From Last Week:

- Pick a plant that you think has had important impacts on human history

- Outline in a few sentences how and why it is important

- Tell the class about it




BIO 235
Plants & People
Evolution &
Domestication
of Crops







Lecture 2
The Origins of Agricutlure

- Archaic foraging to first farmers
- Where, when, how many times, and using which crops, did agriculture arise?
- De Candolle & Vavilov
- Documenting domestication – archaeology & genetics
- The first domesticated plant – the bottle gourd
- Two independent origins or one? – the sunflower

Colin Hughes
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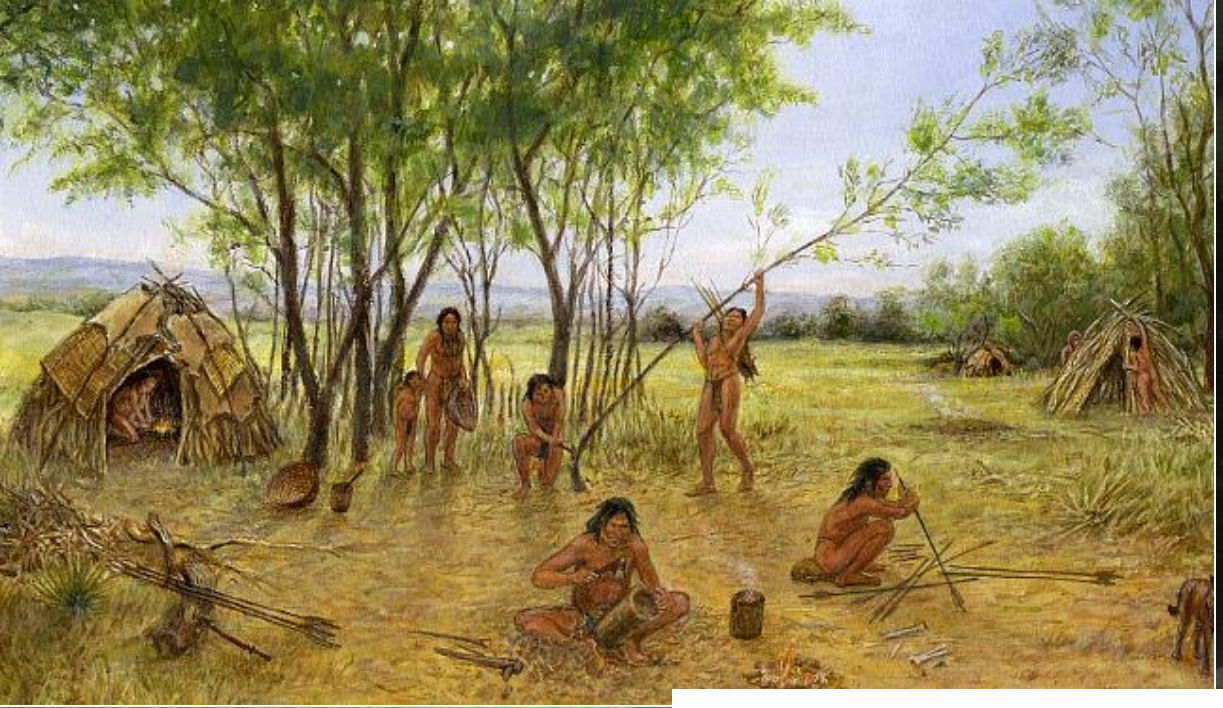

Foraging to Farming

Gorilla - Vegetarian

Chimpanzee - Omnivore

Australopithicus - Omnivore

Neanderthal – Omnivore

Homo sapiens – truly omnivorous

Homo erectus

Homo erectus – Omnivore
1.5 Myr - smaller teeth, smaller jaw muscles, larger brains and notably smaller guts

Gorilla - Vegetarian

Chimpanzee - Omnivore

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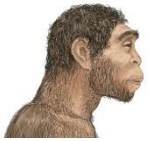
Homo erectus



COOKING

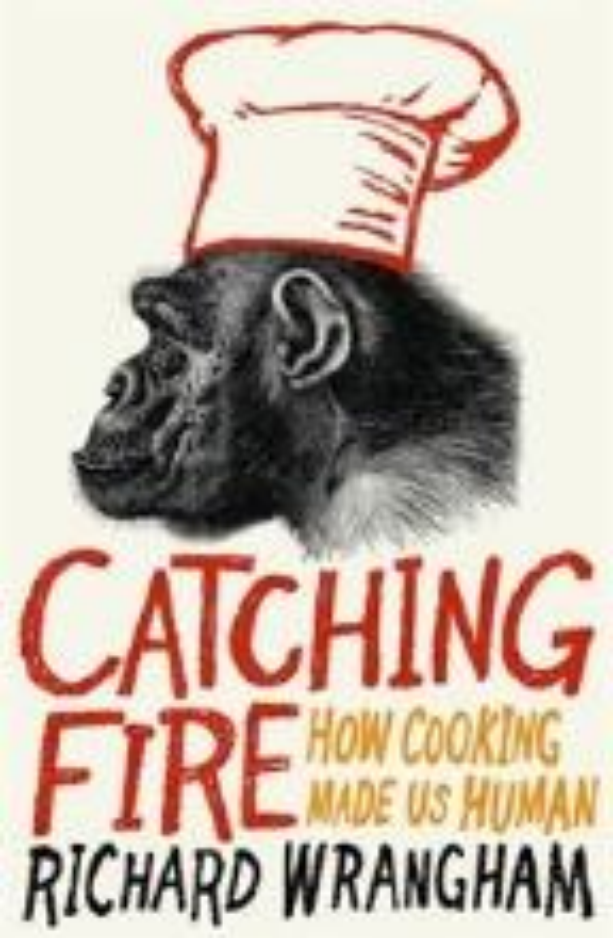
Homo erectus – Omnivore
1.5 Myr - smaller teeth, smaller jaw muscles, larger brains and notably smaller guts

Catching Fire: how cooking made us human

Lecture by Dr. Richard Wrangham, primatologist from Harvard University

I cook, therefore I think, or even *I cook, therefore I am….*

https://www.youtube.com/watch?v=69ckWLrvVhg



Archaic Foraging Diet

Castanea sativa

Quercus robur
Corylus avellana

Sinapsis arvensis
Spergula arvensis

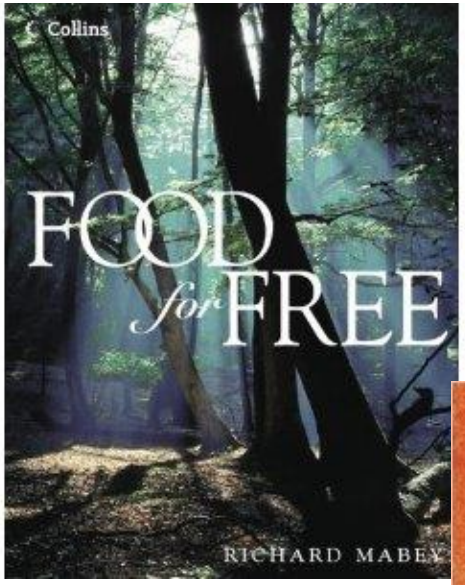
Chonopodium majus
Silverweed roots

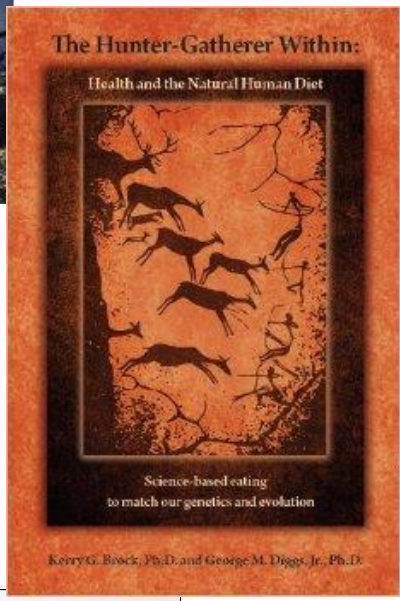
Fungi

Chondrus crispus

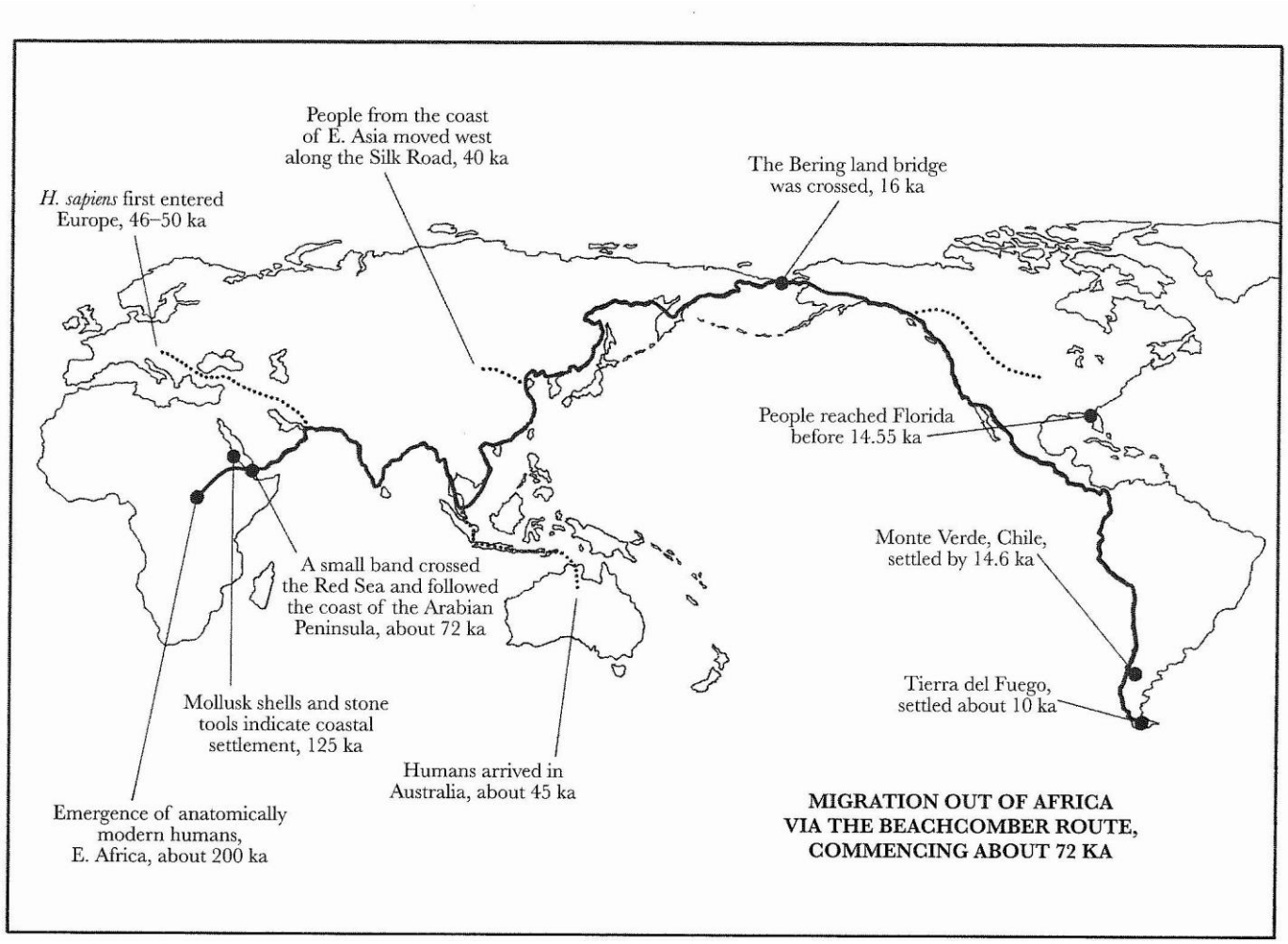
Meat & fish
– e.g. Sus scrofa

Shellfish





Shellfish beachcombing and the global dispersal of modern humans



Silvertown, 2017

Foraging

- MUSCLES - Extremely labour intensive – all available time & whole human population taken up with hunting & gathering – high calory demand & intake
- Highly seasonal
- Entirely local – wild food plants
- Dependent on encyclopaedic & sophisticated knowledge of plants & animals, manifest by complex systems of *folk taxonomy* and common names
- Very little choice – especially at certain times of year
- Will harvest be large enough to hold off starvation for another year?

