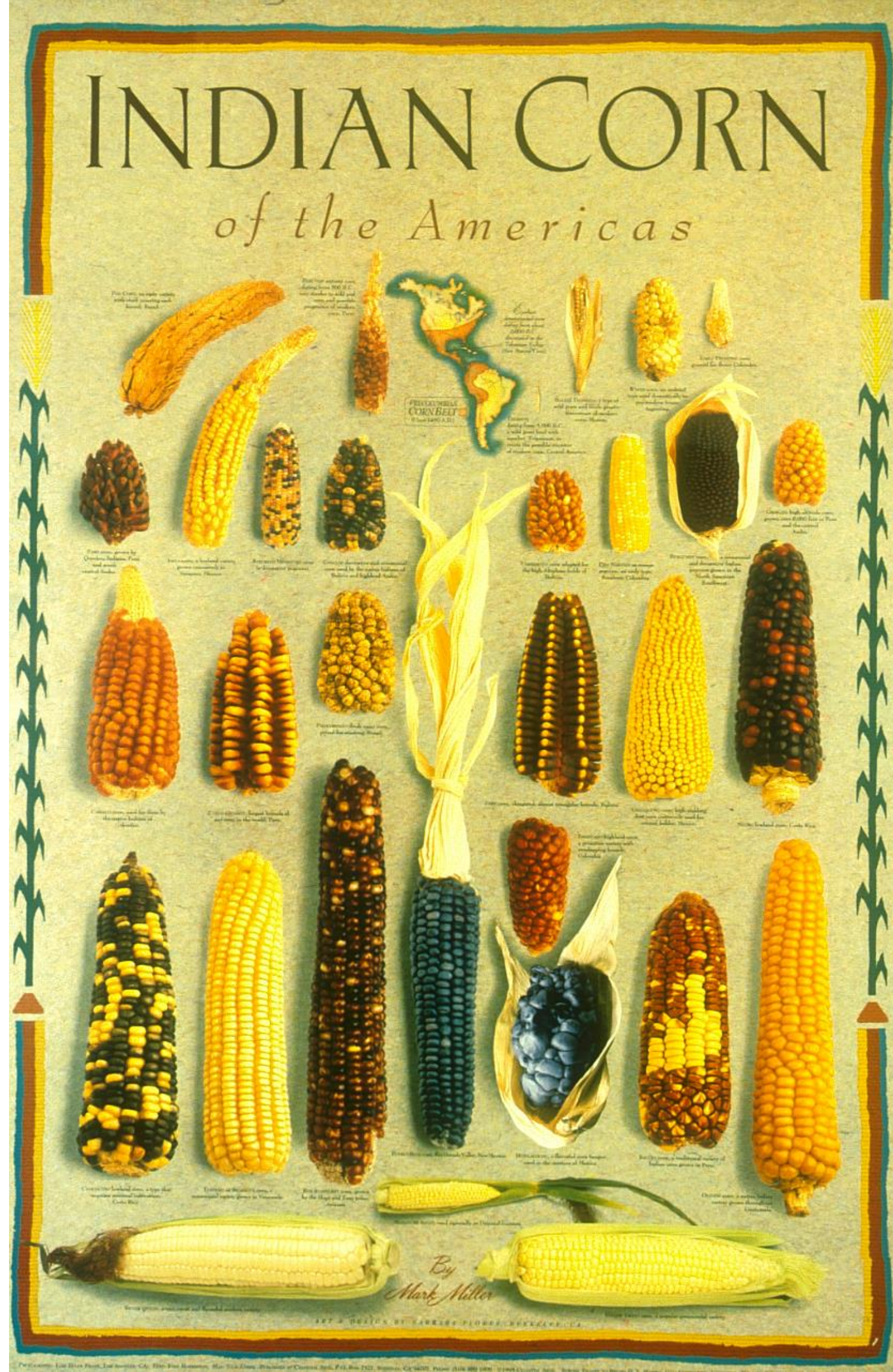
Maize – *Zea mays*

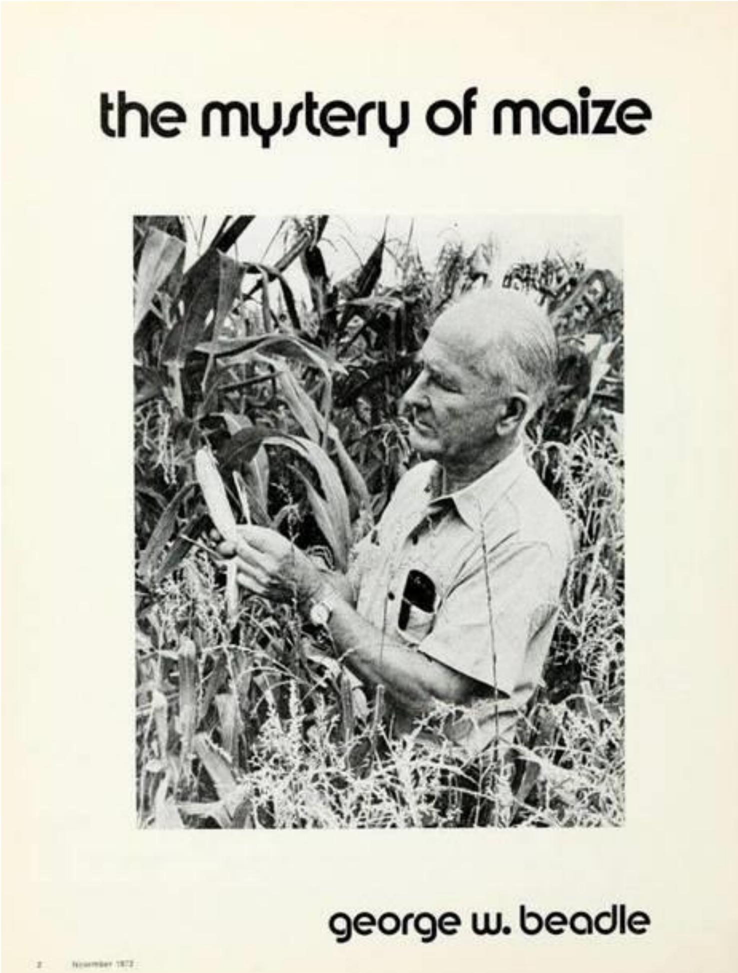
Poaceae

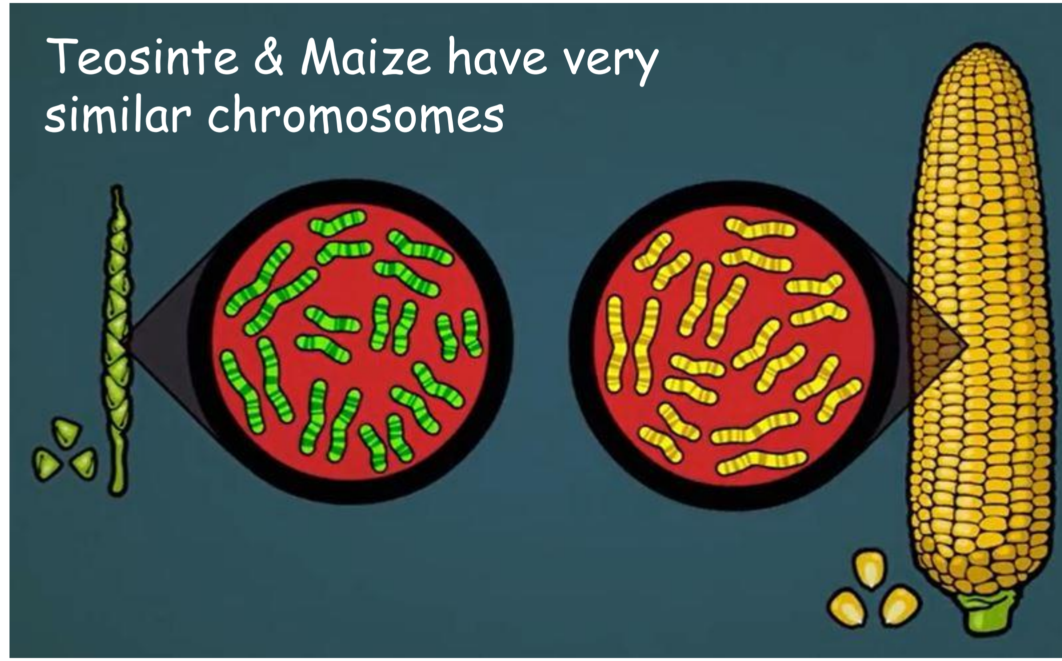
Mesoamerica

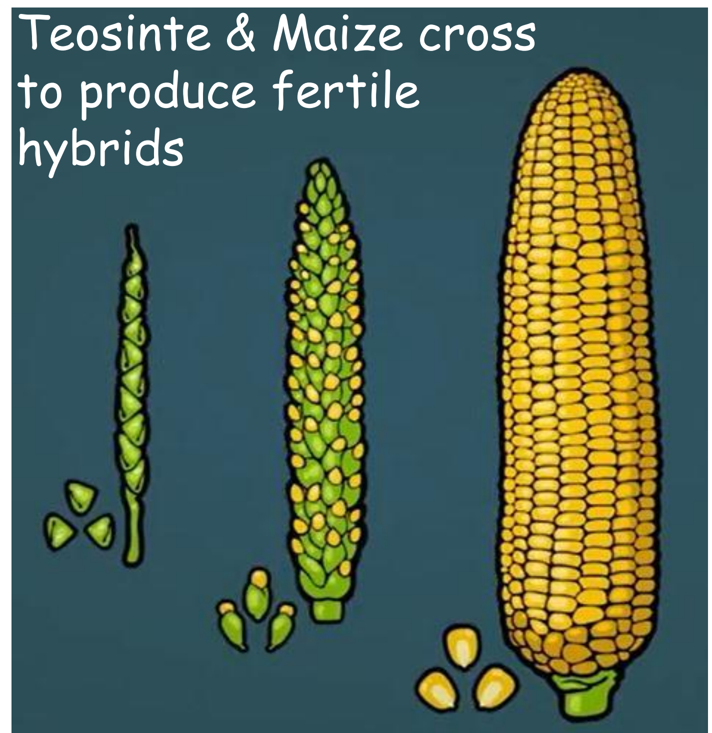


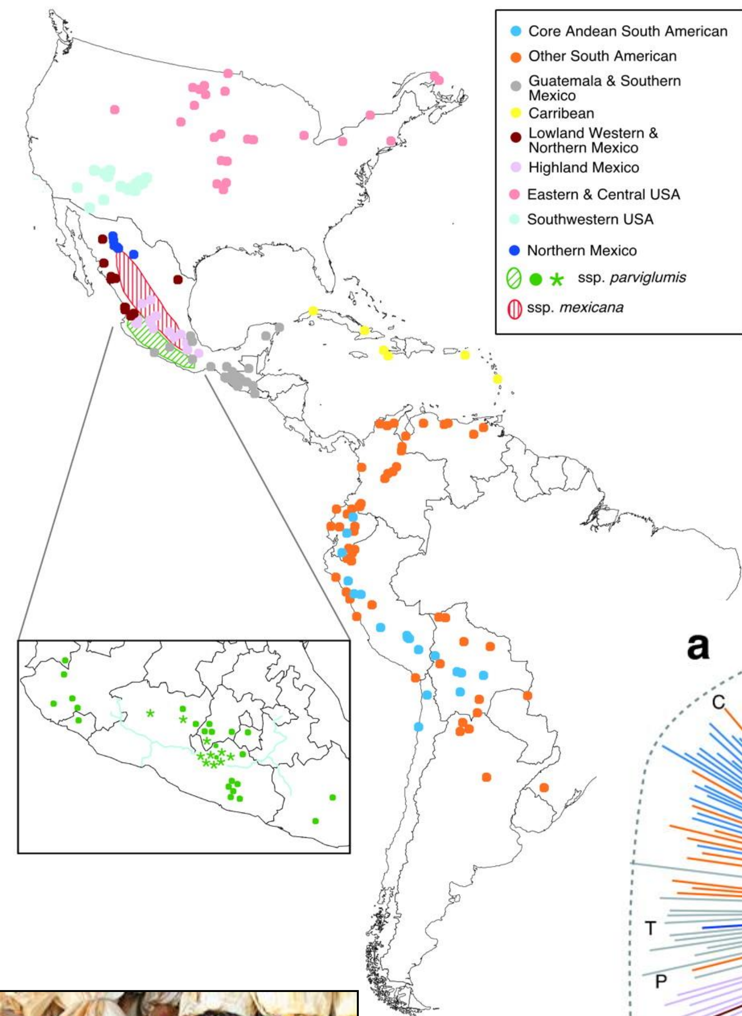
Z. mays ssp. parviglumis




the mystery of maize
george w. beadle
2 November 1972


Teosinte & Maize have very similar chromosomes


Teosinte & Maize cross to produce fertile hybrids



Maize – Genetic Data

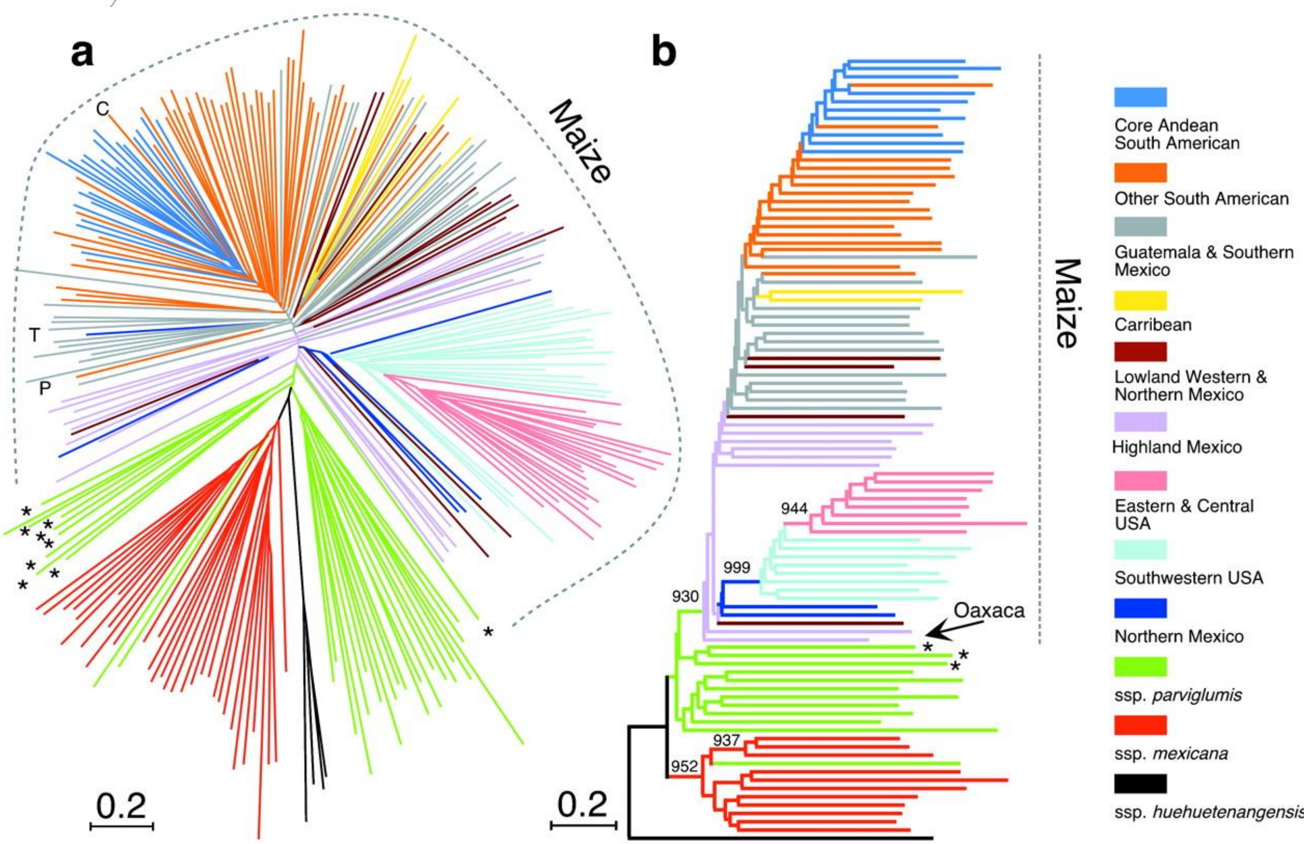
Annual teosinte – *Z. mays* ssp. *parviglumis* distributed in the Balsas Depression of southern Mexico

Maize accessions monophyletic & derived within teosinte suggesting a single domestication event & teosinte as progenitor.

