Announcement: No class on Thursday, office hours moved to Friday this week

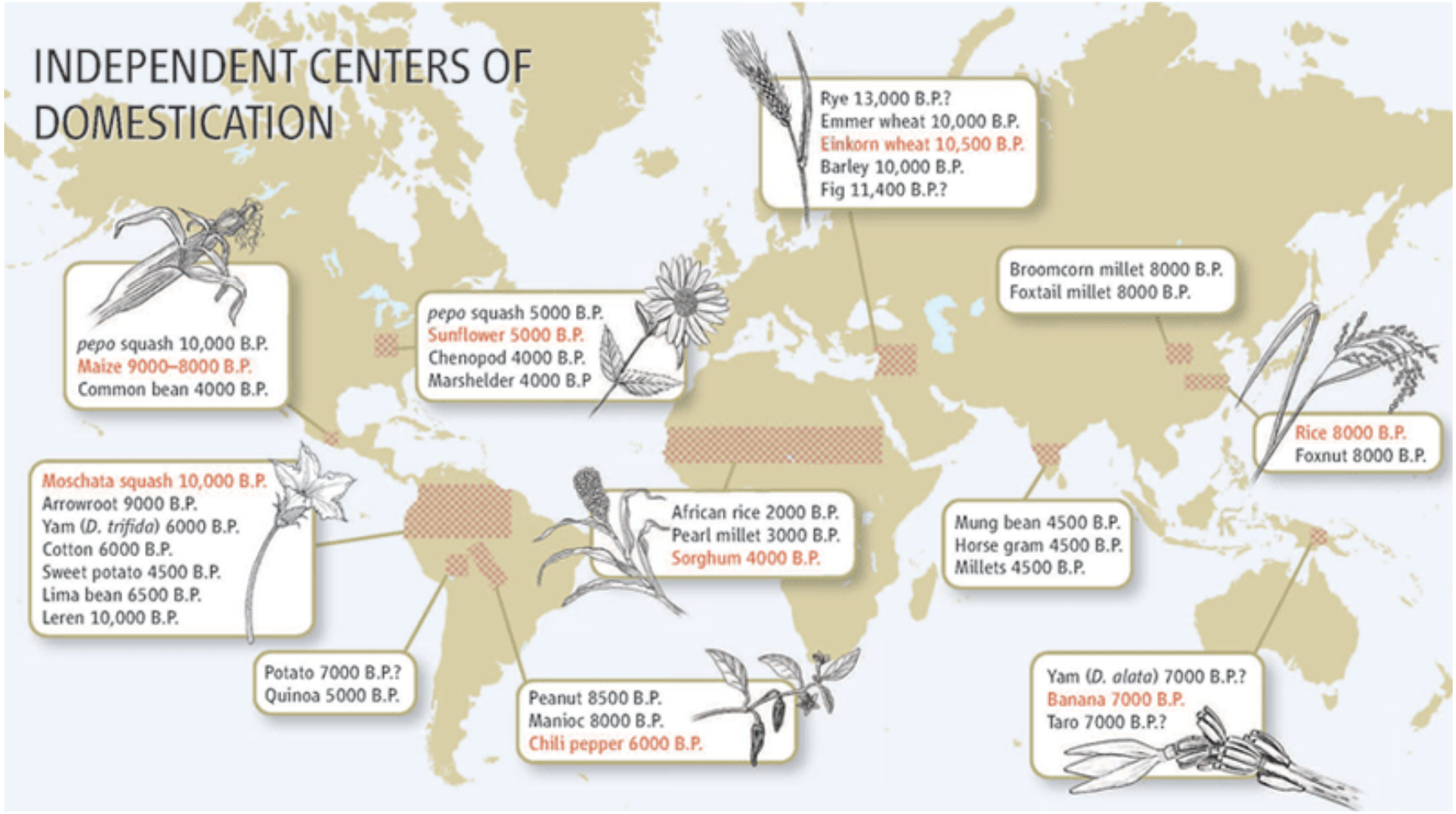
Origins of Agriculture

Who? Where? When? Why? How?

What is agriculture?

Where?

Where? Eastern North America, Mesoamerica, Andes, Amazonia, New Guinea, Near East (Fertile Crescent), S. India, China, Sahel, West Africa, Ethiopia



From Balter 2007, *Science* 316:1830

What methods do researchers use to determine that these are the areas where agriculture first arose?