Farming

- MACHINES - Very small fraction of people directly involved in food production (<2% in U.S.A. and still declining) – most people sedentary – reduced need for calories
- Seasonality has all but gone
- Global – product of crop breeding
- Loss of knowledge of local plants
- Endless consumer choice – spoilt rotten?
- Am I getting too fat? Too much food and its associated impacts. The advent of obesity as a larger health problem than lack of food across most of the world

Alexander von Humboldt (1807). Essai sur la Géographie des Plantes.

The origin, the first home of the plants most useful to man, and which have accompanied him from the remotest epochs, is a secret as impenetrable as the dwelling of all our domestic animals.... We do not know what regions produced spontaneously wheat, barley, oats, and rye. The plants which constitute the natural riches of the tropics, the banana, the pawpaw, the manioc, and maize, have never been found in the wild state. The potato presents the same phenomenon.

Alphonse Pyramus De Candolle (1882). Origin of Cultivated Plants.

- In what manner and at what epochs cultivation began in different countries?
- It is clear that, owing to their well-known qualities.... it was at an early period found easy to cultivate rice and several leguminous plants in southern Asia, barley and wheat in Mesopotamia and in Egypt, several species of Panicum in Africa, maize, the potato, sweet potato and manioc in America.

Alphonse Pyramus De Candolle (1882). Origin of Cultivated Plants.

- The first worldwide Encyclopedia of 250 of the world's most important cultivated plants, with their temporal and geographic origins

• No species was common to the two hemispheres before cultivation, and no evidence of pre-Columbian communication between the New and Old Worlds.
• 199 species came from the Old World and 45 from the Americas.
• A relatively small number of species of Poaceae, Leguminosae and Brassicaceae dominated.
• Absence of cultivated plants in some areas, e.g. The Cape, Australia..
• Some plants seemed to have been cultivated well before others.
• Annuals dominate and came before perennials.
• Some 27 species remained unknown in the wild.

SPECIES NATIVE TO THE OLD WORLD.

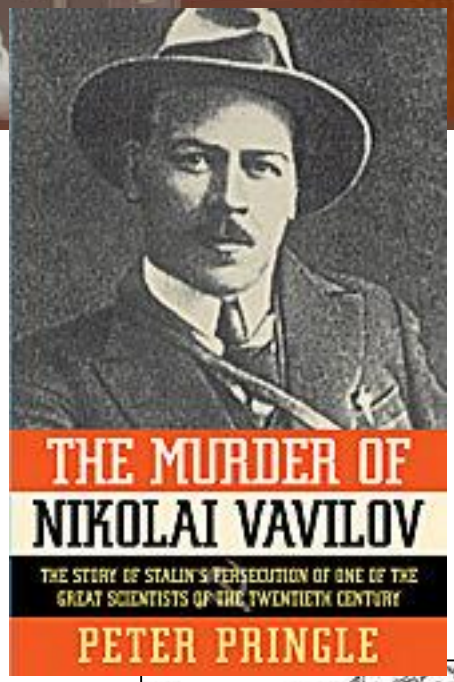
CULTIVATED FOR THE SUBTERRANEAN PARTS.

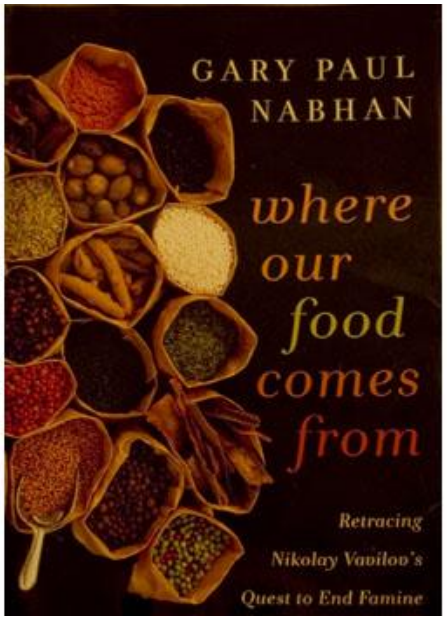
Name and duration.	Date.	Origin.
Radish—Raphanus sativus (1).	B.	Temperate Asia.[1]
Horse-Radish—Cochlearia Armoracia, ♃.	C.	Eastern temperate Europe.
Turnip—Brassica Rapa (2).	A.	Europe, western Siberia (?).
Rape—Brassica Napus (2).	A.	Europe, western Siberia (?).
Carrot—Daucus Carota (2).	B.	Europe, western temperate Asia (?).
Parsnip—Pastinaca sativa (2).	C.	Central and southern Europe.
Tuberous Chervil — Chærophyllum bulbosum (2).	C.	Central Europe, Caucasus.
Skirret—Sium Sisarum, ♃.	C.	Altaic Siberia, northern Persia.
Madder—Rubia tinctorum, ♃	B.	Western temperate Asia, south-east of Europe.
Salsify—Tragopogon porrifolium (2).	C. (?)	South-east of Europe, Algeria.
Scorzonera—Scorzonera hispanica.	C.	South-west of Europe, south of the Caucasus.
Rampion — Campanula Rapunculus (2).	C.	Temperate and southern Europe.
Beet—Beta vulg. (2), ♃. Vegetable.	B.	Canaries, Mediterranean basin, western temperate Asia.
Beet—Beta vulg. (2), ♃. Root.	B.	A result of cultivation.
Garlic—Allium sativum, ♃.	B.	Desert of the Kirghis, in western temperate Asia.
Onion—Allium Cepa (2).	A.	Persia, Afghanistan, Beluchistan, Palestine (?).
Welsh Onion—Allium fistulosum, ♃.	C.	Siberia (from the land of the Kirghis to Baikal).
Shallot—Allium ascalonicum, ♃.	C.	Modification of *A. cepa* (?), unknown wild.
Rocambole—Allium Scorodoprasum ♃.	C.	Temperate Europe.
Chives—Allium Schænoprasum, ♃.	C. (?)	Temperate and northern Europe, Siberia, Khamschatka, North America (Lake Huron).
Taro—Colocasia antiquorum, ♃.	B.	India, Malay Archipelago, Polynesia.

[1] Dr. Bretschneider writes to me from Pekin, Dec. 22, 1882, that the species is mentioned in the *Ryd*, a work of the year 1100 B.C. I do not know if we must suppose the original habitat to be China or western Asia.