Most closely allied teosinte is in the Balsas Depression

Earliest branching maize lineage from Oaxaca.

Matsuoka et al 2002 PNAS

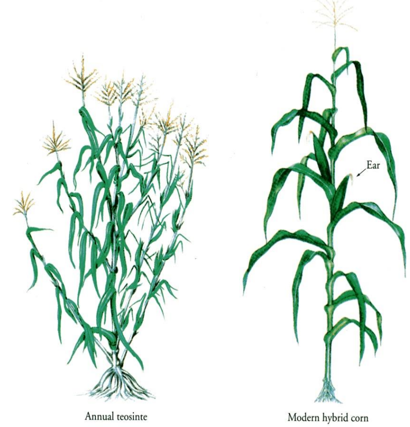


teosinte branched 1

teosinte

maize *tb1* mutant

Doebley (2004)

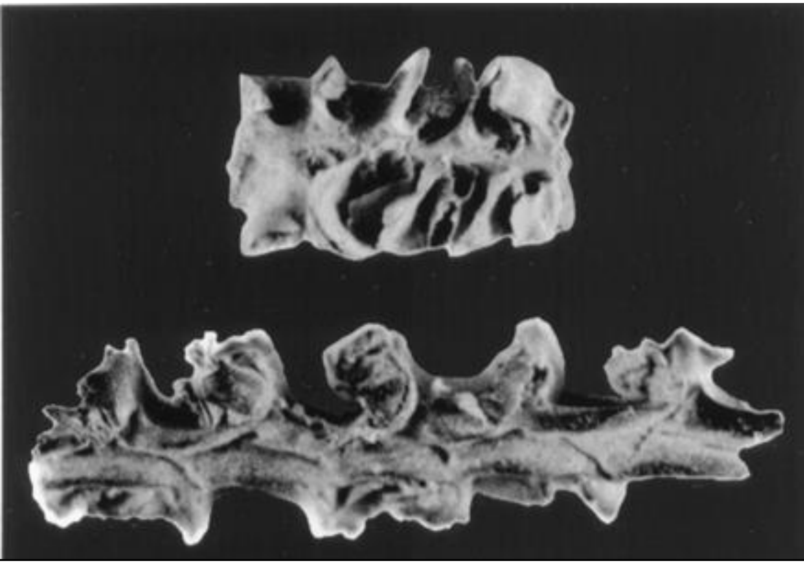


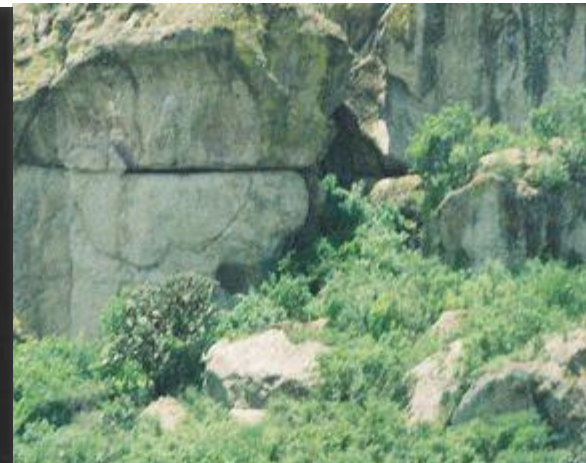
- *tb1* is a key domestication gene in maize
- It encodes a TCP protein (TCPs are growth regulators)
- It is expressed in the axillary meristems of maize but not teosinte
- Maize shows strong evidence of selection in the tb1 gene promoter region
- Presence of maize tb1 gene in teosinte suppresses outgrowth of axillary branches
- Identical *tb1* genes in different maize accessions support single origin

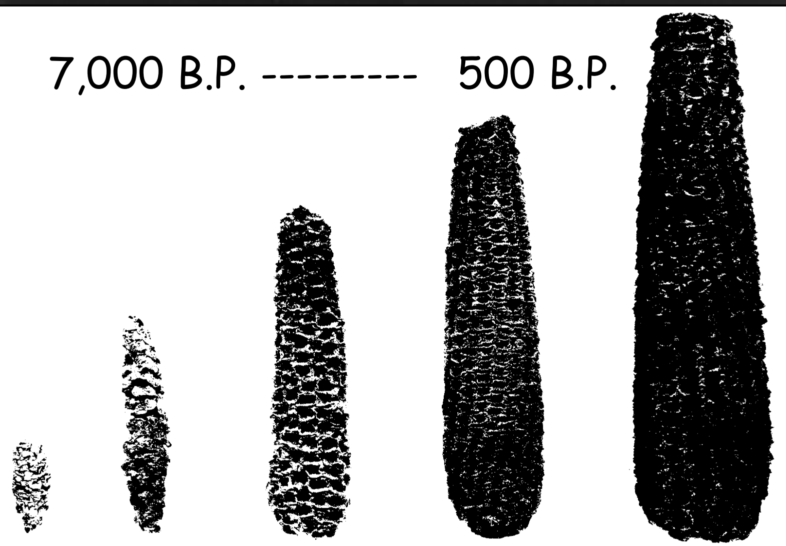
Maize – Archaeological Data I

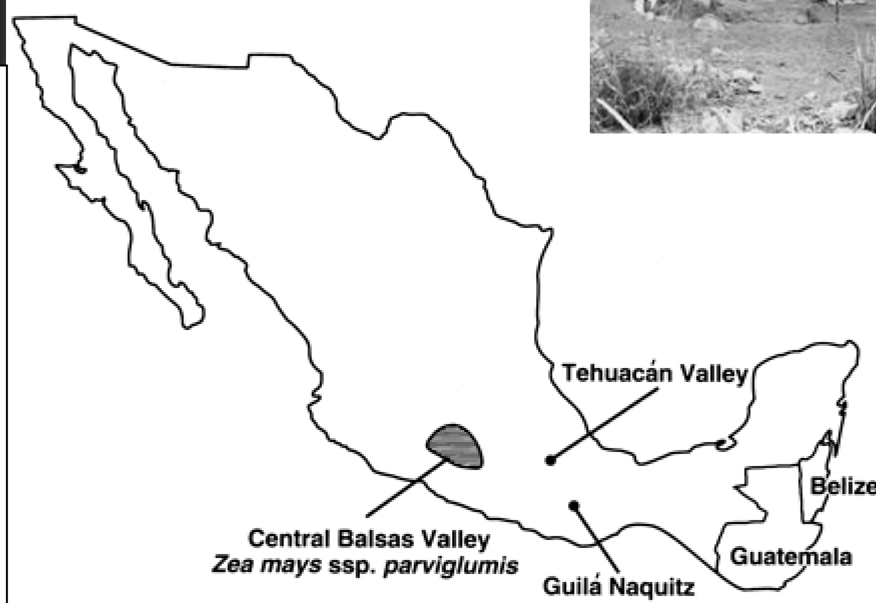
Guilá Naquitz Cave in southern Mexico
Earliest domesticated maize cobs – 6,250 BP

Piperno & Flannery 2001 PNAS



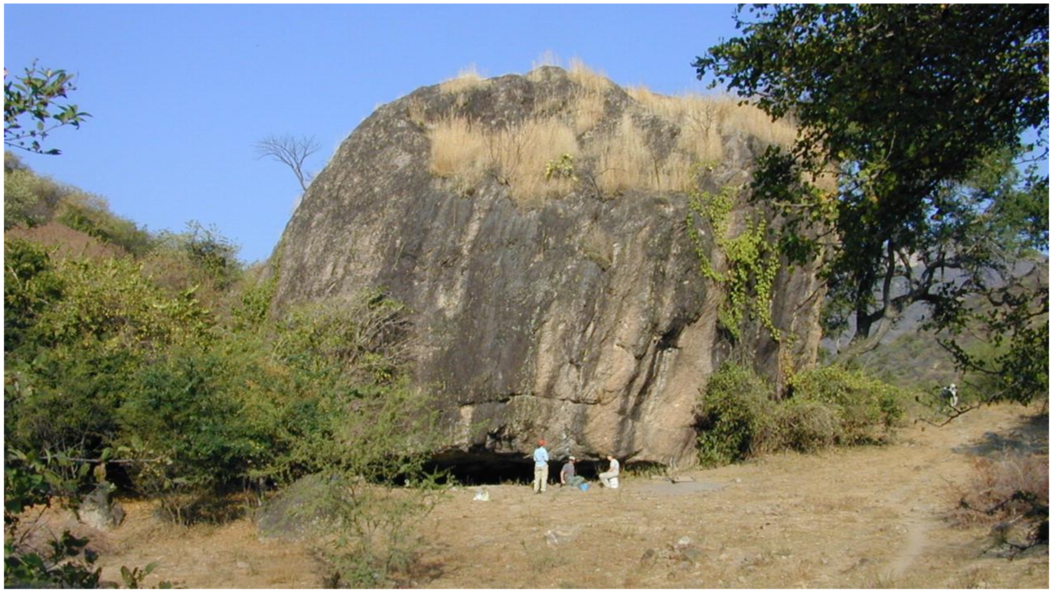


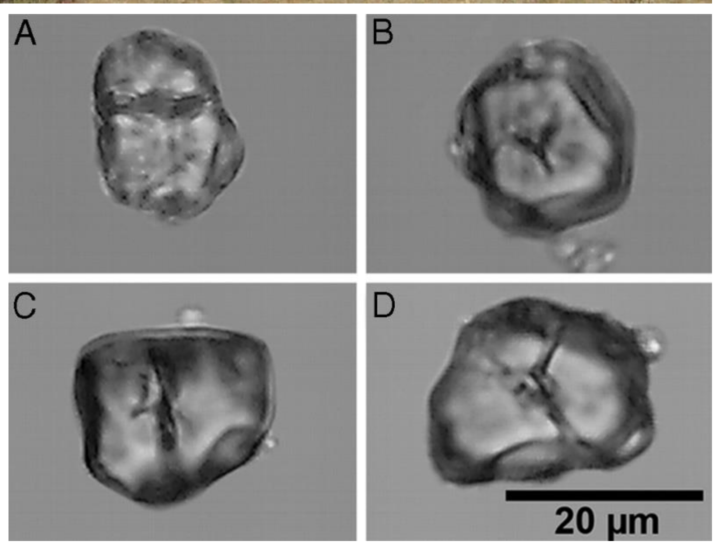


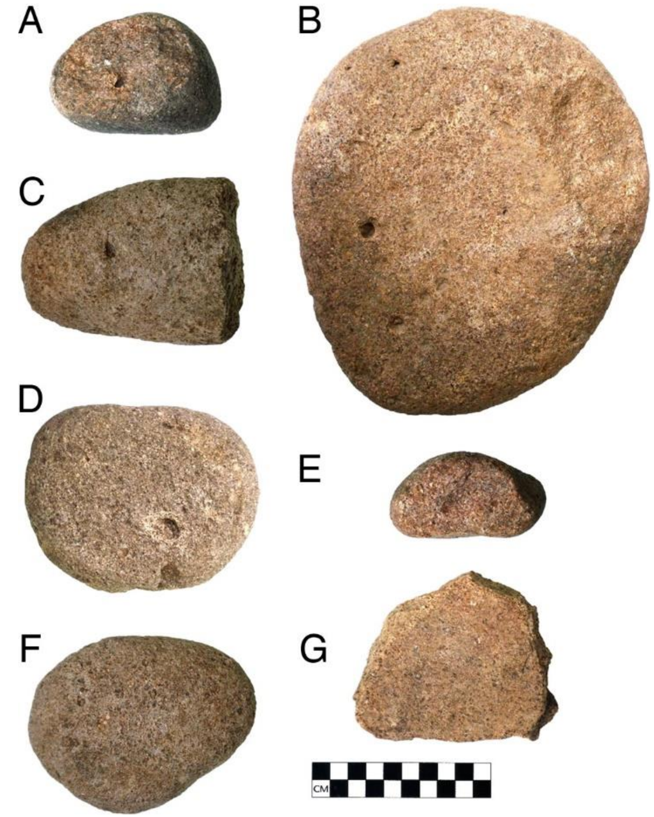


Maize – Archaeological Data II

Xihuatoxtla Rock Shelter, Balsas Depression, southern Mexico
Earliest maize starch grains – 8,700 BP







Piperno et al 2009 PNAS

Teosinte becomes popcorn

Maize Conclusions

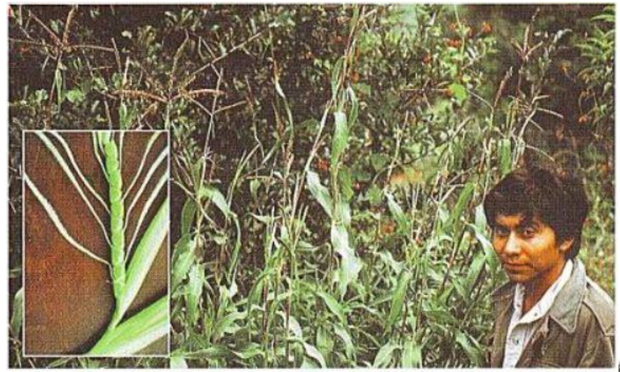
Clear evidence of a *single origin* in southern MEXICO

An exciting correspondence between the archaeological and genetic evidence to within 400-500km between the populations of teosinte in the Balsas thought to be the ancestors of domesticated maize and the Guilá Naquitz cave where the oldest domesticated maize cobs were found.