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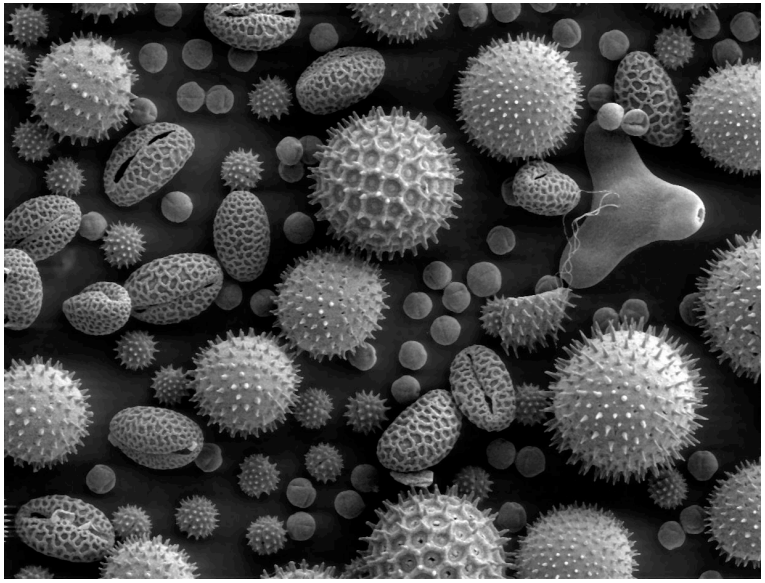
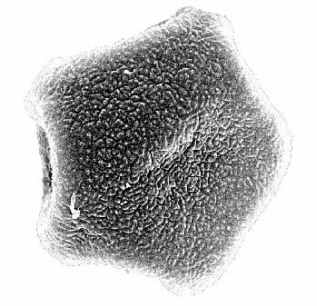
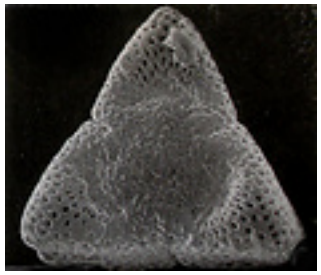
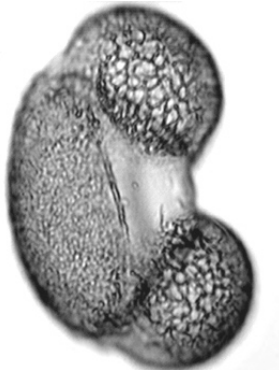
Macrofossils: pollen grains

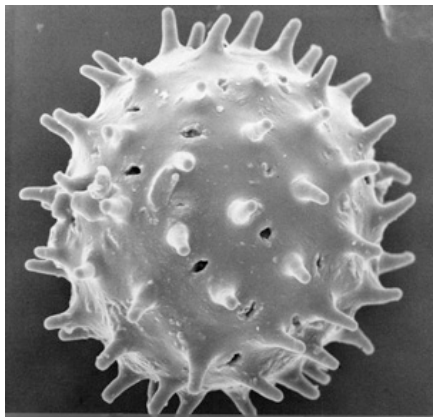
Pollen exine (outer layer) is very tough, made of *sporopollenin*, a polymer that protects from desiccation and decay

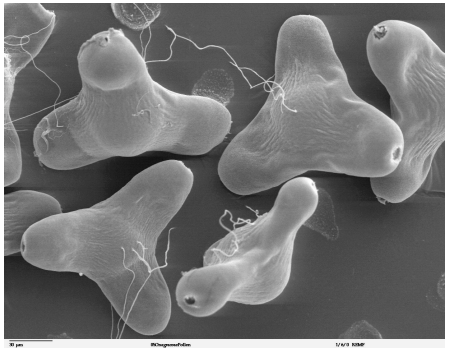












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Macrofossils: pollen grains, seeds, corn cobs, wheat spikelets