Nikolai Vavilov 1887-1943

vaviblog





http://www.vaviblog.com/

Vavilov' Centres of Crop Domestication

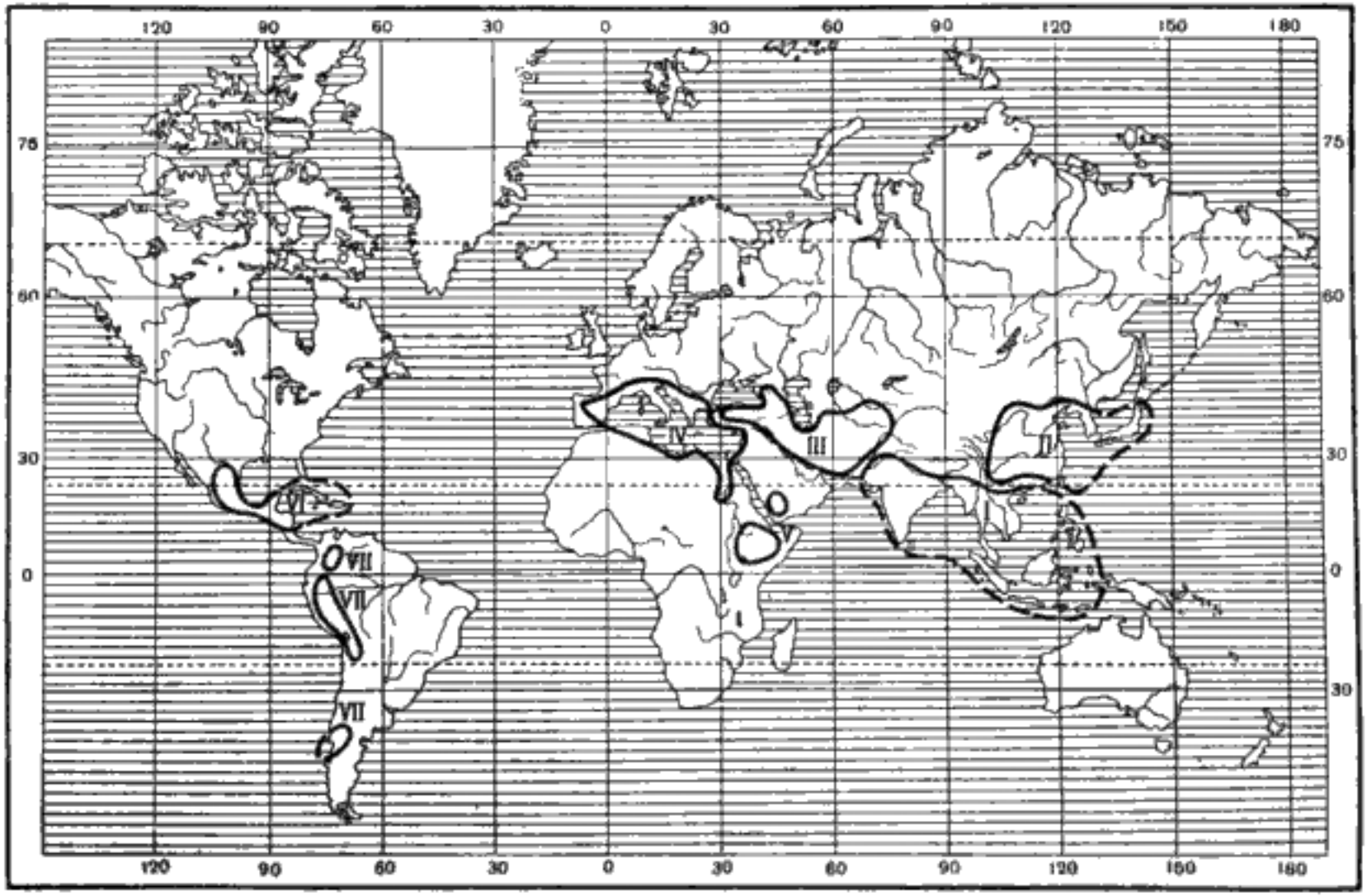
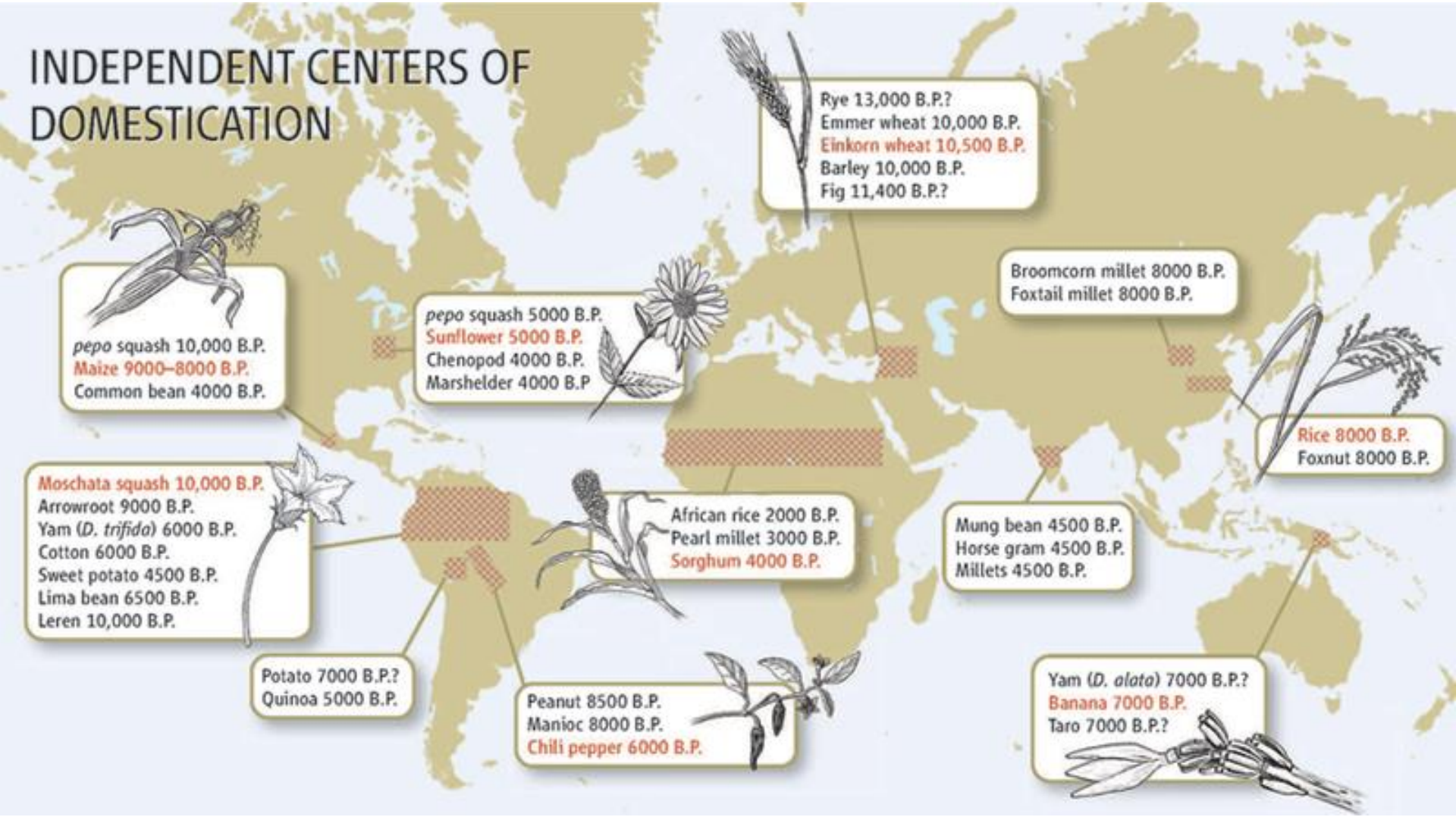


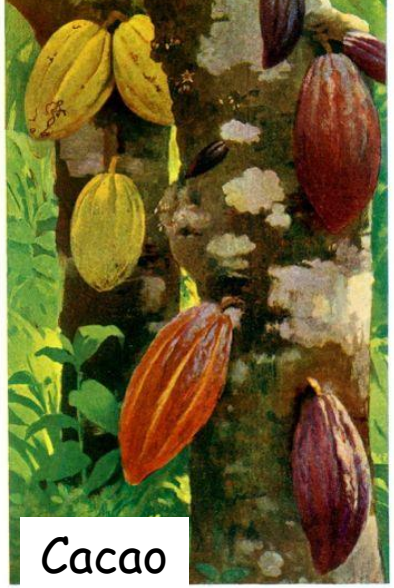
Fig. 1. Center of origin of cultivated plants. I. The tropical south-Asiatic center; II. the east-Asiatic center; III. the southwestern-Asiatic center; IV. the Mediterranean center; V. the Abyssinian center; VI. the Central American center; and VII. The Andean (South American) center.



Balter 2007 Science

Pepo squash

Phaseolus beans



Cacao

Papaya

pepo squash 10,000 B.P.
Maize 9000–8000 B.P.
Common bean 4000 B.P.

Sunflower 5000 B.P.
Chenopod 4000 B.P.
Marshelder 4000 B.P

Mesoamerica

Pavo - turkey

Moschata squash 10,000 B.P.
Arrowroot 9000 B.P.
Yam (*D. trifida*) 6000 B.P.
Cotton 6000 B.P.
Sweet potato 4500 B.P.
Lima bean 6500 B.P.

African rice 2000 B.P.
Pearl millet 3000 B.P.
Sorghum 4000 B.P.