Even close correspondence is evident with the more recent archaeological evidence for maize domestication by 8,700BP in the Balsas, the exact area where genetic evidence predicted.

https://www.youtube.com/watch?v=mBuYUb_mFXA

Recent botanical exploration and discovery of maize relatives



1979 – Rafael Guzman and the discovery of *Zea diploperennis*, 2200-2400m, Sierra de Manantlan, western Mexico
Iltis et al (1979) *Science*

Zea diploperennis (Gramineae): A New Teosinte from Mexico

Abstract. *A perennial teosinte or "wild maize" endemic to the Cerro de San Miguel, Sierra de Manantlan, Jalisco, Mexico differs from* Zea perennis *by dimorphic rhizomes, robust habit, and a larger number of longer, laxer tassel branches. The fact that it is a diploid* ($2n = 20$) *has taxonomic and agronomic significance. The seeds are used locally for food.*

Earlier this year, Guzmán (*1, 2*) reported his remarkable rediscovery of perennial teosinte, thought extinct in the wild since 1921 (*3*), at two sites in southern Jalisco, Mexico. Subsequently, both sites were visited by three of us (H.H.I., J.F.D., and R.G.M.), and specimens, seeds, and rhizomes were collected and initial analyses were made. This report confirms Guzmán's conclusion regarding the Ciudad Guzmán population—that it is, indeed, conspecific with the tetraploid ($2n = 40$) *Zea perennis* (Hitchcock) Reeves and Mangelsdorf, originally discovered in this area by Hitchcock in 1910. However, the plants from the second location, Cerro de San Miguel, though similar in many ways, are a clearly distinct diploid taxon, here described for the first time:

Zea **diploperennis** Iltis, Doebley & Guzmán. **sp. nov.**
Similis a *Zea perennis* sed robustior, culmis 1-2 cm diam., rhizomatibus perennibus dimorphis (gracilioris non nisi 5–15 cm × 5–10 mm, brevioris crassis, tuberosis 1–4 cm × 9–15 mm), uterque cum internodiis brevibus 2–6 mm longis, foliis multo majoribus (40–80 × 4–5 cm), inflorescentiis ♂ cum 3–13 ramis, robustioribus et 6–15 cm longis. Typus: Iltis, Doebley & Guzmán 450.

Robust, erect, maizelike, loosely clump-forming perennial, with five to ten, or more, primary culms from one rhizome system; rhizomes of two intergrading sorts, (i) *cordlike long shoots*, 5 to 15 cm long, 5 to 10 mm in diameter, these with many dense short (2 to 6 mm) internodes, scaleless when mature, usually vertical or strongly ascending and changing abruptly into the much thicker culms, or less often horizontal and producing one to several culms from short lateral shoots, or (ii) *thick and tuberous, ovoid to obovoid short shoots* 1 to 4 cm long, 9 to 15 mm in diameter, each of these produced horizontally from the lowest two or three nodes of the primary culms, clothed when young with triangular, strongly convergent-veined, overlapping, connivent scales, at times growing upward (into a long shoot?) and producing a culm, or sometimes remaining dormant to eventually produce one to four lateral short or long shoots (or both).

Primary culms 10 to 25 dm tall, 1 to 2 cm in diameter, unbranched (or with one to three inconspicuous lateral branches), the nodes, internodes, and leaf sheaths glabrous throughout except for a more or less dense fringe of long hairs on upper sheath margin and auricles of the upper leaves; ligule a thin membrane 1 to 2 mm long, the collar prominent; leaf blades linear-lanceolate, *the major central or lower ones 40 to 80 cm long, 4 to 5 cm wide*, subcordate, glabrous, or subglabrous, except for a few marginal long hairs near base.

Male inflorescences with (2 to) 3 to 13 ± divergent to nodding branches; these 6 to 15 cm long, 12 to 20 mm wide, the central one barely exceeding the others; branching axis 1 to 4 cm long; spikelets in sessile or pedicellate pairs (pedicels 1.5 to 3 mm long), crowded and overlapping (for example, 14 spikelet pairs in 4 cm); the branch internodes short (2 to 6 mm); the branch rachis about 1 mm wide, in cross-section triangular with ciliate edges; spikelets 8.5 to 11.5 mm long, about 3 mm wide; outer glumes very thin and translucent, often purple-

2000 - Hugh Iltis & the discovery of *Zea nicaraguensis*, 0-20m, Pacific coastal Nicaragua
Iltis & Benz (2000) *Novon*

Wild maize makes more headlines in 2011

American Journal of Botany 98(9): 1537–1548. 2011.

Three new teosintes (*Zea* spp., Poaceae) from México[1]

J. J. Sánchez G.[2], L. De La Cruz L.[2], V. A. Vidal M.[4], J. Ron P.[2], S. Taba[3], F. Santacruz-Ruvalcaba[2], S. Sood[5], J. B. Holland[5], J. A. Ruíz C.[4], S. Carvajal[2], F. Aragón C.[4], V. H. Chávez T.[3], M. M. Morales R.[2], and R. Barba-González[6]

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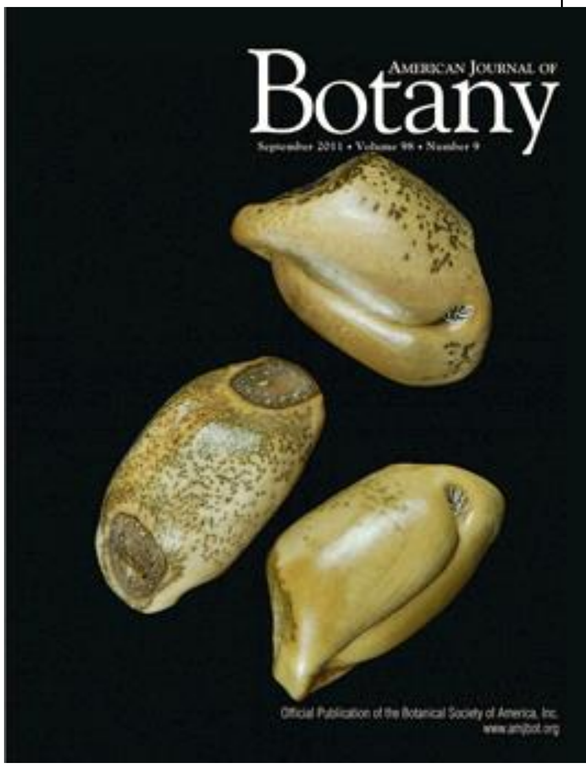
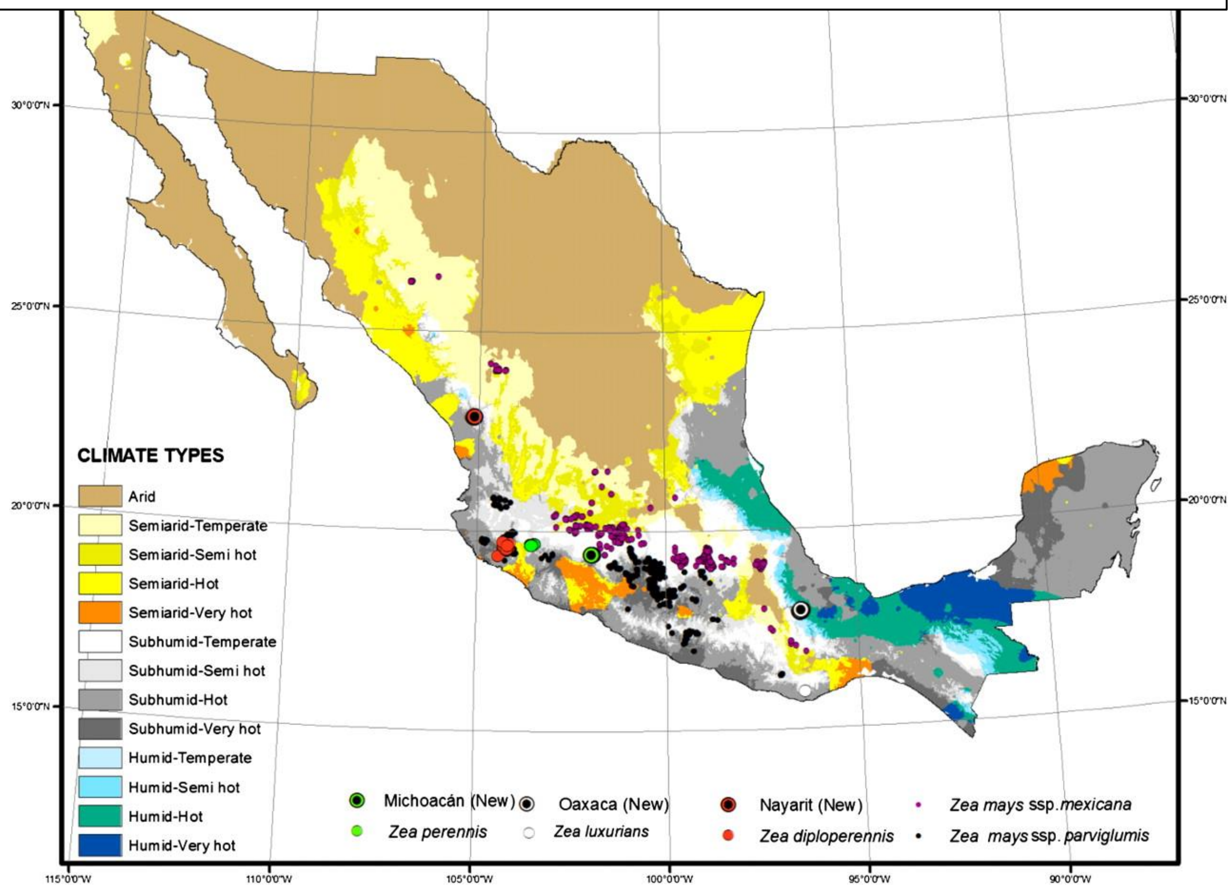
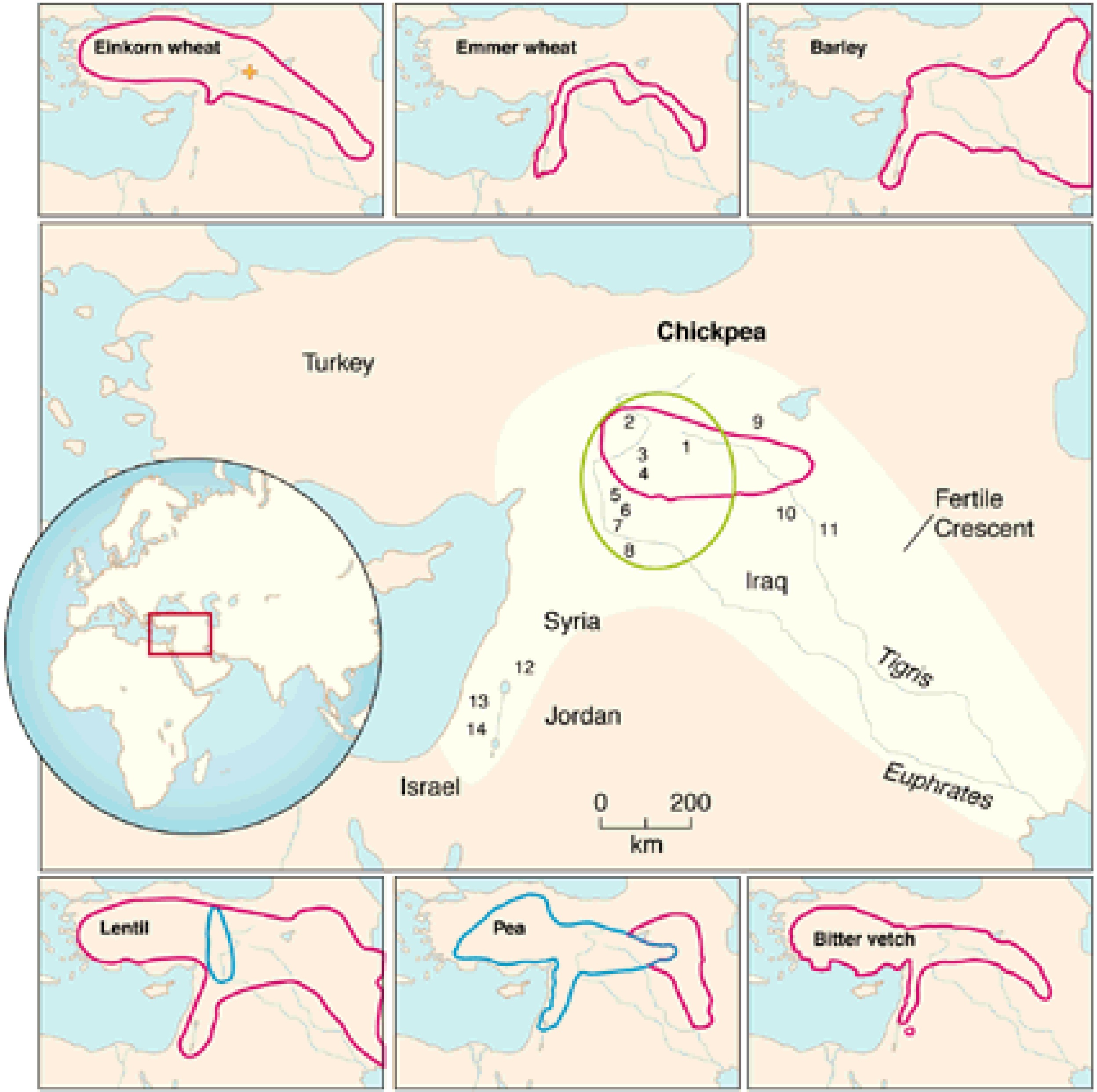


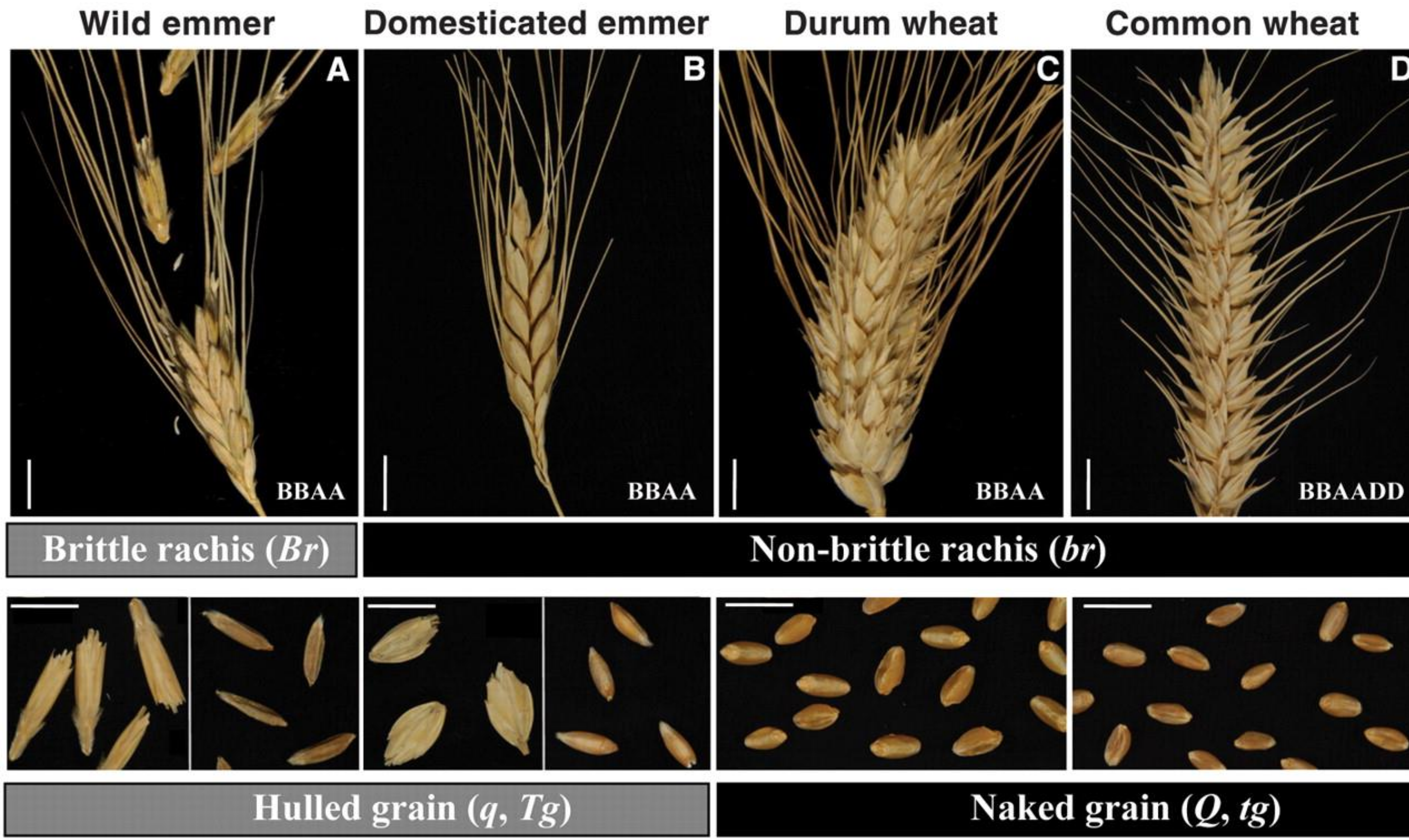


<u>Wheat</u> - In 2007 world production of 607 million tonnes; second only to rice as main human food crop and ahead of maize, after allowing for use in animal feeds. Globally, wheat is the leading source of vegetable protein in human food, with a higher protein content than maize or rice.