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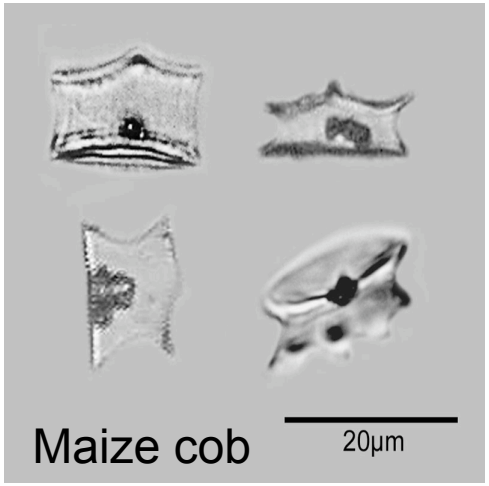
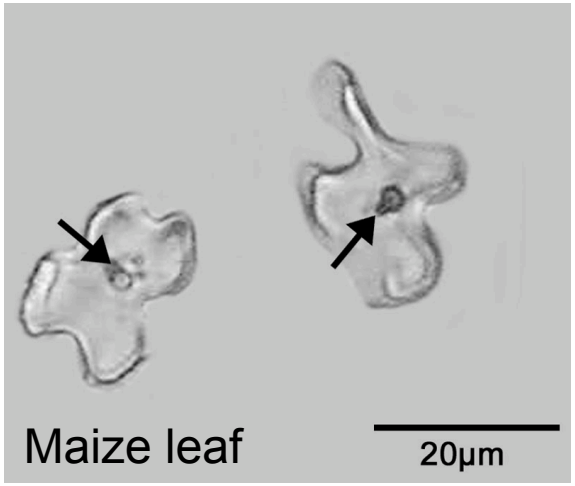
Microfossils: phytoliths--crystals found in plant tissues made by calcium oxalate, calcium carbonate, or silica

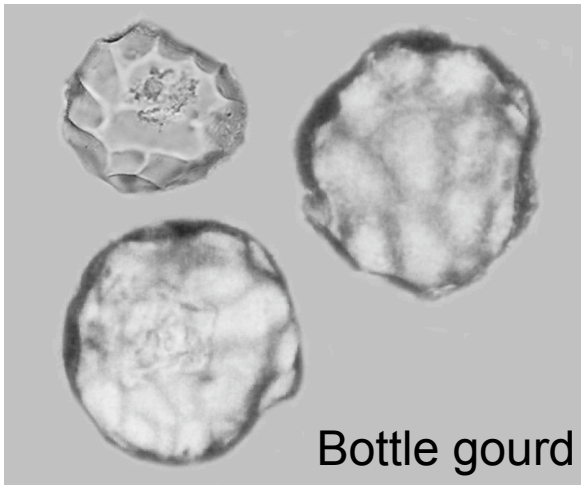
Phytoliths are very distinctive in shape and size, even varying between parts of same plant; e.g., maize leaf versus maize cob

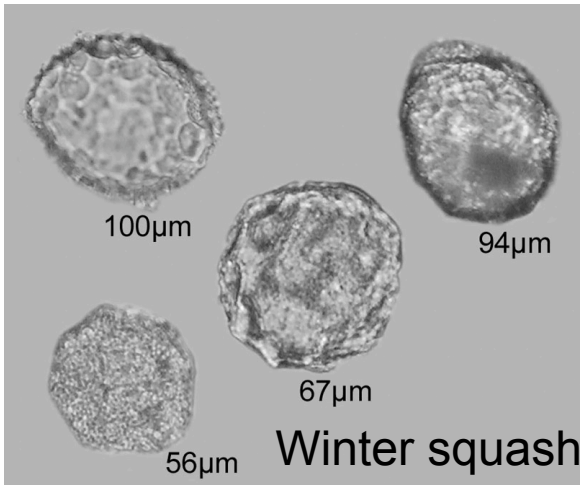


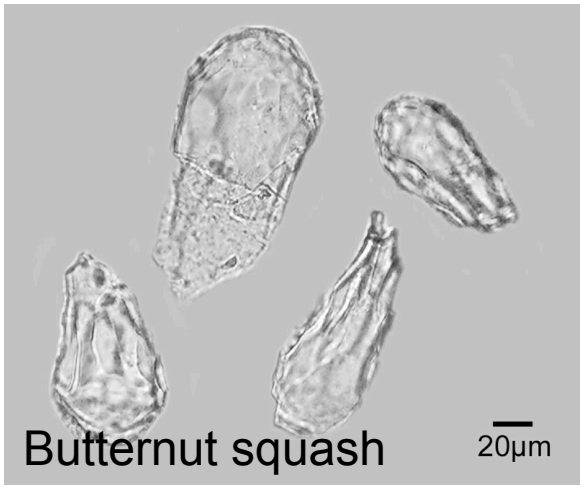


Phytolith diversity

Cucumber/squash family







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Macrofossils: pollen grains, seeds, corn cobs, wheat spikelets