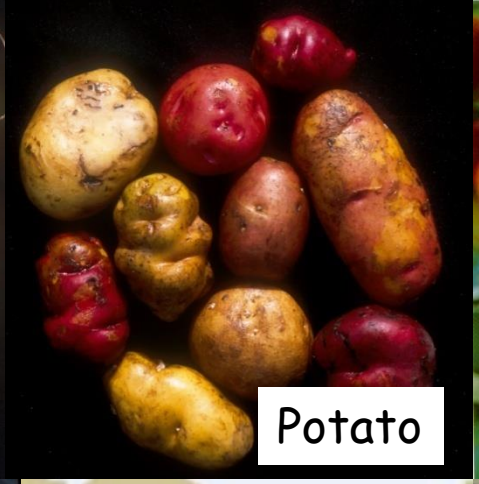
Maize

Avocado

Chayote

Cotton


Mashua


Potato


Tomato

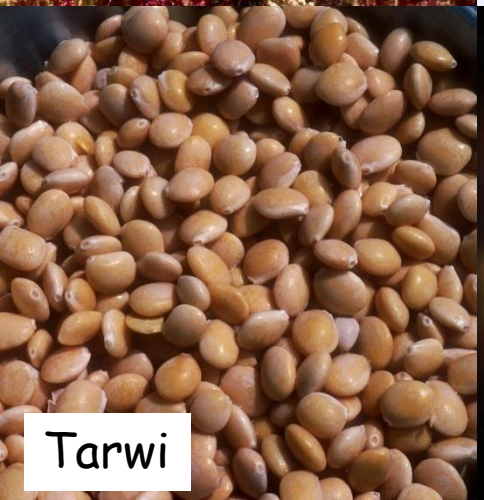

Amaranth


Quinoa

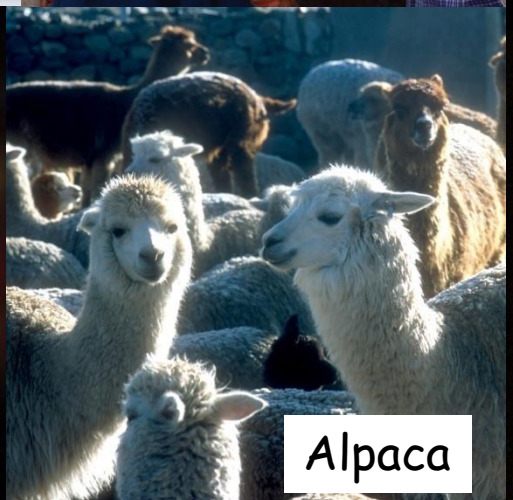

Andes


Guinea Pig


Oca


Tarwi


Ulluco

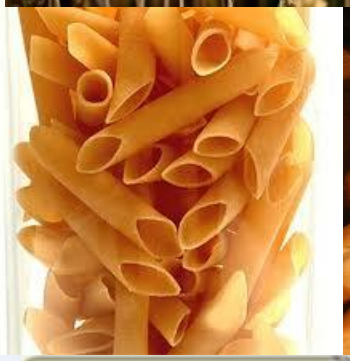

Alpaca


Peanut

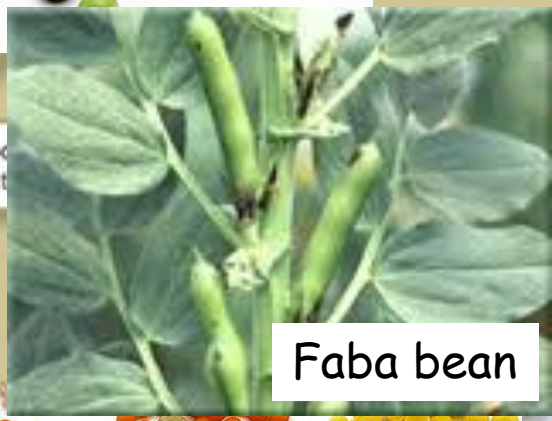

Wheat


Barley

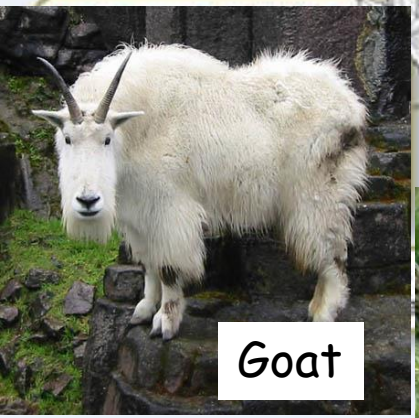

Pea



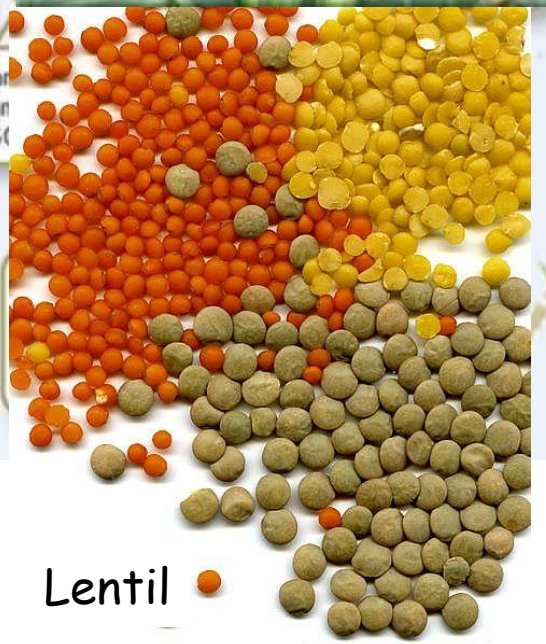

Rye


Faba bean

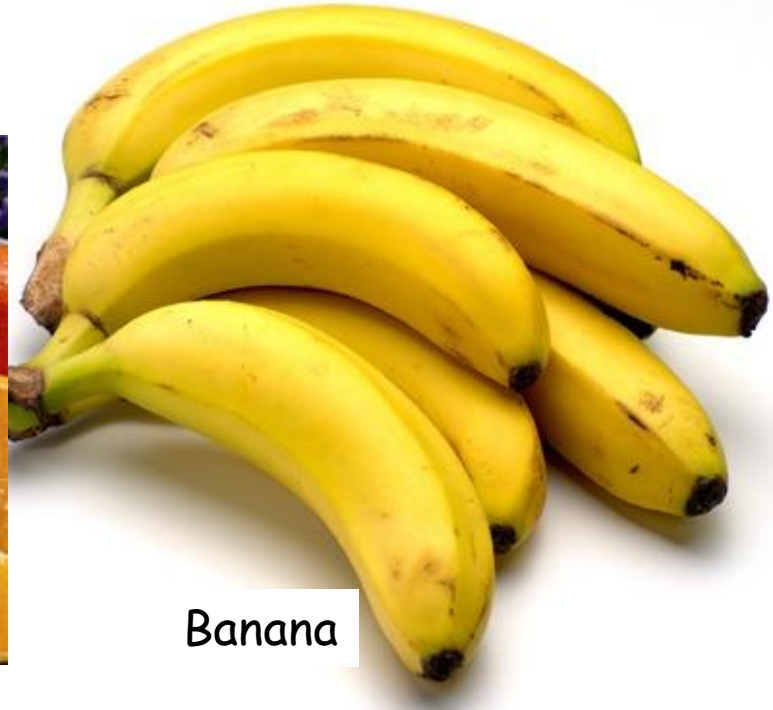
Fertile Crescent


Goat


Sheep


Lentil


Citrus


Banana


Sugarcane


Yam


Taro

New Guinea

Cereals (grasses) & Pulses (legumes)

- Maize (*Zea*) & *Phaseolus* beans in Mesoamerica
- Rice (*Oryza*) & Soya beans (*Glycine*) in China
- Wheat (*Triticum*) / barley (*Hordeum*) & lentils (*Lens*) / peas (*Pisum*) / Faba beans (*Vicia*) in the Fertile Crescent
- Millet (*Echinochloa*) & Mung beans (*Vigna*) in India

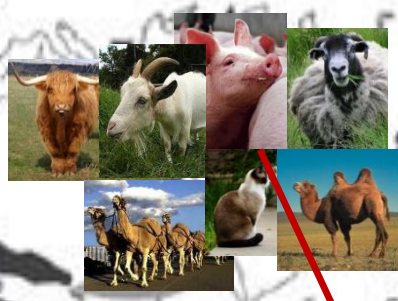
Independent Centres of Agriculture & Livestock Domestication

Lapland
- Reindeer

Eastern N America
-NONE!

Mesoamerica
- Turkey

ONLY ONE!



Himalaya
- Yak

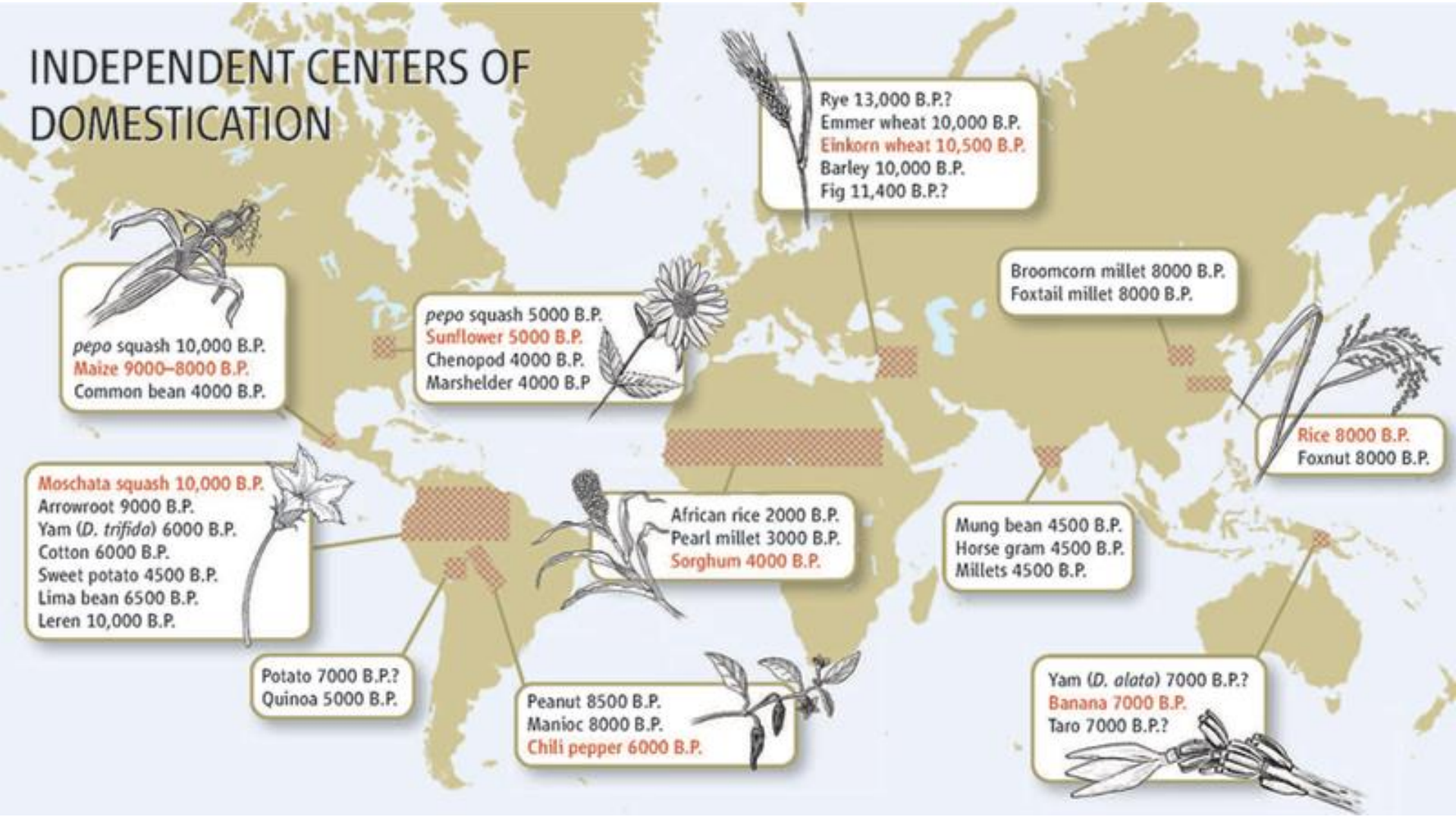
China
- Dog
- Chicken

Andes
- Llama
- Alpacca
- Guinea pig

NE Africa
- Donkey

Fertile Crescent
/ Near East
- Cattle
- Sheep
- Pig
- Goat
- Horse
- Dromedary camel
- Bactrian camel
- Cat

New Guinea
-NONE!



Balter 2007 Science

Different crops in different areas without overlap
More or less simultaneous & ?independent

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

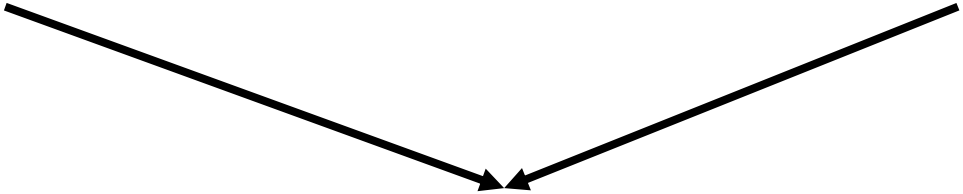
-pinpoint and quantify morphological changes associated with domestication

Archaeological Data

-identification and dating of plant remains

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

-determine location of earliest domesticated remains



Pinpoint geographical location of domestication

Bottle Gourd
Lagenaria siceraria

'The earliest plant domesticate'

'Container plant' – uniquely valuable source of strong, light weight, hard-shelled containers highly prized before the advent of pottery

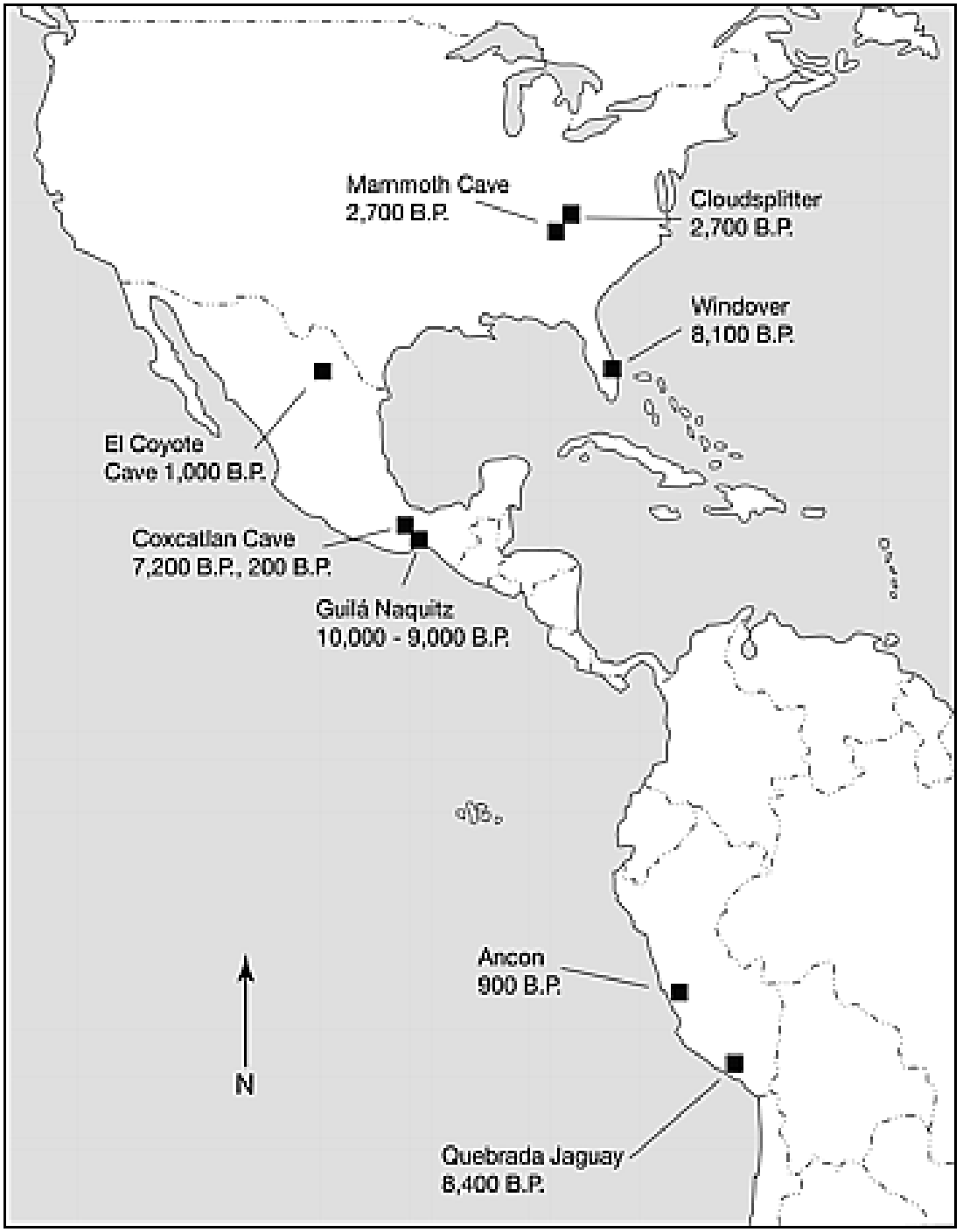
Bottle Gourd - Archaeological Data

- Despite the fact that bottle gourd is an Old World plant, bottle gourd rind fragments are found widely in the New World