The Fertile Crescent & the origin of wheat

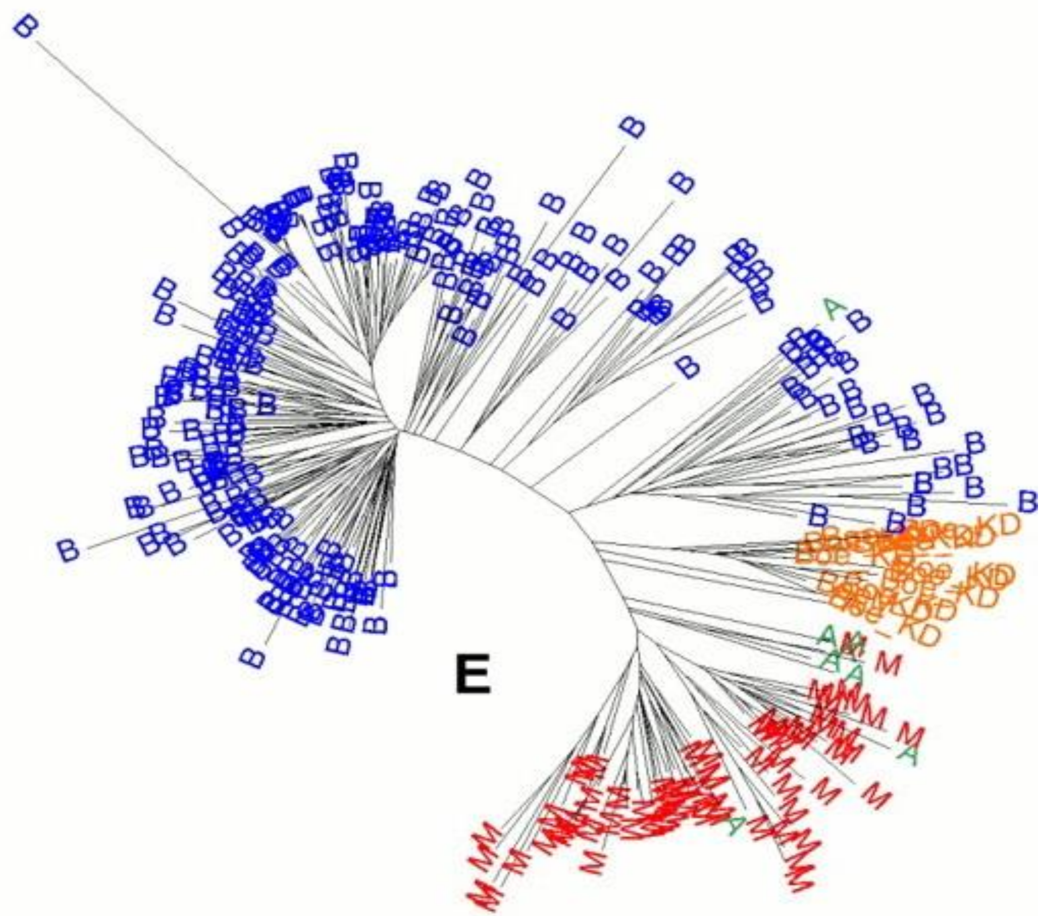


Wheat – a series of polyploids derived from diploid Einkorn wheat, *Triticum monococcum*, the earliest cultivated wheat.



Origins of Einkorn Wheat – Genetic Data

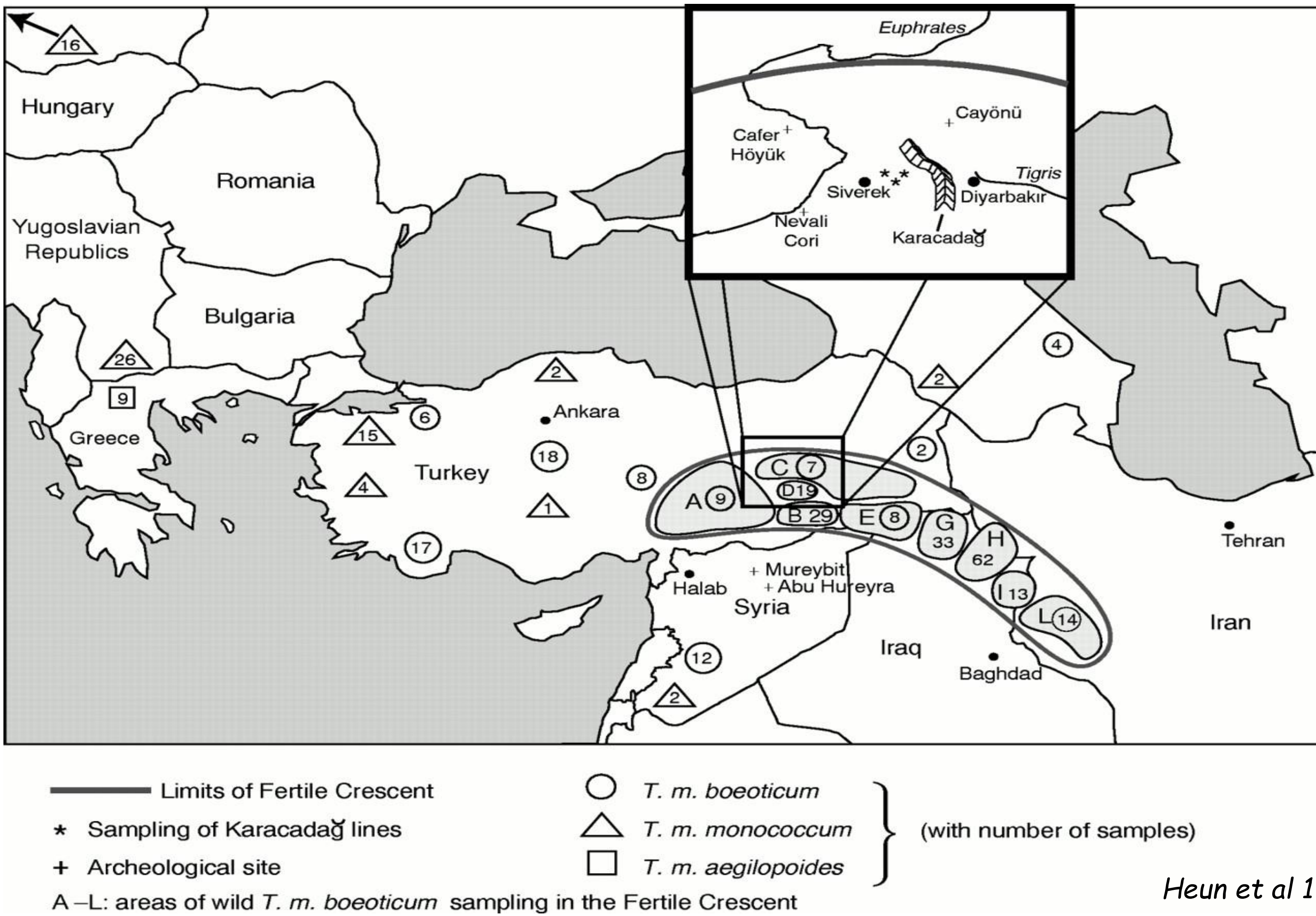
M = Domesticated Einkorn wheat *Triticum monococcum* subsp. *monococcum* – the earliest culivated wheat – monophyletic suggesting a single origin
B = Wild progenitor *T. monococcum* subsp. *boeoticum*
KD = *boeoticum* accessions from the Karacadag Mtns of SE Turkey



Heun et al 1997 Science

Origins of Einkorn Wheat – Archaeological Data

Abu Hureyra in NE Syria where the earliest evidence of farming domesticated einkorn around 9,500 BP has been found lies just 200km from Karacadag area where genetic data suggest einkorn wheat was first domesticated.

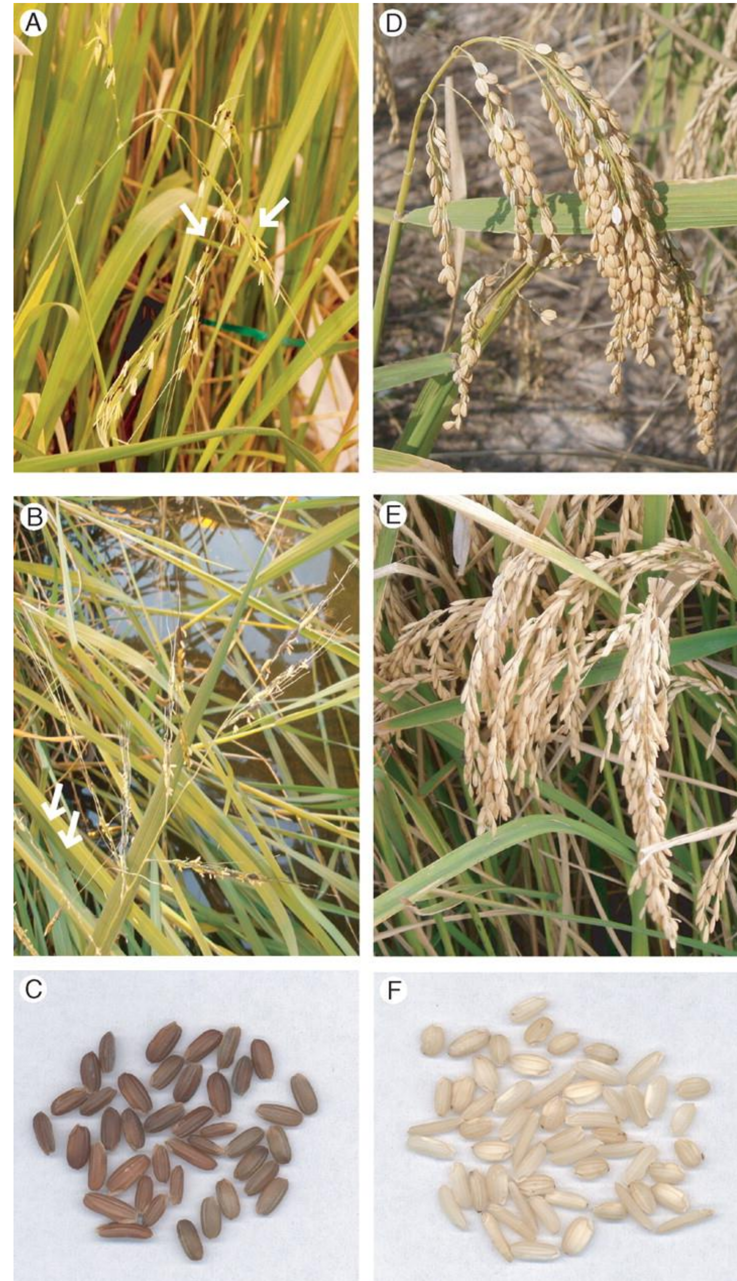


Heun et al 1997 Science

Rice - The world's most important staple food crop; feeds >50% of the world's population and > people than any other crop since the time of its domestication; 20% of all calories consumed by humans; 408,661 million metric tonnes produced per year.

<u>Rice – *Oryza sativa*</u>

Despite being the world's most important staple food crop, and although it is now well established that *O. rufipogon* is the wild ancestor of domesticated rice, the number of domestication events and their precise location are the focus of debate.



Rice – one domestication or two?

• *Oryza* comprises 21 wild species.
• Two cultivated species, *O. sativa* (which is grown worldwide) and *O. glaberrima* (which is restricted to west Africa).
• Within *O. sativa* there is huge diversity in ecology, physiology and morphology, encompassing some 120,000 different named cultivars, ranging from traditional varieties preserved by local indigenous farmers to commercially bred 'elite' cultivars developed during the green revolution.
•Two major groups: *japonica* - upland hills of south China, SE Asia and Indonesia, and *indica* - lowlands of tropical Asia, plus a number of other types - drought tolerant *Aus* varieties from India and Bangladesh; deep water *Ashinas* varieties from Bangladesh; aromatic *Basmati* varieties from India.
•Cultivation and domestication started c.6,000BP across a broad area from eastern India to south China.
•The wild ancestor, *O. rufipogon*, is found across this entire range.