Microfossils: phytoliths, **starch grains** (amyloplasts)

Starch grains: plants make and store starches in amyloplasts; like phytoliths they can be species-specific, even differing between cultivars and wild relatives

Starch grains reveal early root crop horticulture in the Panamanian tropical forest

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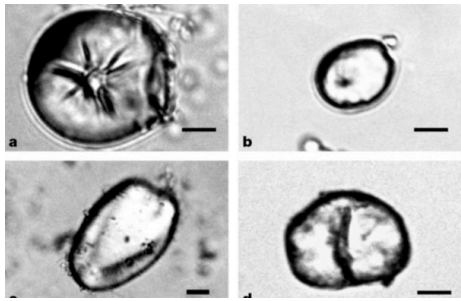

Figure 1 Various starch grains. **a**, A starch grain from manioc recovered from milling stone 42. **b**, A starch grain from the putative wild ancestor of manioc, *Manihot esculenta* spp. *flabellifolia*. **c**, A starch grain from a species of *Dioscorea* recovered from milling stone 350. **d**, A starch grain from maize from milling stone 42. This type is unique to maize and is found in Race Jala from Mexico. Scale bar, 5 μm (**a**, **b**, **d**); 10 μm (**c**).

Table 2 Size of starch grains in domesticated plants and close wild relatives compared with archaeological grains

Modern plants	Taxonomic status	Range and s.d. of mean length (μm)	Range (μm)	*n*
Manihot esculenta ssp. *flabellifolia*	Wild ancestor of *M. esculenta*	8 ± 2.1	4–12	50
Manihot esculenta	Domesticated	13 ± 2.6 to 16 ± 3.4	6–28	600
Panamanian Poaceae (small-grained, 30 species)	Wild	3 ± 0.9 to 11 ± 2.7	2–18	800
Panamanian Poaceae (large-grained, 5 species)	Wild	14 ± 2.9 to 20 ± 4.8	8–30	250
Zea mays spp. *parviglumis**	Wild ancestor of *Z. mays*	8 ± 2.1 to 9 ± 2.1	4–16	200
Zea mays	Domesticated	8 ± 1.5 to 16 ± 4.9	4–24	750
Dioscorea spp.	Wild	17 ± 4.9 to 63 ± 20	8–100	550
Dioscorea trifida	Domesticated	37 ± 8.3 to 48 ± 12.8	24–84	100
Archaeological grains	**Tool number**	**Mean length**	**Range**	***n***
Manihot esculenta	42	14	10–24	8
(all Layer C)	26a	18	16–20	5
	26b	18	–	1
Manihot esculenta	Layer C combined	17 ± 3.7	10–24	14
Zea mays, Layer C	42	18	–	1
	26a	15	10–24	15
	26b	13	12–14	2
	439	17	10–22	7
	350	18	10–24	25
	38	14	–	1
Zea mays	Layer C combined	16 ± 4.1	10–24	51
Zea mays	Layer B combined	15 ± 4.9	10–22	26
Dioscorea spp.	42	15	14–16	3
(all Layer C)	26	42	24–60	2
	350	36 ± 7.3	30–52	16

Range of mean length of starch grains in modern plants is the range of means in the populations/races of each species studied. s.d. is the standard deviation for grains in the populations/species having the smallest and largest grains. Range is the range for all starch grains sized in these species. The five wild Panamanian Poaceae (large-grained) with starch grains that demonstrate size overlap with maize (*Cenchrus*, *Anthephora*, *Orthoclada*, *Panicum* spp.) have morphologies distinct from maize.
* Four different populations of *Zea mays* spp. *parviglumis* were studied.

How know whether the plants were being cultivated rather than just gathered from wild and consumed?