- Accelerator mass spectrometer (AMS) radiocarbon dating shows earliest occurrences of bottle gourd in the Americas from 9,000-10,000 years in Mexico, 8,400 years in Peru and 8,000 years in Florida

- Found amongst the earliest New World cucurbits used for food and in Florida preceding the first evidence of locally domesticated food crops by several millennia

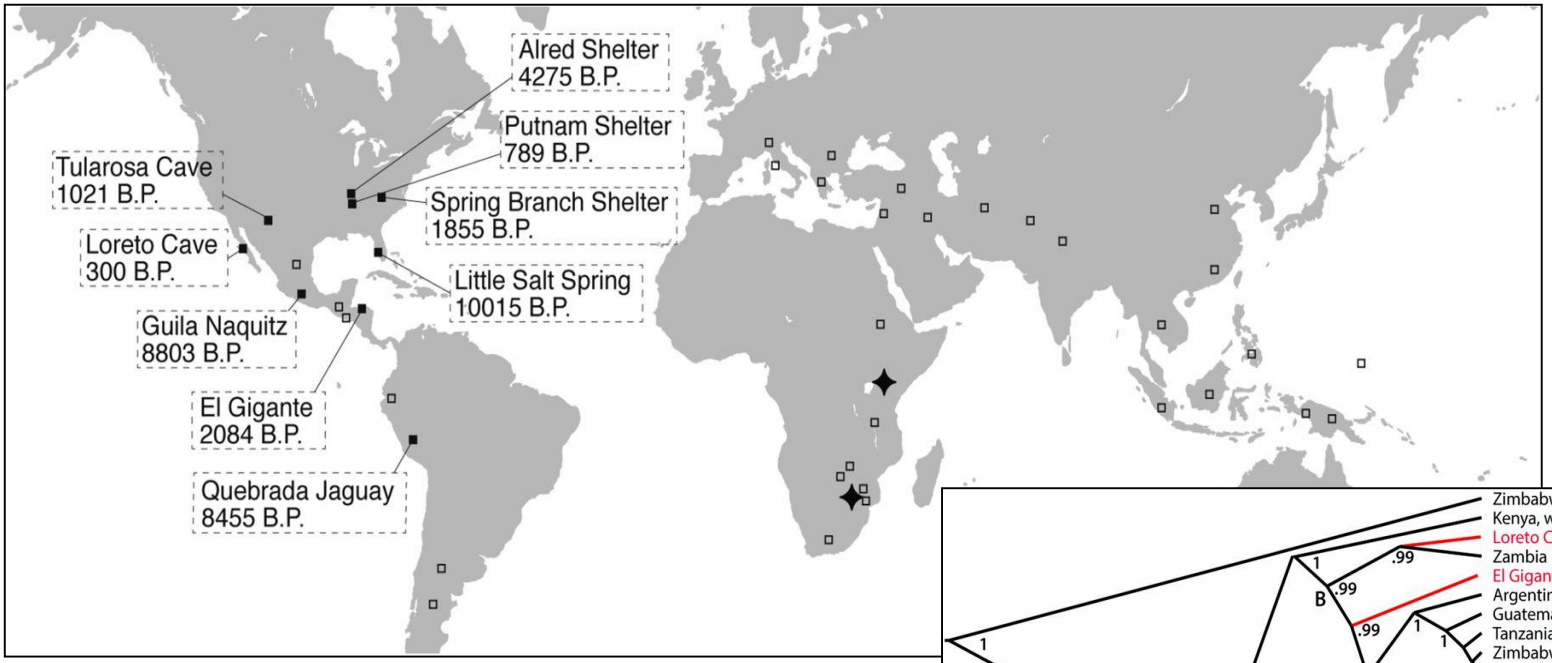
Erickson et al 2005 PNAS

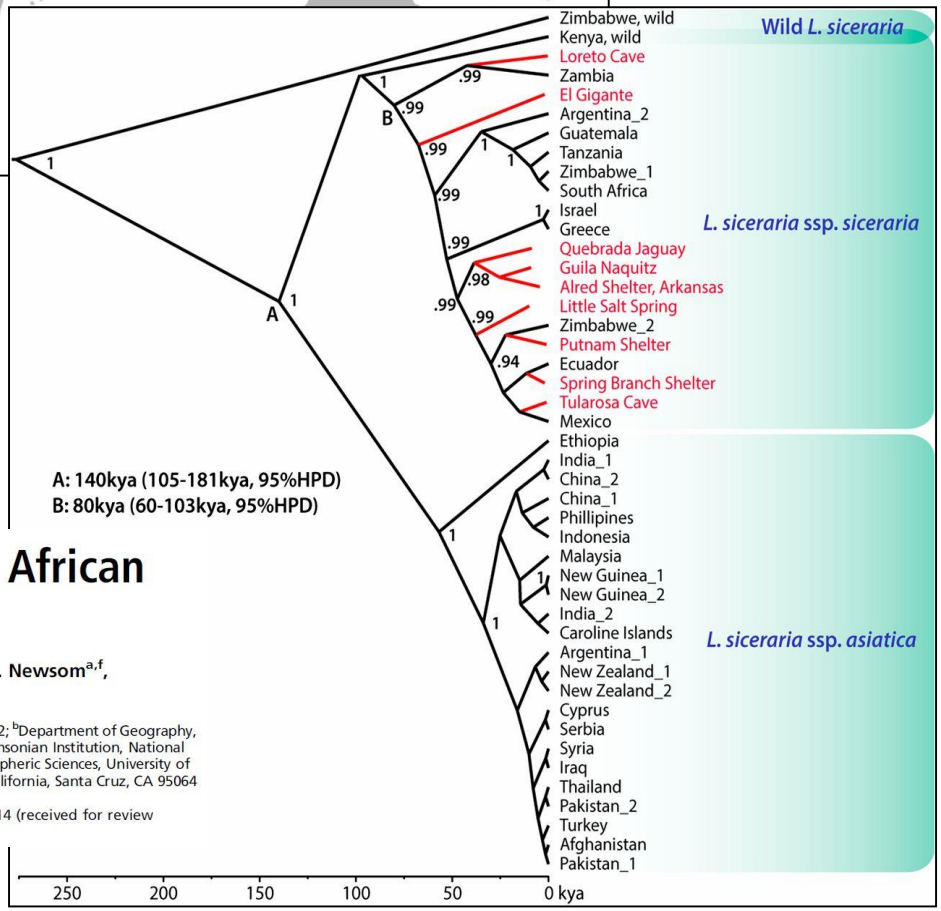


Bottle Gourd - Genetic Data

- Low levels of overall genetic variation
- 3 diagnostic plastid DNA indels distinguish Asian land races from African material
- Ancient DNA from New World rind fragments predating European arrival in the Americas shows all are identical to Asian land races
- The one post-European fragment is of the African type

Erickson et al 2005 PNAS





PNAS

Transoceanic drift and the domestication of African bottle gourds in the Americas

Logan Kistler[a,1], Álvaro Montenegro[b], Bruce D. Smith[c], John A. Gifford[d], Richard E. Green[e], Lee A. Newsom[a,f], and Beth Shapiro[g]

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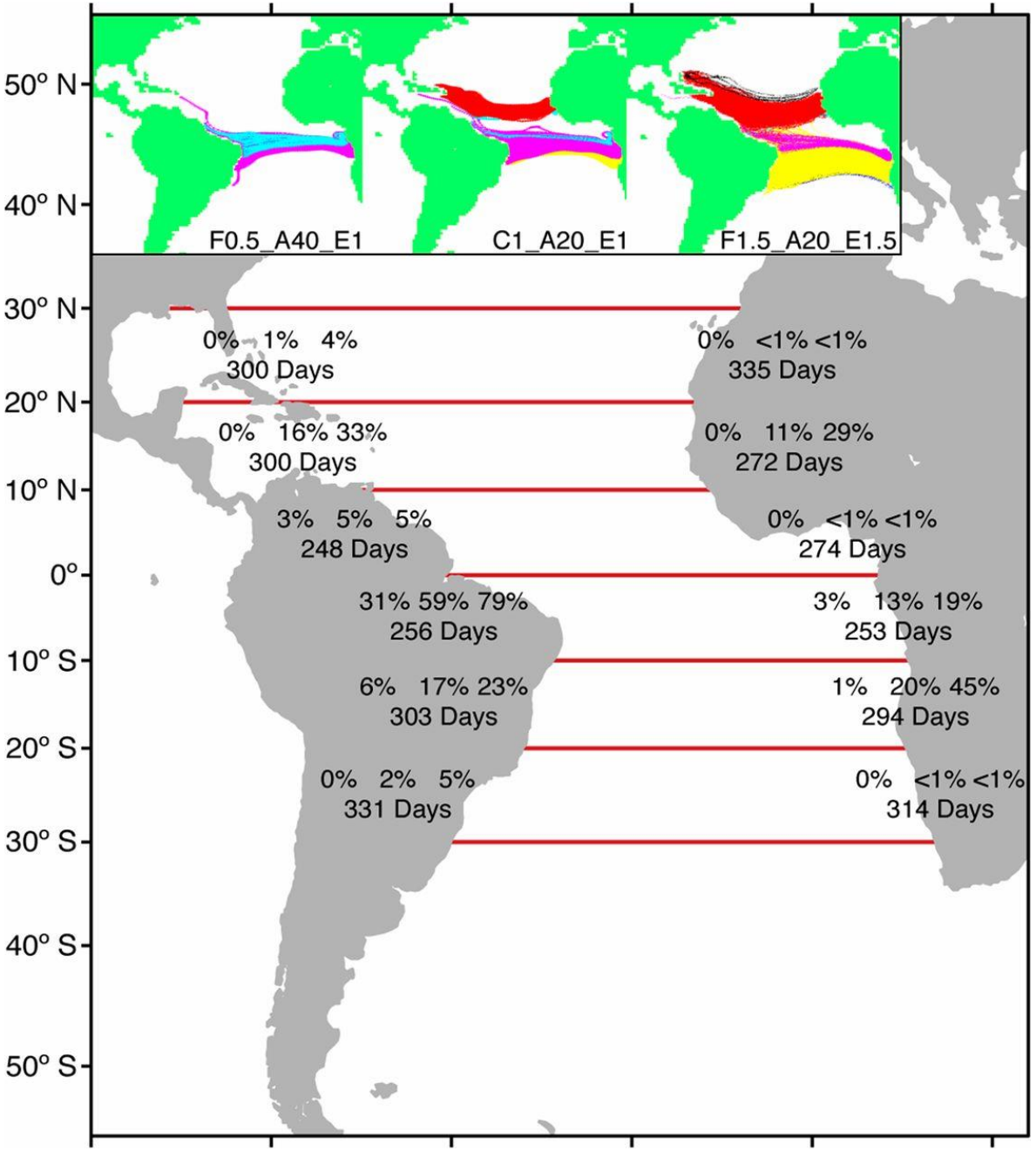
Edited by Gayle J. Fritz, Washington University in St. Louis, St. Louis, MO, and accepted by the Editorial Board January 10, 2014 (received for review October 3, 2013)