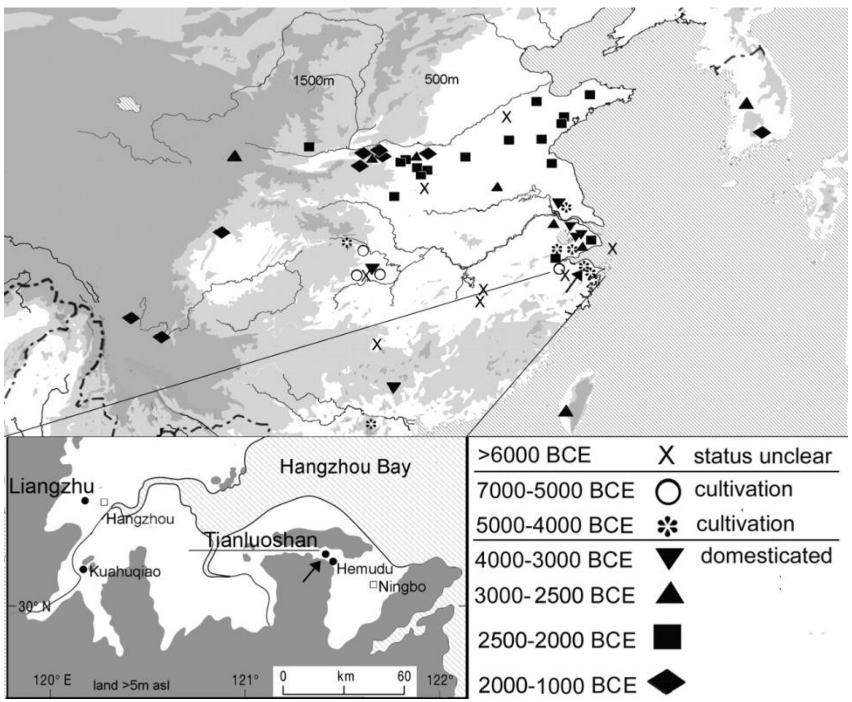
•The question is whether all this diversity arose from a single domestication event, with first *japonica* domestication in lowland south China and subsequent development of *indica* varieties in upland regions, or whether there were geographically independent origins of *indica* in the Ganges floodplain and *japonica* in lowland Yangtze floodplain.

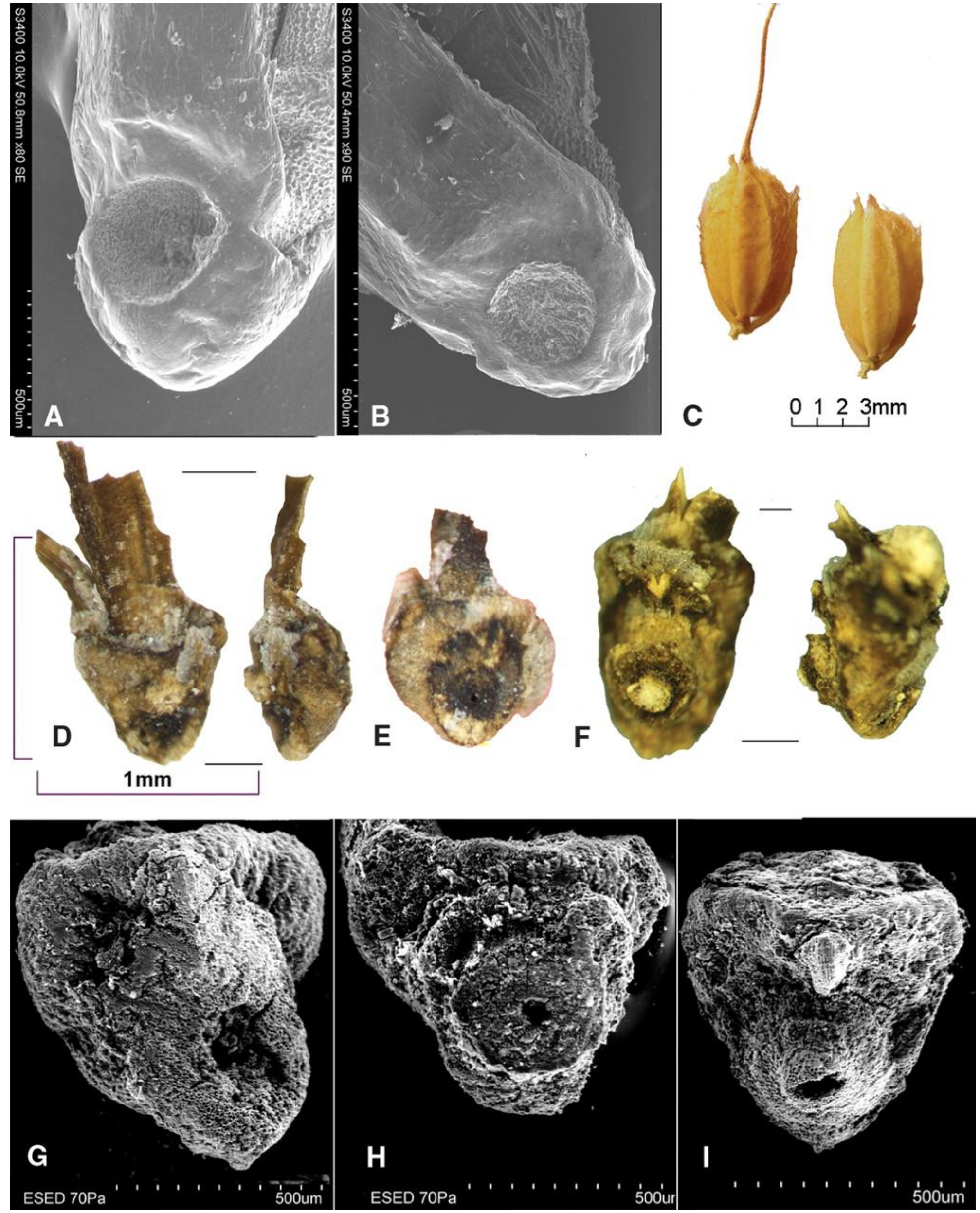
•This domestication history is complicated by large scale movement associated with trading of cultivated rice varieties and movement of people across Asia.

Rice – archaeological data

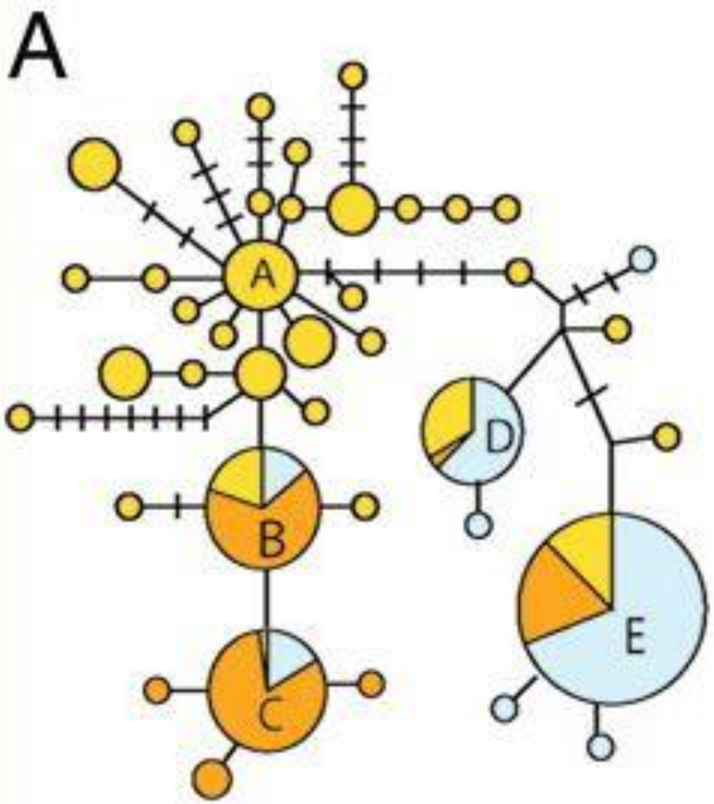
Tianluoshan, Yangtze River in China

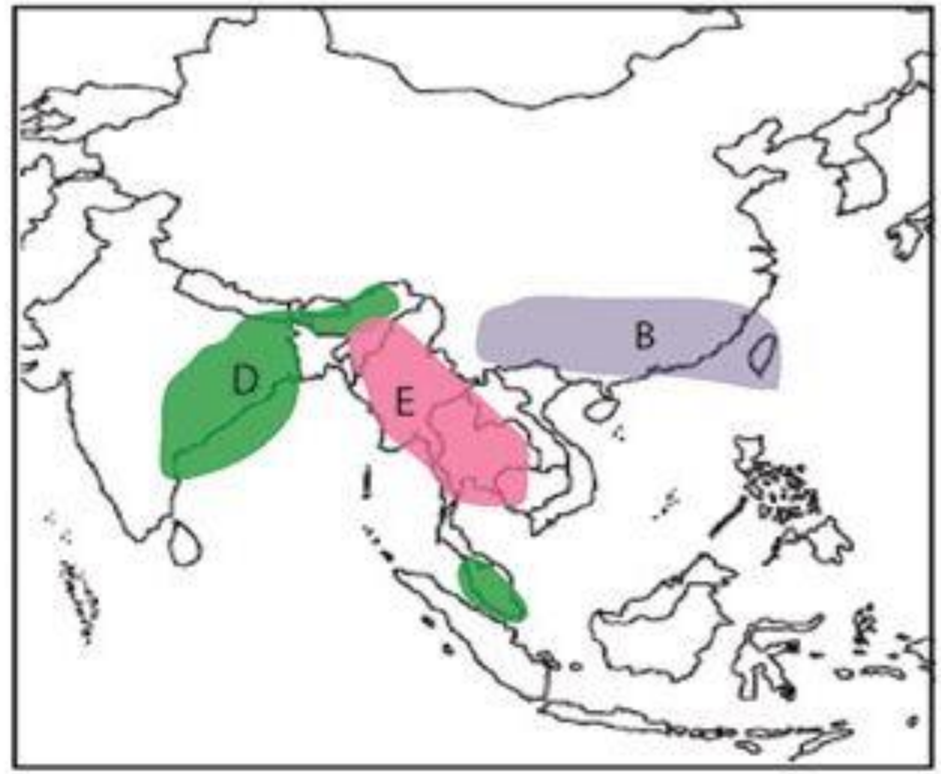
Abscission layer on rice grain diagnostic of non-shattering spikelets, i.e. Domestication from 4,000 BP. 2,641 archaeologcial spikelt bases examined





Fuller et al (2009)





Haplotype	B	C	D	E
p-VATpase				
indica	21%	16%	**94%**	**77%**
japonica	**79%**	**84%**	6%	23%

Nuclear *gene* network

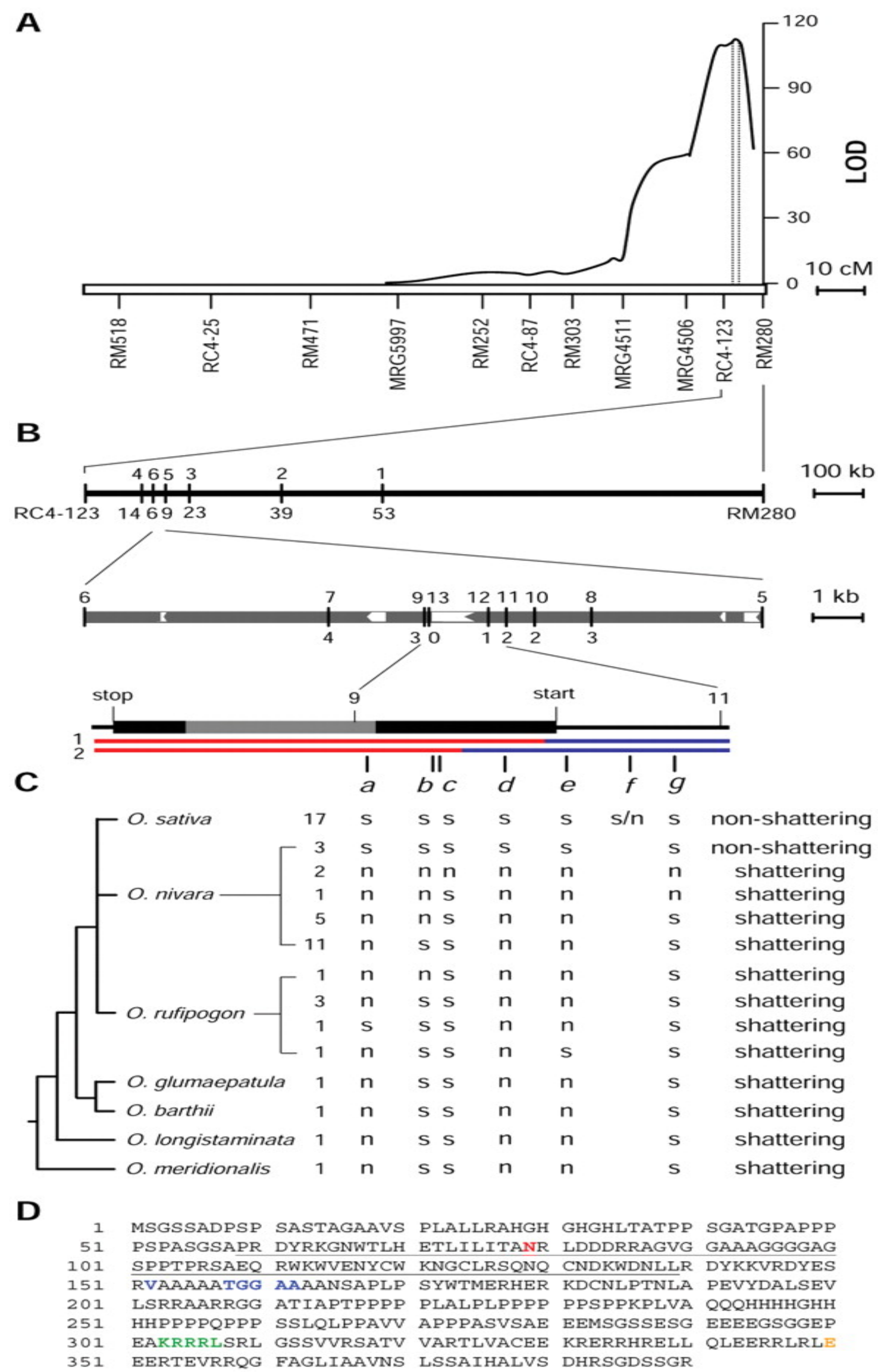
A = *rufipogon*
B & C = *japonica*
D & E = *indica*

Londo et al. (2005)

The non-shattering *sh4* rice allele

- Cloning of the rice shattering gene *sh4* which is required for the development of the abscission zone and which is thus a key domestication gene in development of non-shattering domesticated rice varieties.
- A survey of 17 divergent domesticated rice cultivars covering indica and japonica, showed that all the cultivars invariably carry the same functional mutation in the *sh4* gene.
- In contrast all wild species had the wild-type *sh4* gene.
- This supports a single origin of the non-shattering *sh4* allele in cultivated rice.

Does the single origin of the non-shattering *sh4* allele and its fixation in all diverse domesticated rice cultivars surveyed so far mean a single origin of cultivated rice?