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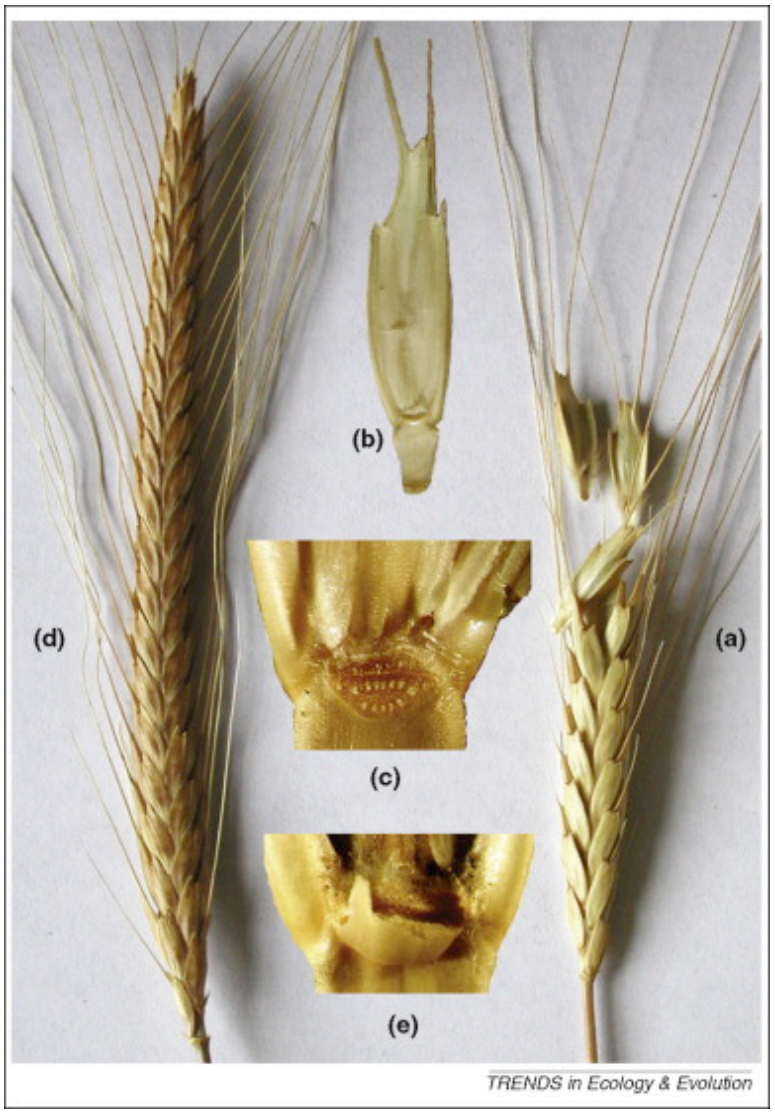
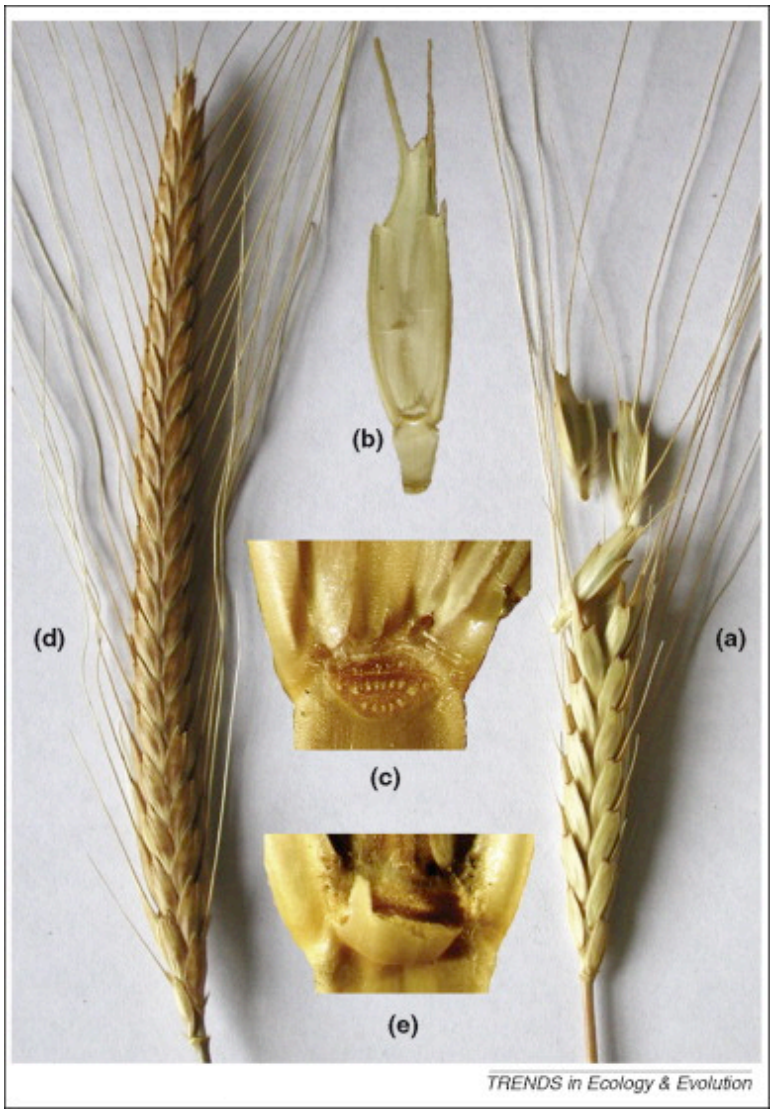
Phytoliths, starch cells often differ between wild relatives and domesticates