Modeling transoceanic drift

Seeds contained within bottle gourd fruits are known to remain viable up to one year floating in seawater

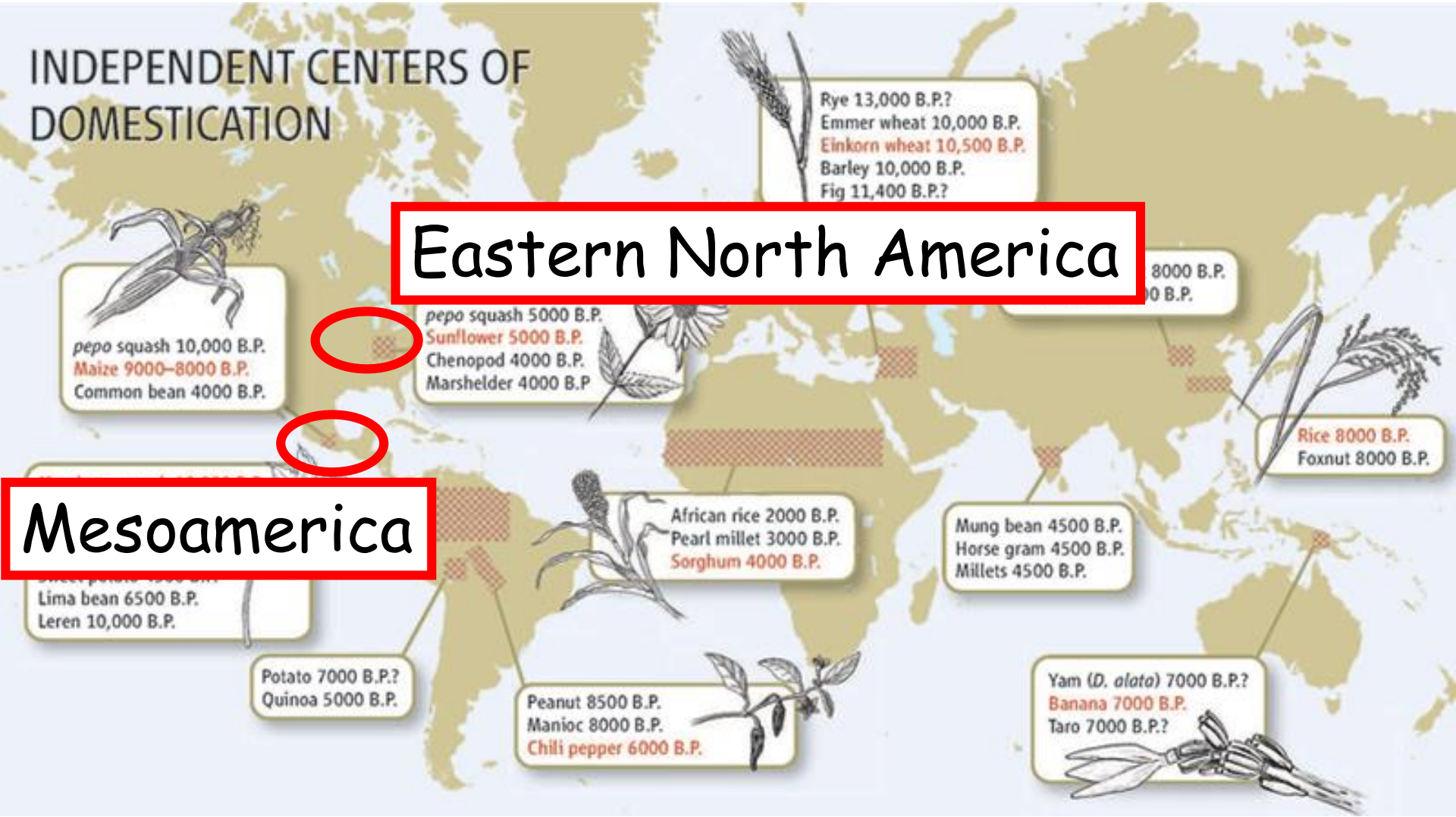


Kistler et al (2014)

Bottle Gourd - Conclusions

- Combined evidence from archaeology and genetics
- Powerful evidence from ancient DNA
- American bottle gourd came directly from Africa, not via Asia
- Grown as a domesticated plant in the New World as early as 10,000 BP
- The earliest known plant domesticate and coinciding with initial domestication of the dog somewhere in Eurasia
- Bottle gourd and dog – 2 utilitarian species brought under domestication long before any crop or livestock domesticates

One independent origin of agriculture or two?

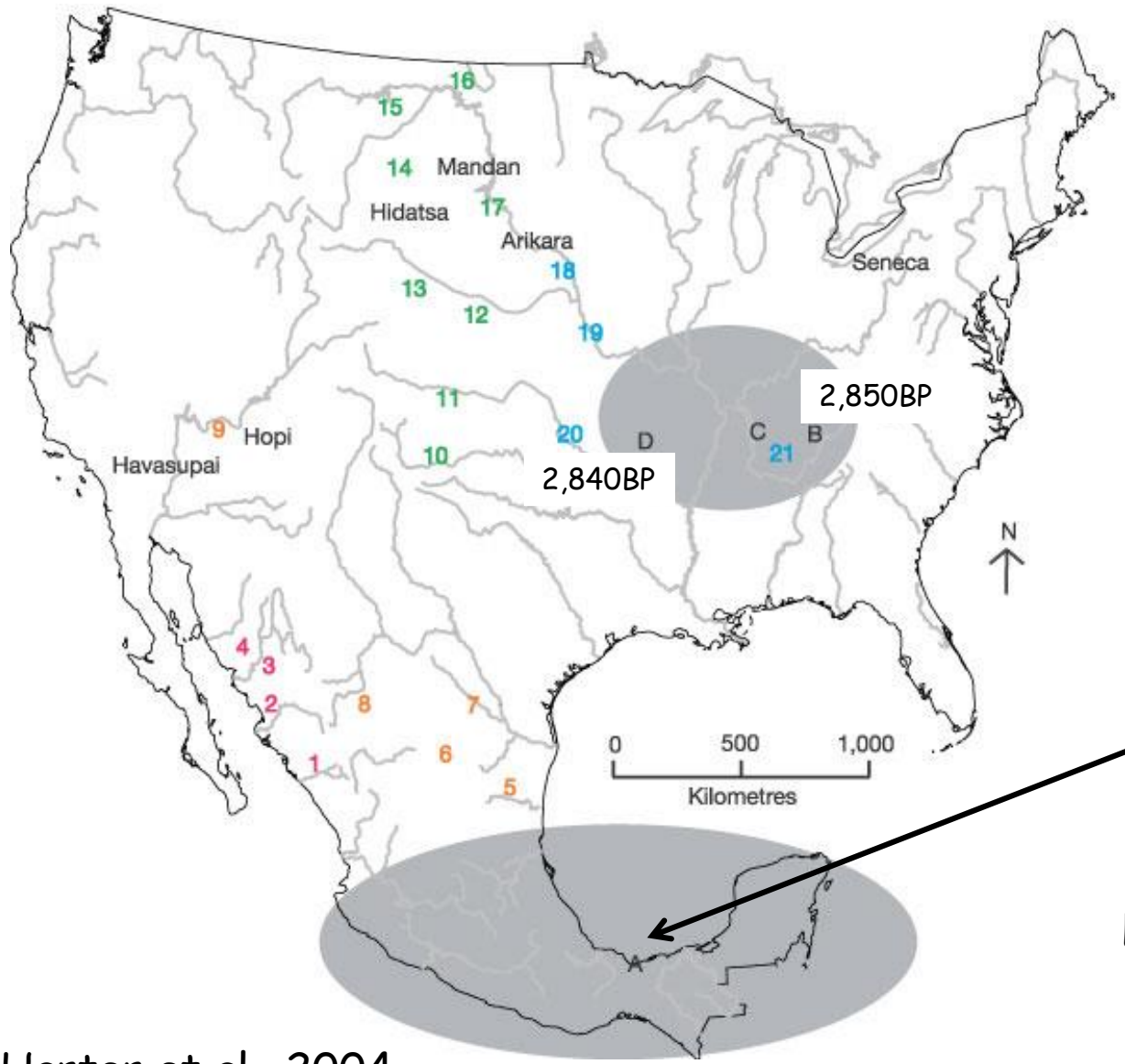


Balter 2007 Science

Sunflower - *Helianthus annuus*
Asteraceae

http://www.artquotes.net/masters/vangogh/vangogh_sunflowers1888.jpg

Sunflower domestication – competing theories?