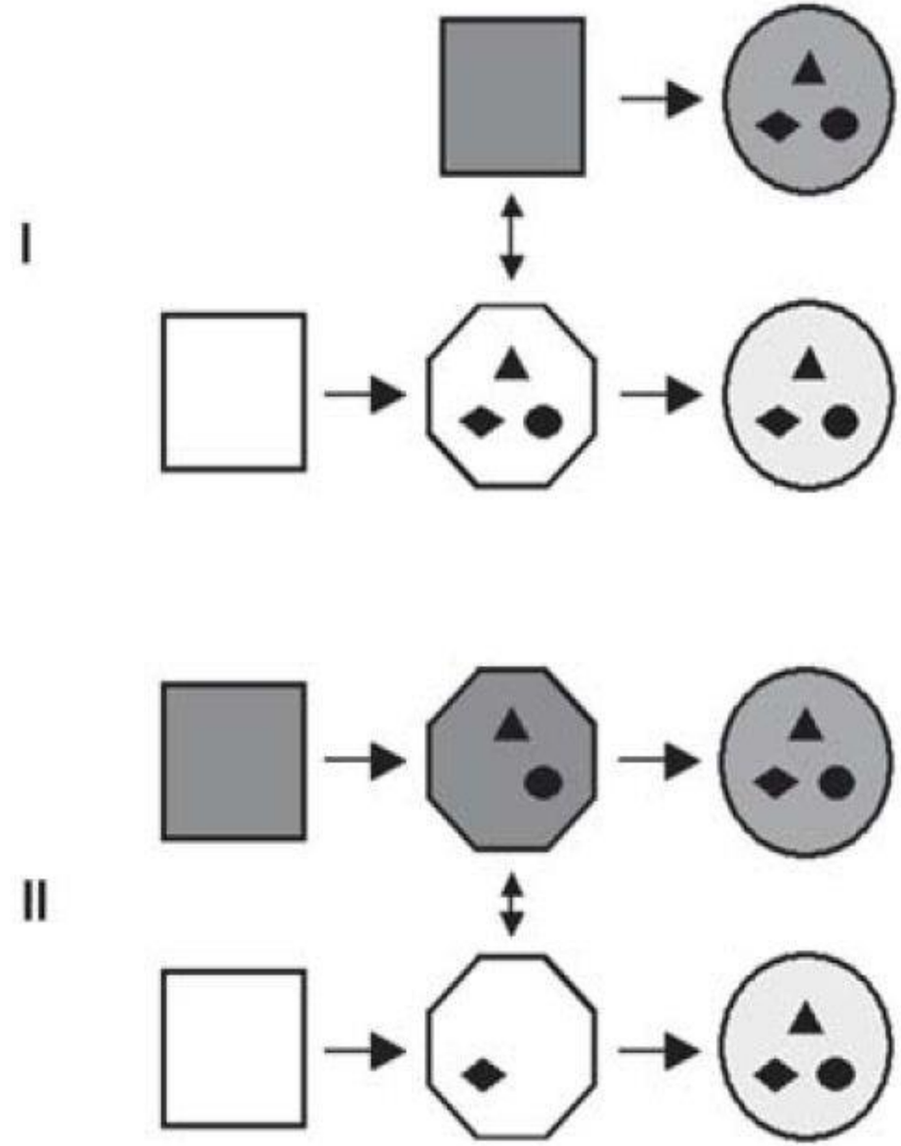
Li *et al.* (2006)

I - Single origin of rice

- Domestication from a small wild population over a long period.
- Earliest domesticated cultivars have fixed alleles for most critical domestication traits, including the non-shattering sh4 allele.
- This cultivar introduced across Asia where exchanged genes with local populations of O. rufipogon via hybridization and introgression
- japonica and indica emerged as divergent hybrid lines selected for different climatic conditions and agricultural practices.

II - Multiple origins

- Starting from divergent wild populations with different alleles fixed for the same trait in different cultivars.
- Subsequent crosses between these semi-domesticated cultivars at an early stage of rice cultivation allowed farmers to select the best alleles for critical domestication traits which became rapidly and widely fixed in both of the independently derived initial domesticates.

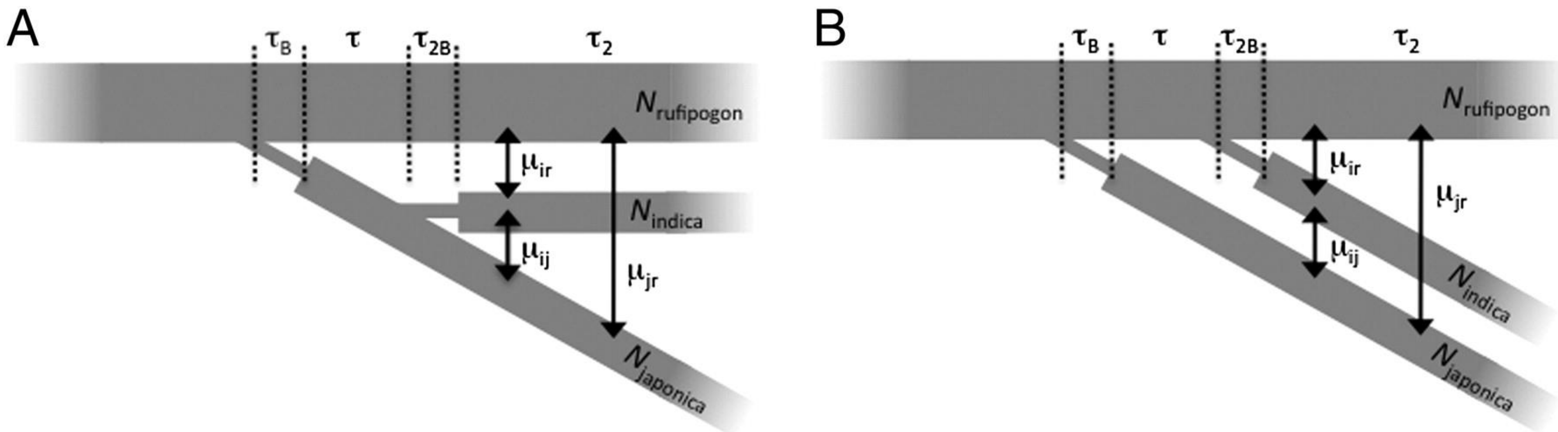


Squares = wild populations; hexagons = earliest domesticated rice cultivars; circles = contemporary rice cultivars; shading indicates genomic divergence; shapes inside = critical domestication alleles that are fixed in contemporary cultivars. Double arrows = hybridization; single arrows = progress of domestication

Sang & Ge (2007)

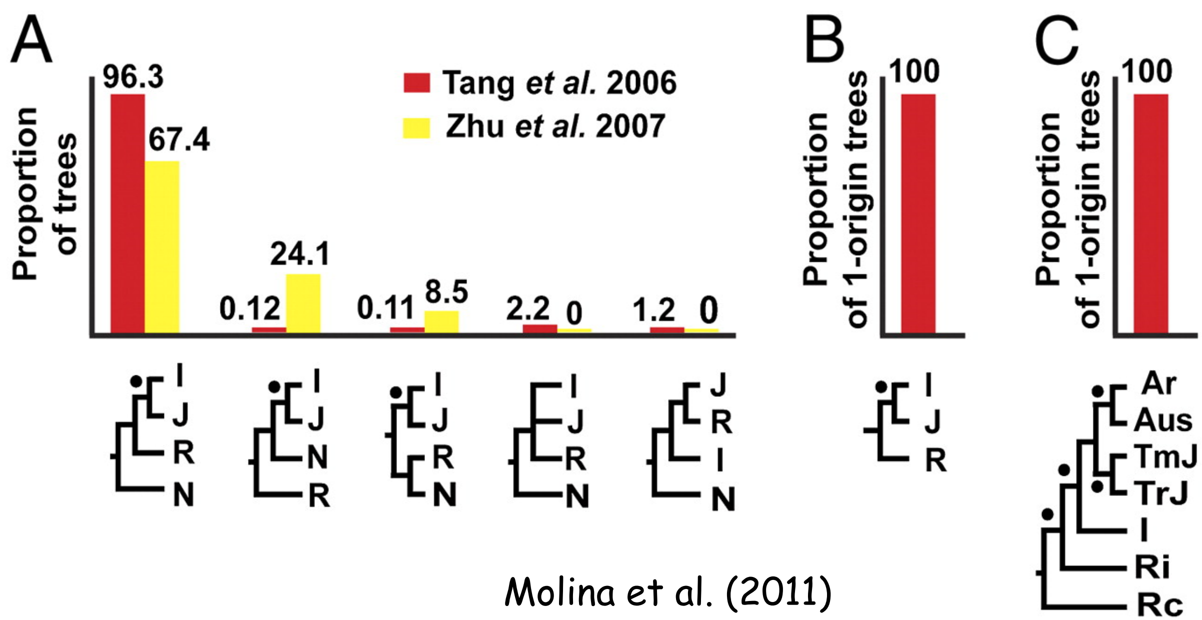
Single origin

Two independent origins

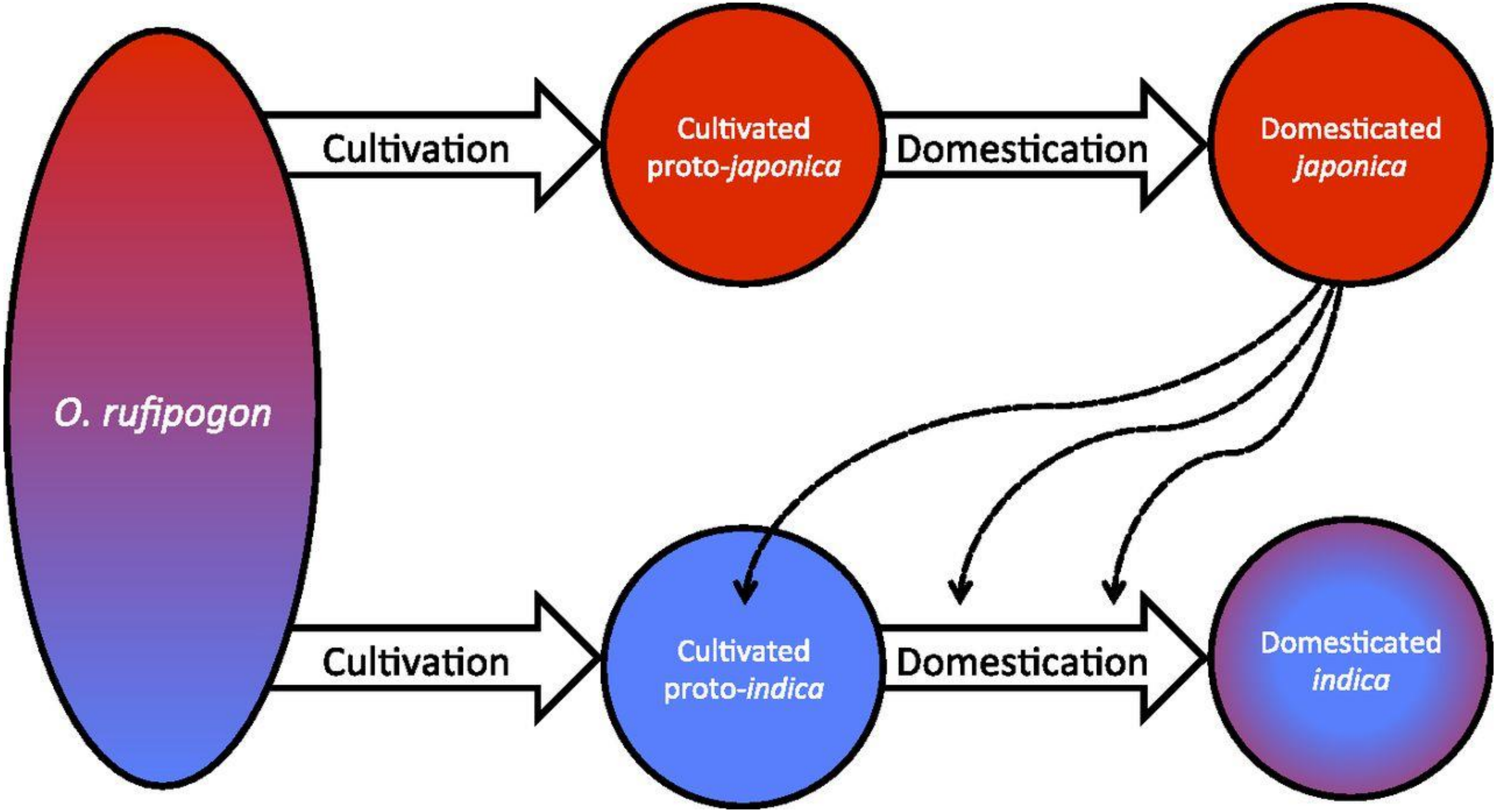


Persistence of ancestral polymorphisms through incomplete lineage sorting resulting in sequence similarities that do not necessarily reflect species and population relationships, and incongruent gene trees when multiple loci are analysed independently. Re-analysis of data using the multi-species coalescent can detect signals of species differentiation even before gene trees are reciprocally monophyletic.

These all point to a single origin where japonica is sister to indica.

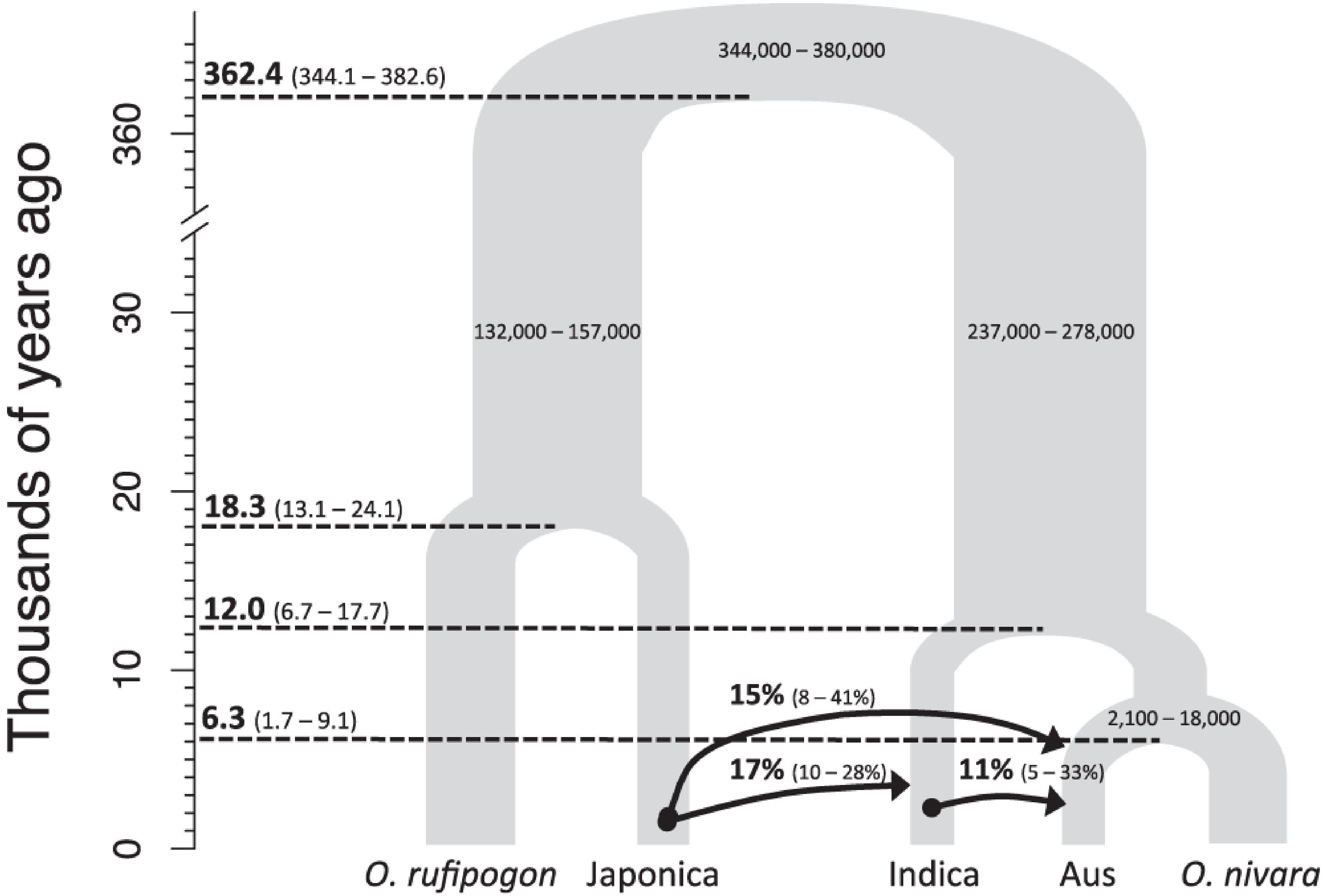


Molina et al. (2011)



Gross & Zhao (2014)

The rice paradox: multiple origins but single domestication in Asian rice



Choi et al. (2017)

Rice Conclusions

- Much initial evidence to suggest that the genomes of the major cultivar groups came from different wild populations that diverged considerably earlier than the time of rice domestication.

- However, the non-shattering allele of sh4, primarily responsible for the reduction of grain shattering from wild to cultivated rice, as well as other domestication genes, originated only once during domestication.

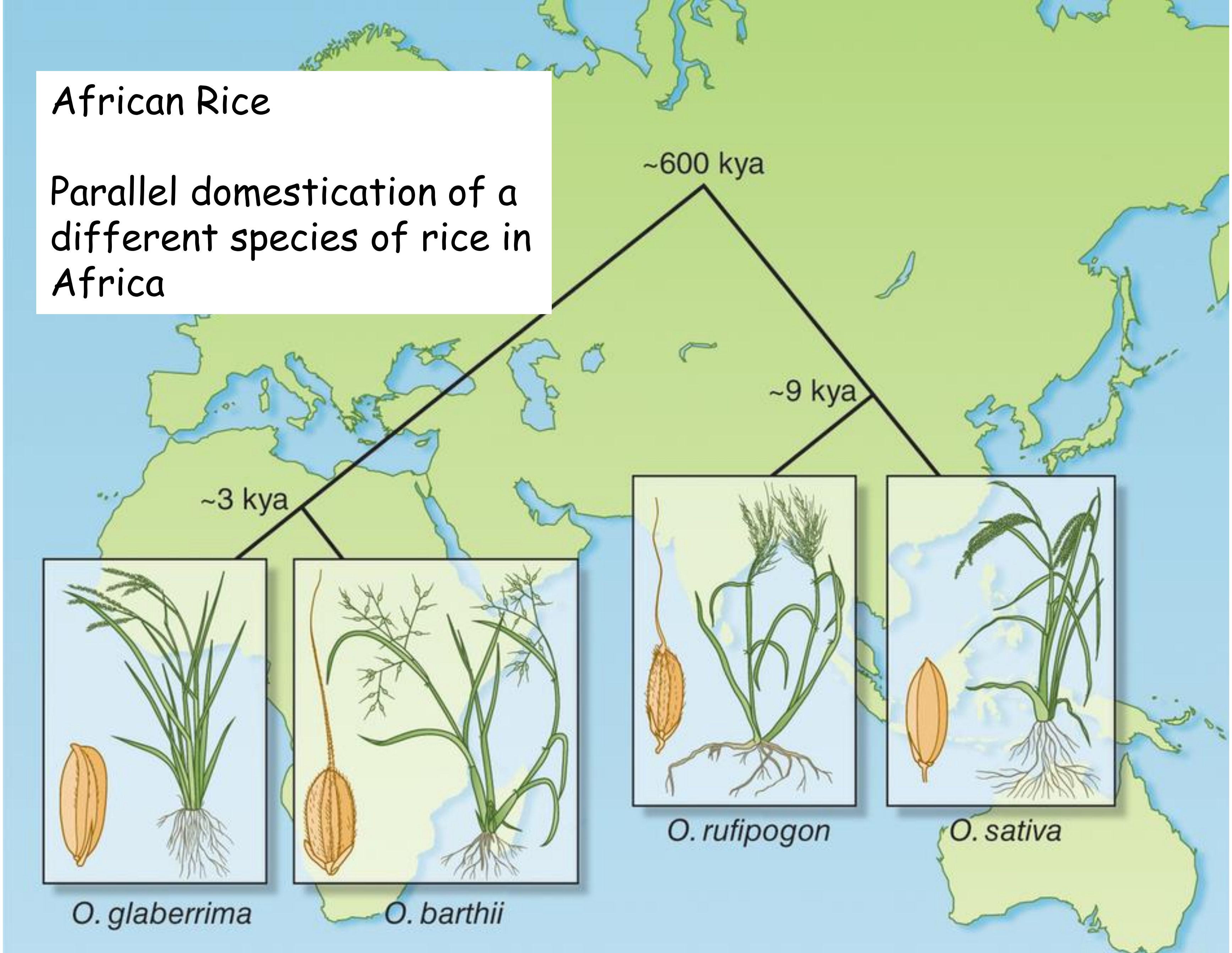
- Re-analyses of DNA sequence data using the multi-species coalescent to account for ancestral polymorphism and incomplete lineage sorting, and whole genome analyses all point towards a single origin.

- Thus, despite the remarkable rapid accumulation of molecular and phylogenetic data for rice, including the first genome sequence for a crop plant, over recent years, it is remarkable how difficult it remains to reconcile the conflicting evidence between a single vs multiple origins.

- This suggests that rice domestication is indeed a very complex puzzle, due to human activities that may have eroded the genetic signatures that might reveal the evolutionary histories of these lineages and which have almost certainly prompted continuous geneflow and introgression between cultivars.

African Rice

Parallel domestication of a different species of rice in Africa



Purugganan 2014

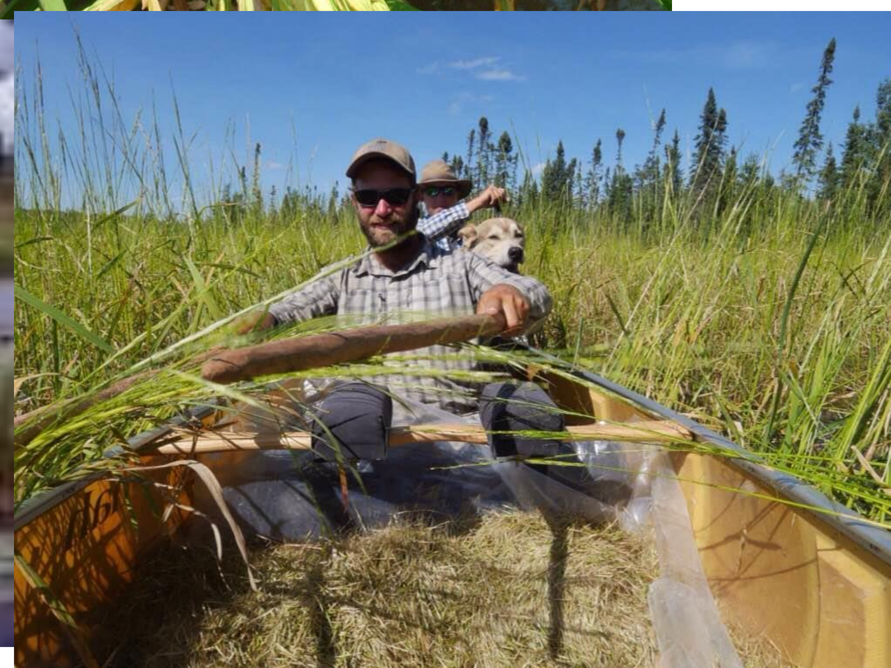
Neotropical Rice

4 New World Oryza wild rice species

Oryza glumaepatula

Canoe & flail harvesting

Arroz de pato – duck rice
Arroz de brejo – swamp rice



nature ecology & evolution

ARTICLES

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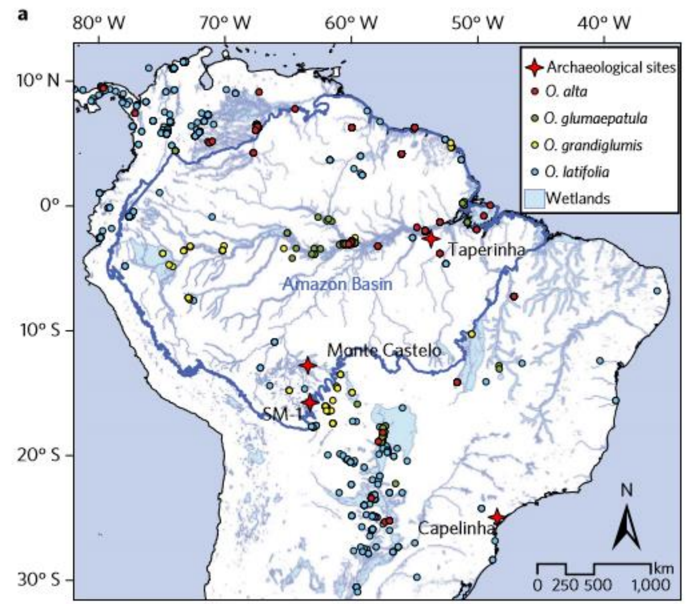
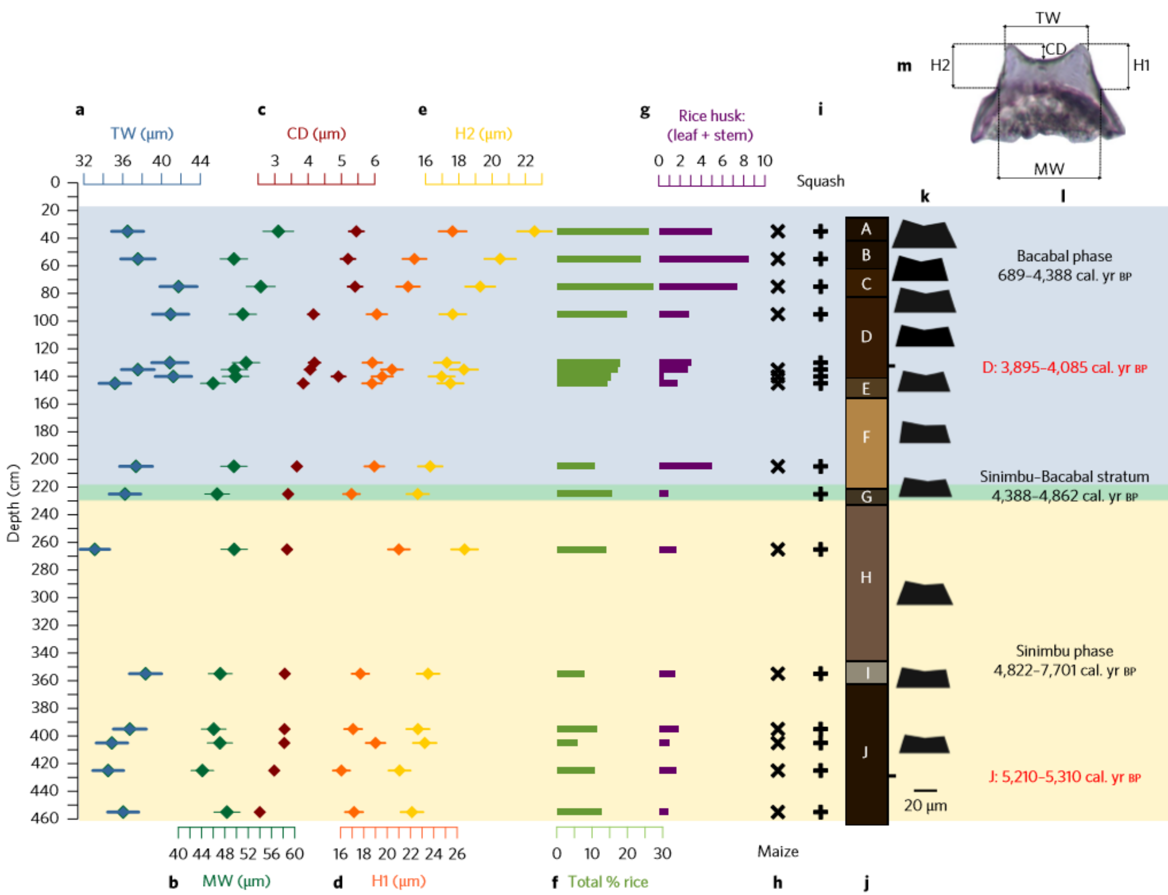
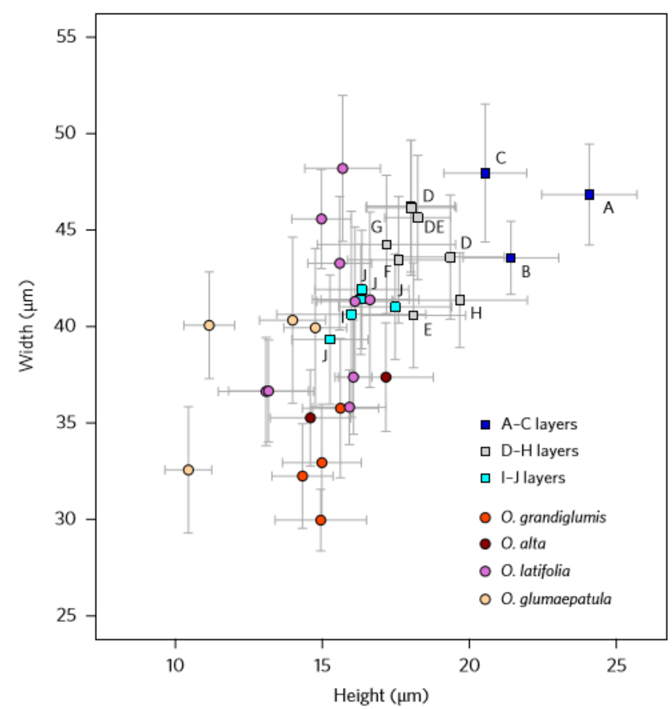
Evidence for mid-Holocene rice domestication in the Americas

Lautaro Hilbert[1], Eduardo Góes Neves[2], Francisco Pugliese[2], Bronwen S. Whitney[3], Myrtle Shock[4], Elizabeth Veasey[5], Carlos Augusto Zimpel[6] and José Iriarte[1]*