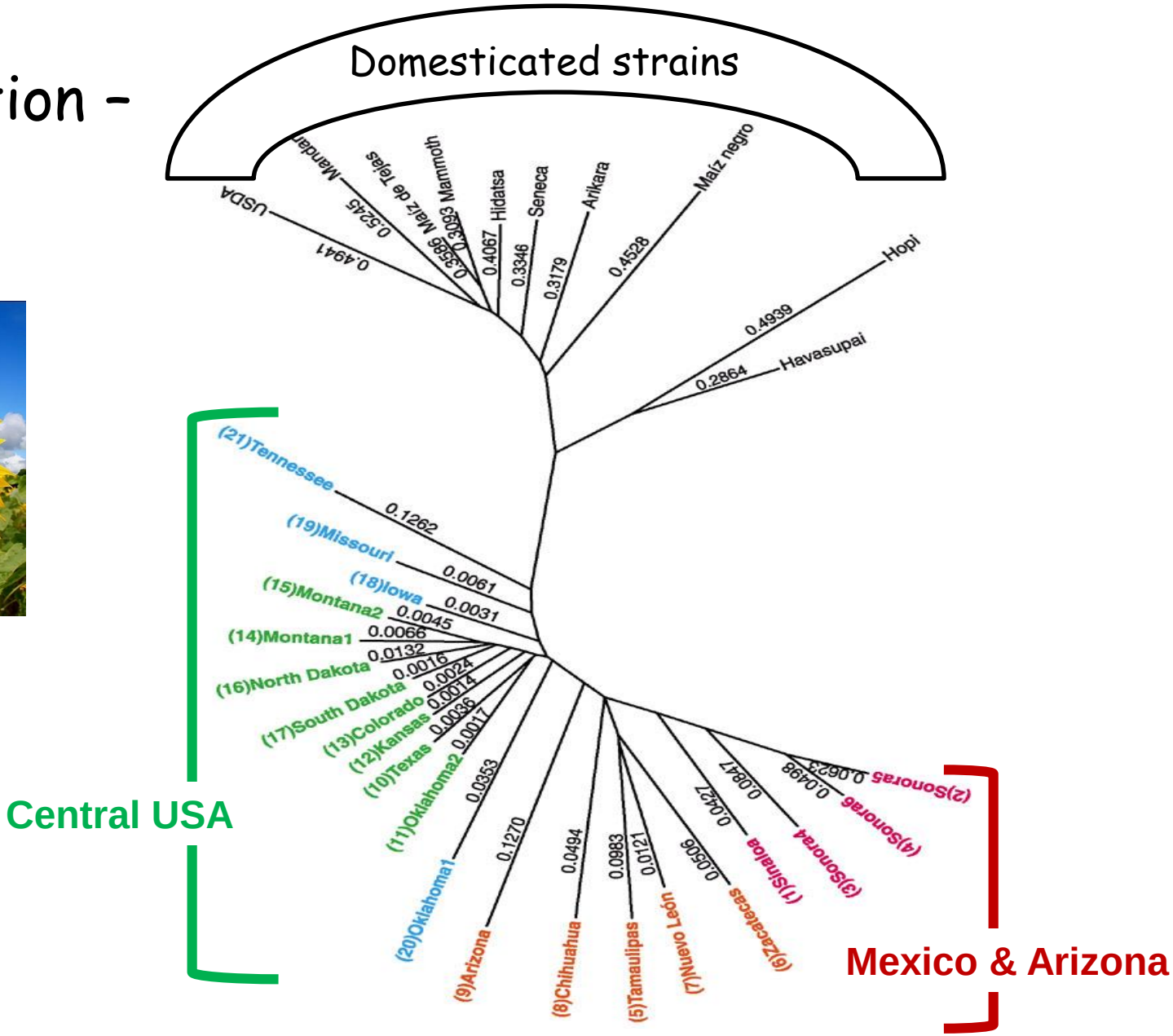
Harter et al., 2004

Lentz et al., 2001, 4130BP

0 5 mm

Fig. 2. Photograph of the partially carbonized *Helianthus annuus* achene (left) and seed (right) retrieved from Units 7 and 8, respectively, at San Andrés.

Sunflower domestication – competing theories?



Harter et al., 2004

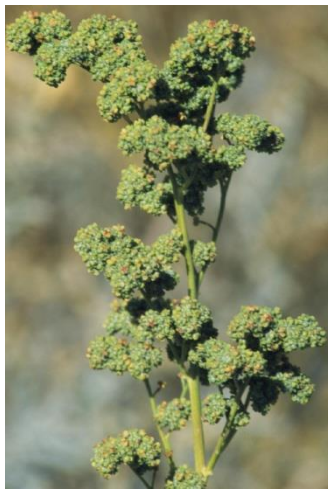
Problems with Mexican Hypothesis (Smith 2006)

- No documentation that San Andrés seed is *Helianthus annuus*.
- San Andrés achene lacks striations indicative of *H. annuus*.
- San Andrés is outside of current wild range

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.)

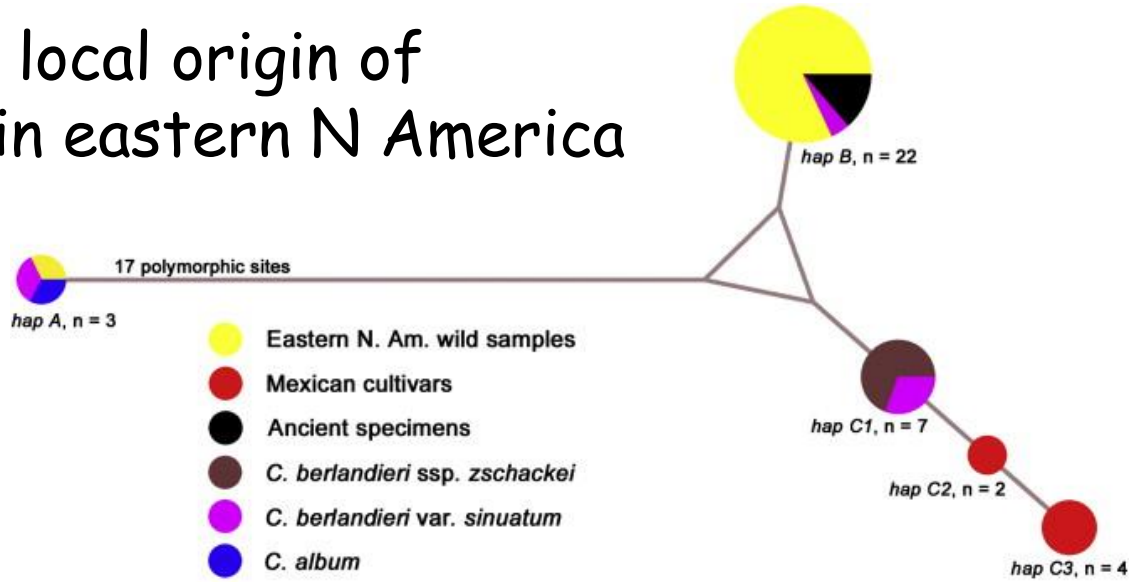
From Smith 2006

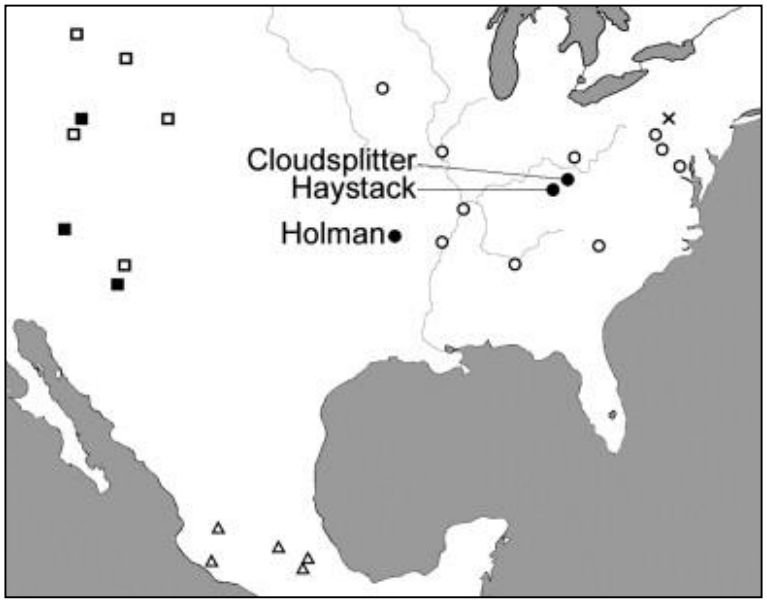
Ancient DNA confirms a local origin of domesticated chenopod in eastern N America



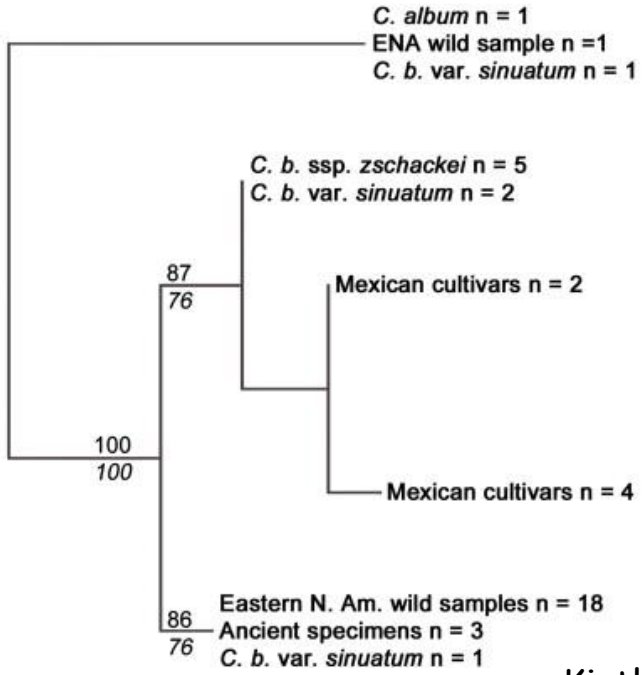
C. berlandieri

C. quinoa





b



Kistler & Shapiro (2011)

nature plants

PERSPECTIVE

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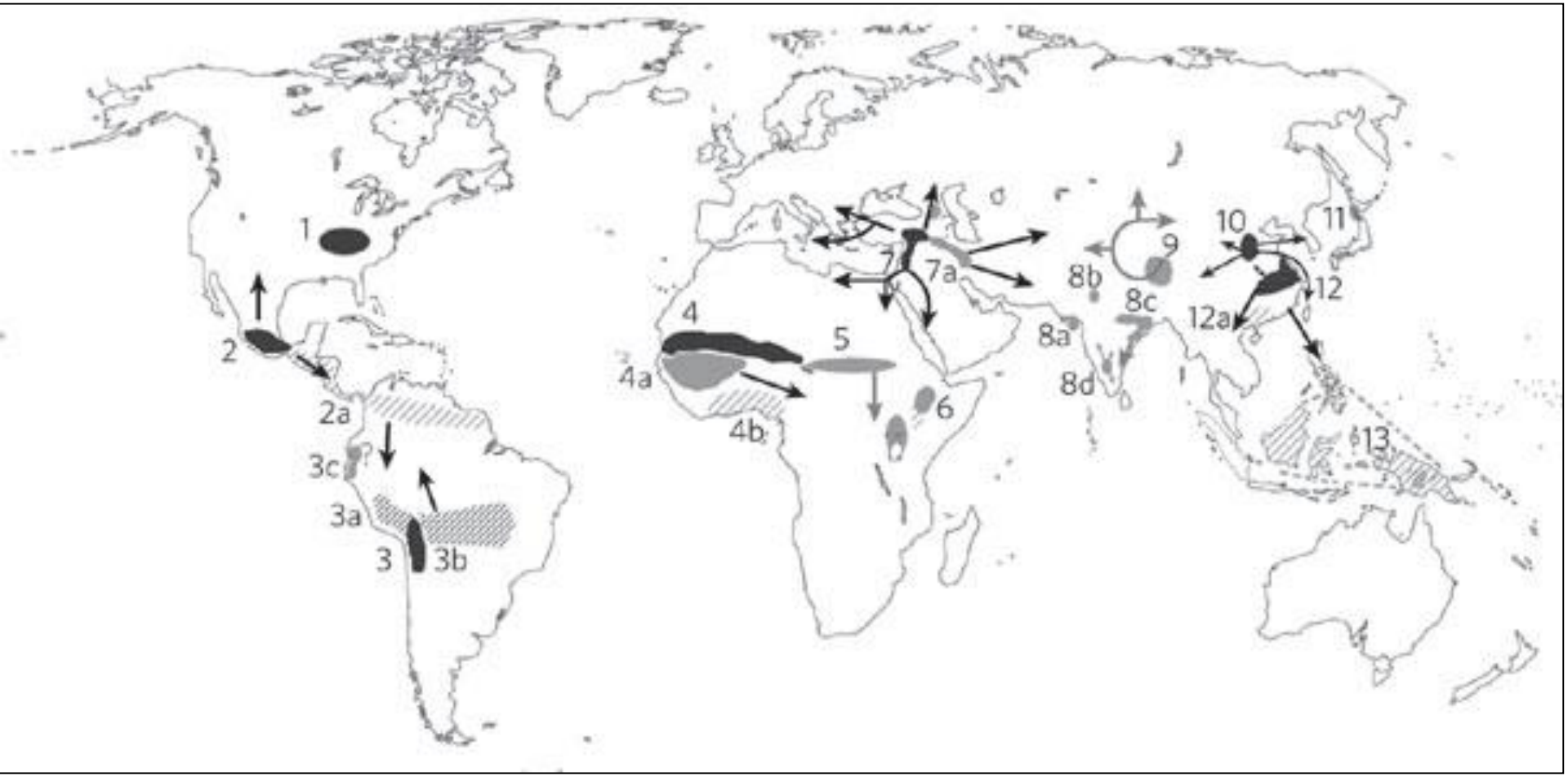
Growing the lost crops of eastern North America's original agricultural system