November 2017







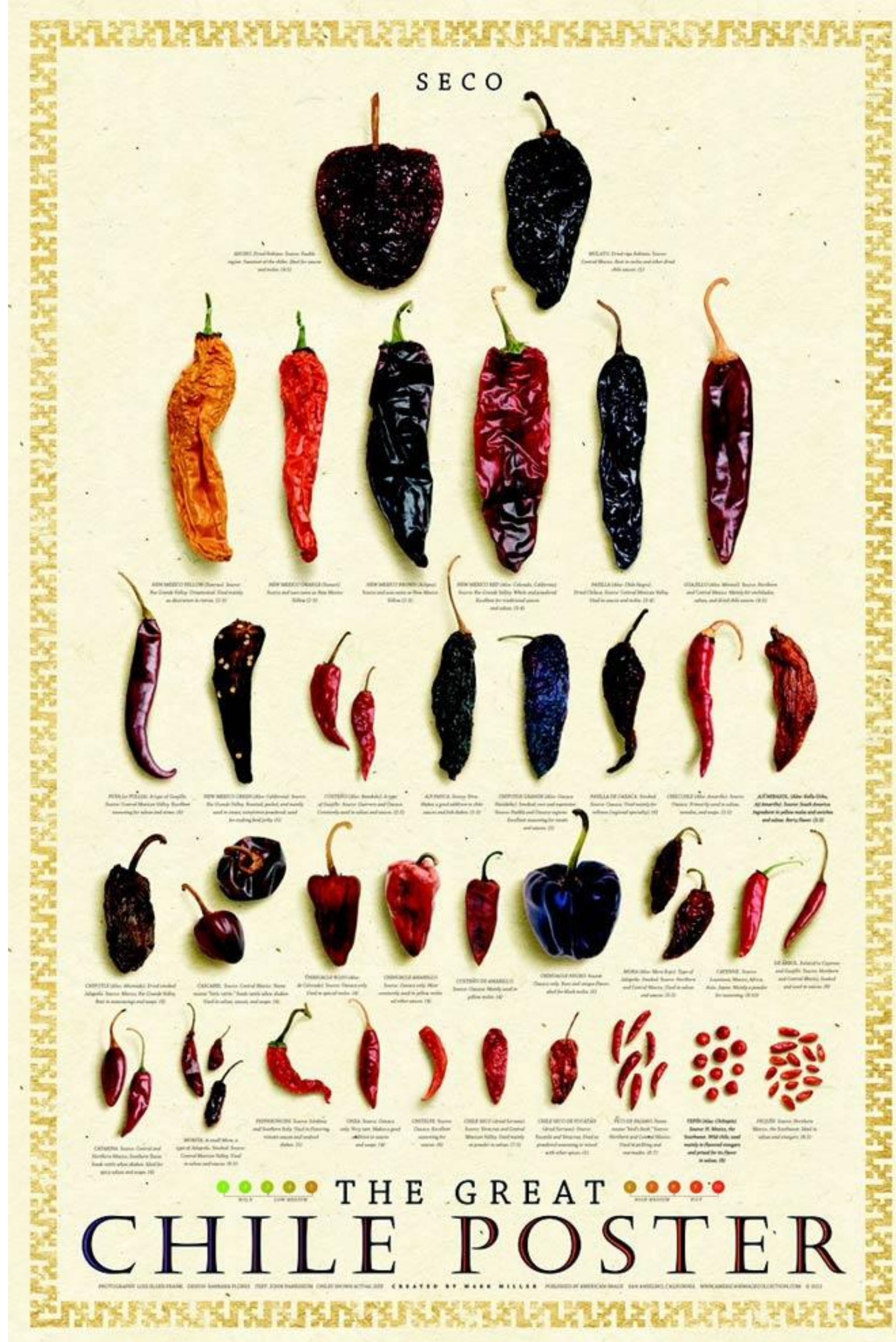
Chili peppers from Mexico

Capsicum annuum
Solanaceae

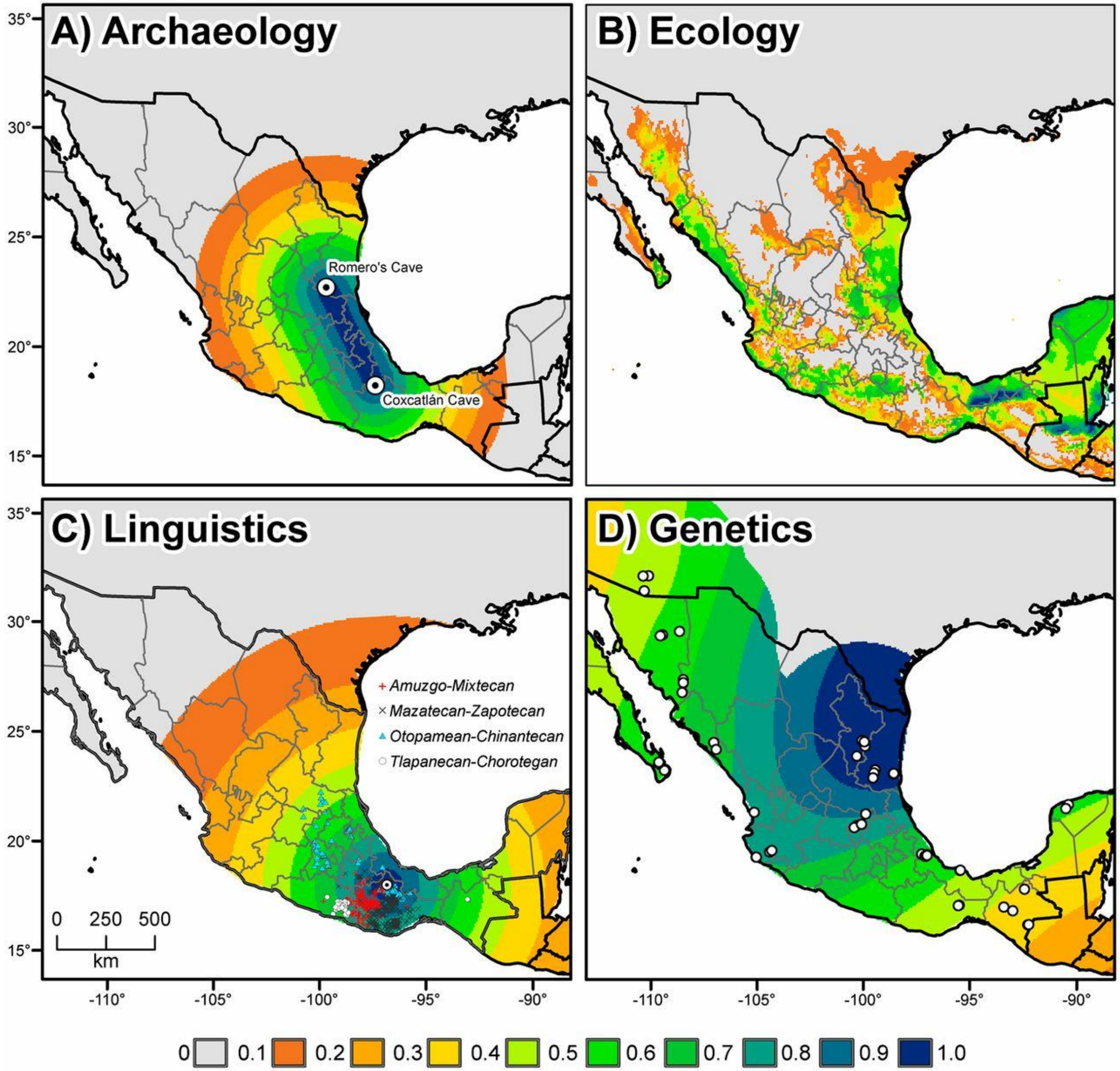
The world's most widely grown spice

Evidence from:
- Archaeology
- Genetics
- Paleobiolinguistics
- Ecology – species distribution modelling

Combining data using modelling approaches

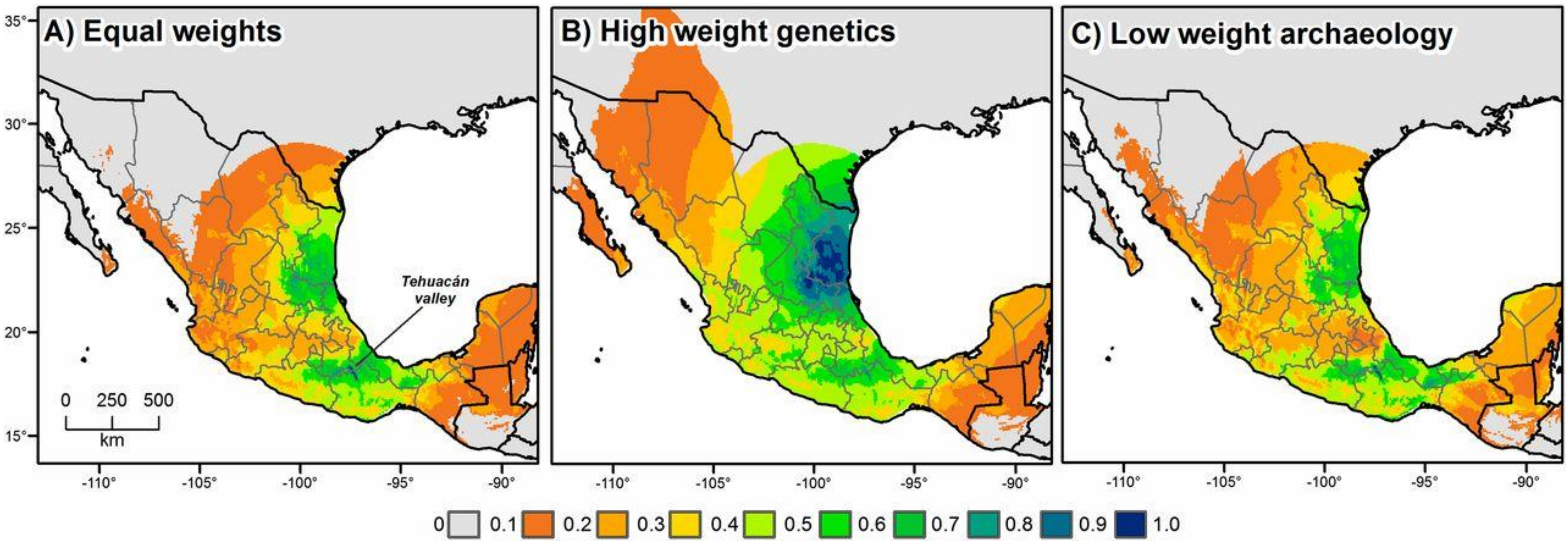


Possible area of Mexico for *Capsicum annuum* domestication based on different sources of evidence



Kraft et al. 2014

Consensus models of the likelihood that cultivated chili pepper originated in an area



Kraft et al. 2014

Source Materials – full list available on OLAT

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Colin Hughes, Sept 2018

For Next week:

Draw a phylogenetic tree that shows multiple independent origins of a crop

BIO 235 – Plants & People – Evolution and Domestication of Crops

Course Assignment – What do we eat today?

Compile a complete list of all the plants and plant parts that you eat, drink or otherwise consume during the course of one week, i.e. over seven consecutive days. Include everything – breakfast, lunch, dinner, snacks, inhalations and ***all*** major and minor ingredients. Leave **nothing** out.

Annotate your list, as far as you can, in a table showing: common name / scientific name / plant family / part of the plant (seed, fruit, root, stem, leaves, etc) / region of origin (i.e. where does the plant grow naturally) / and place of production (i.e. where was the plant that supplied your food grown). For example: potato / *Solanum tuberosum* / Solanaceae / stem tuber / Andes / Switzerland. Only record each plant once on your list, even if you eat it several times.

Make an estimate of your 'food kilometers' for each plant product and for the week in total, i.e. how far in total did all the elements of your weekly food travel to reach you?

Analyse and summarize in **a few pages** any interesting features about the taxonomic diversity and geographic distribution of your food intake, and what it means in relation to how we use plants, and how that is changing through time. **Step back and think!**

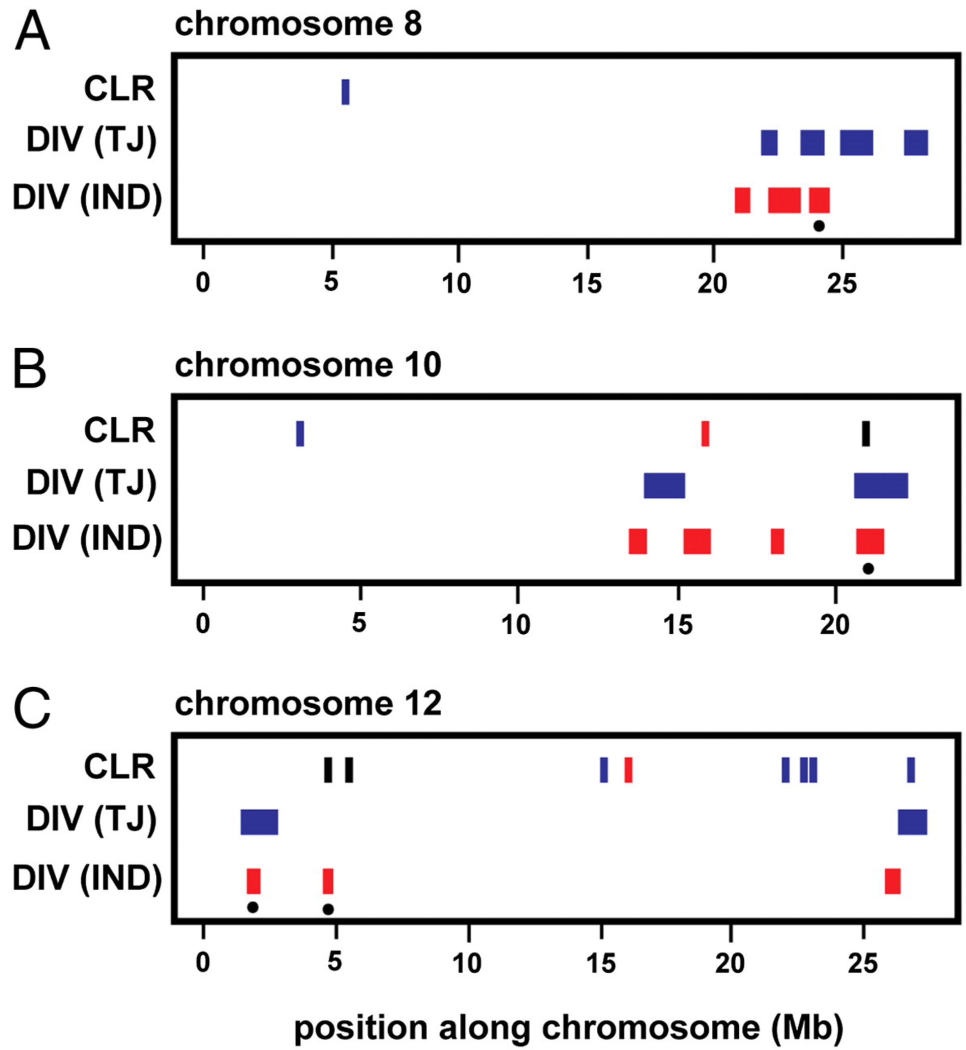
Submit a **hard (paper) copy** of your assignment to me by 6**th November**, i.e. 5 weeks from today. The assignment is worth 50% of the overall BIO235 assessment.

Any questions: ask me, or email me!
Colin Hughes, Oct 2018, Email: colin.hughes@systbot.uzh.ch

Key domestication genes *Sh4* – non-shattering and *prog1* have nearly identical sequences in all indica and japonica lines

4 selective sweeps that are shared across *japonica* and *indica* lines all correspond to known domestication loci. The remaining sweeps are not shared and correspond to neutral (diversification) loci.

Further evidence that there was a single origin of domesticated rice.



Molina et al. (2011)