Natalie G. Mueller[1]*, Gayle J. Fritz[1], Paul Patton[2], Stephen Carmody[3] and Elizabeth T. Horton[4]

a. Goosefoot – *Chenopodium berlandieri*
b. Sumpweed / Marsh Elder – *Iva annua*
c. Little Barley – *Hordeum pusillum*
d. Erect Knotweed – *Polygonum erectum*
e. Maygrass – *Phalaris carolinum*

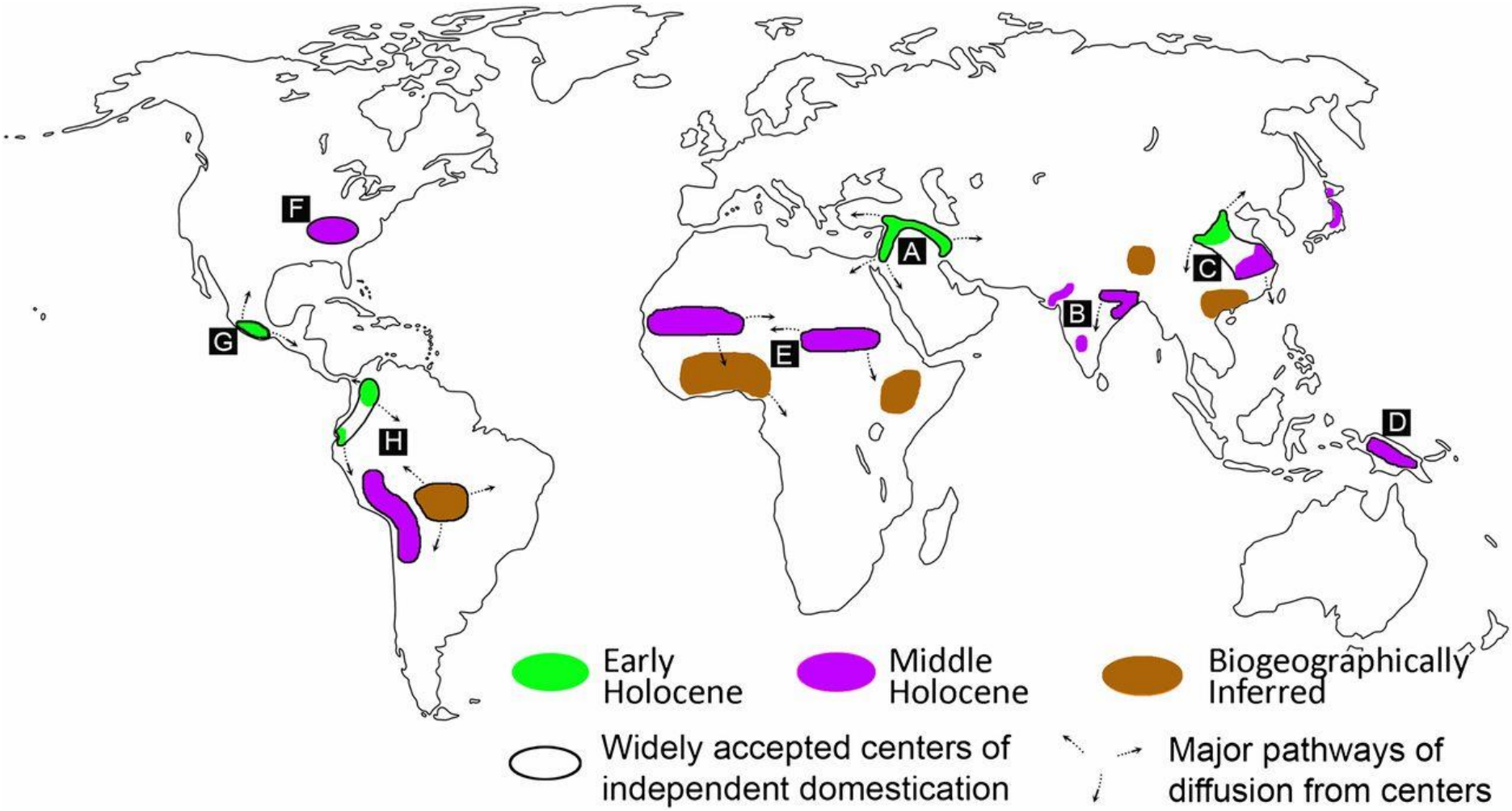
Independent Origins of Agriculture



13 ***independent*** centres
+/- ***simultaneous*** over a period of c.5,000 yrs

(Purugganan & Fuller, 2009, Nature)

Independent Origins of Agriculture



Larson et al (2014)

Domestication / Origins of Agriculture - Questions ??

- Independent centres offer a promising comparative set of developmental trajectories for investigation to reveal general underlying principles and processes.

- For example, the Fertile Crescent presents a remarkable array of plant and animal domesticates that were domesticated relatively quickly resulting in a powerful and expansive agricultural economy. In contrast, in eastern N. America no animals were domesticated and just four crops, only two of which survived as modern crops.

- These contrasting scenarios offer a rich worldwide mosaic of diverse agricultural systems.

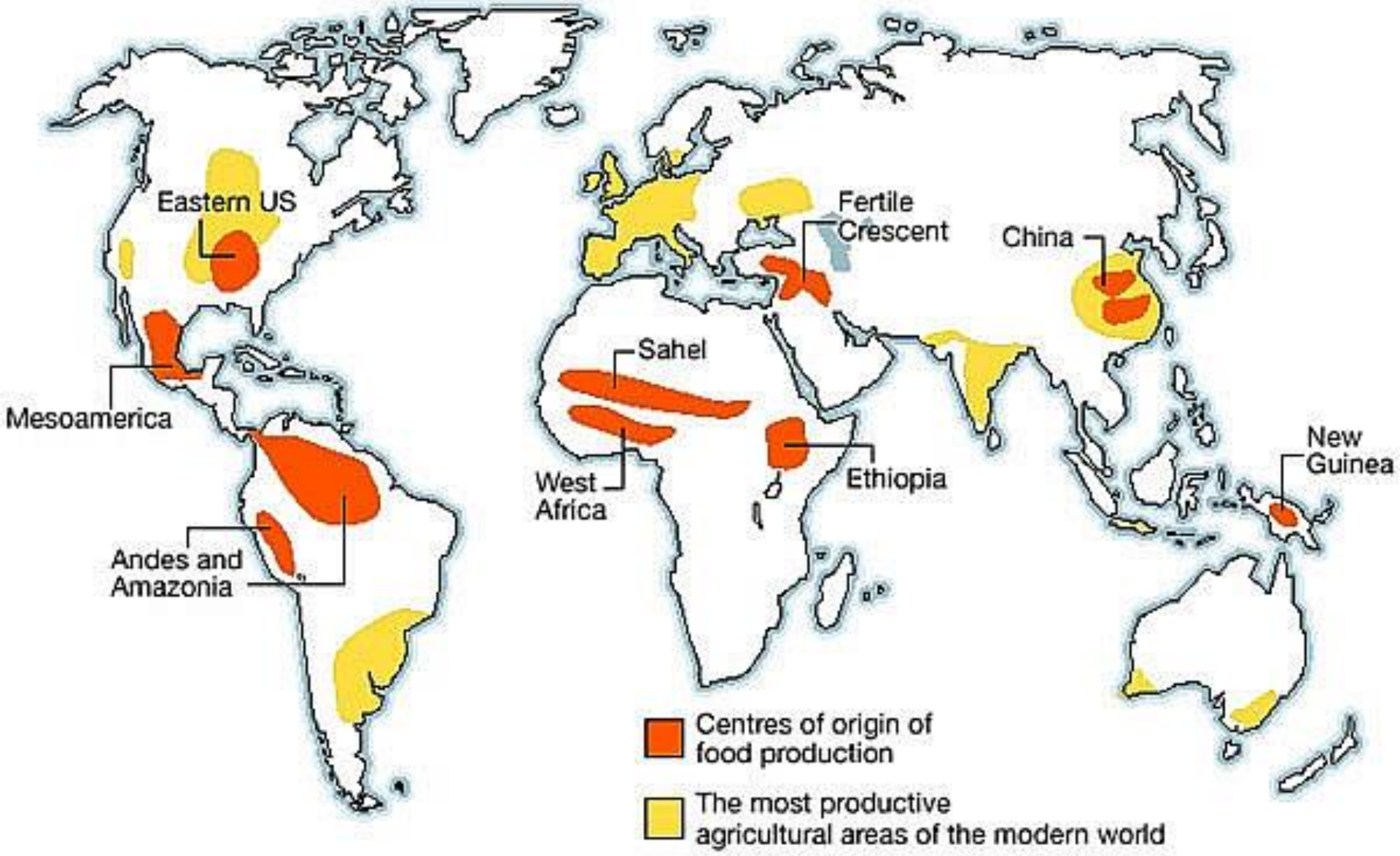
- Why more or less simultaneous origin of agriculture independently in different places? Is there a global explanation?

- Why did agriculture arise in these areas and not others?

- Why did domestication involve so few species? – 350,000 flowering plant species, but only c.100 important domesticated crops?

- Why do these areas not overlap more significantly with areas of most productive modern agriculture?

Centres of plant and animal domestication



Jared Diamond (2002)

BIO 235 LECTURE 2
The Origins of Agriculture

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Online Case studies in Crop Domestication: http://www.botany.wisc.edu/courses/botany_940/06CropEvol/CropEvol.html
Colin Hughes, Sept 2019

For Next week:

Why did agriculture arise?

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

Is there a global explanation?