Also macrofossils will look different--domesticated traits

Domestication characteristics



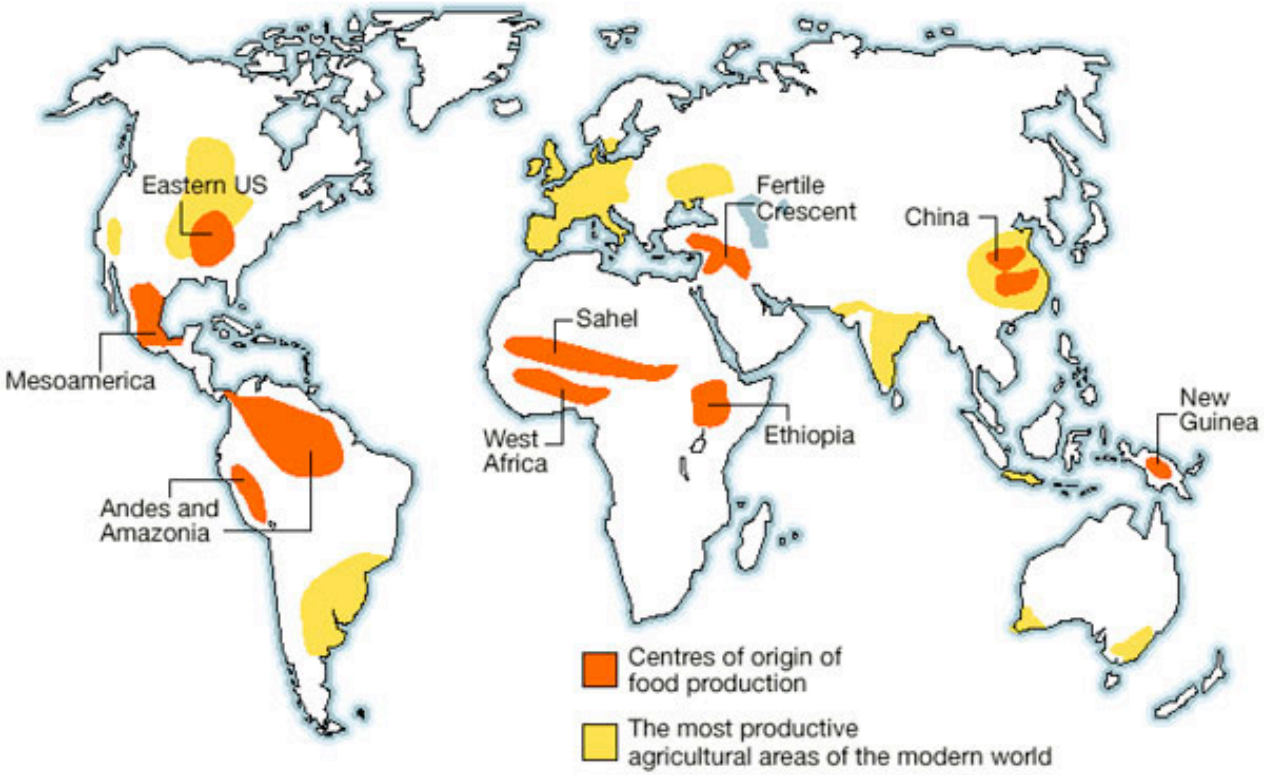
Domestication characteristics



- Nonshattering
- Larger seeds
- Thinner seed coats
- Loss of dispersal structures (ie., awns, hairs) or defensive structures (spines)
- Loss of seasonal cues for germination
- Synchronous ripening
- Growth habit—more compact for planting
- Reduction in secondary compounds

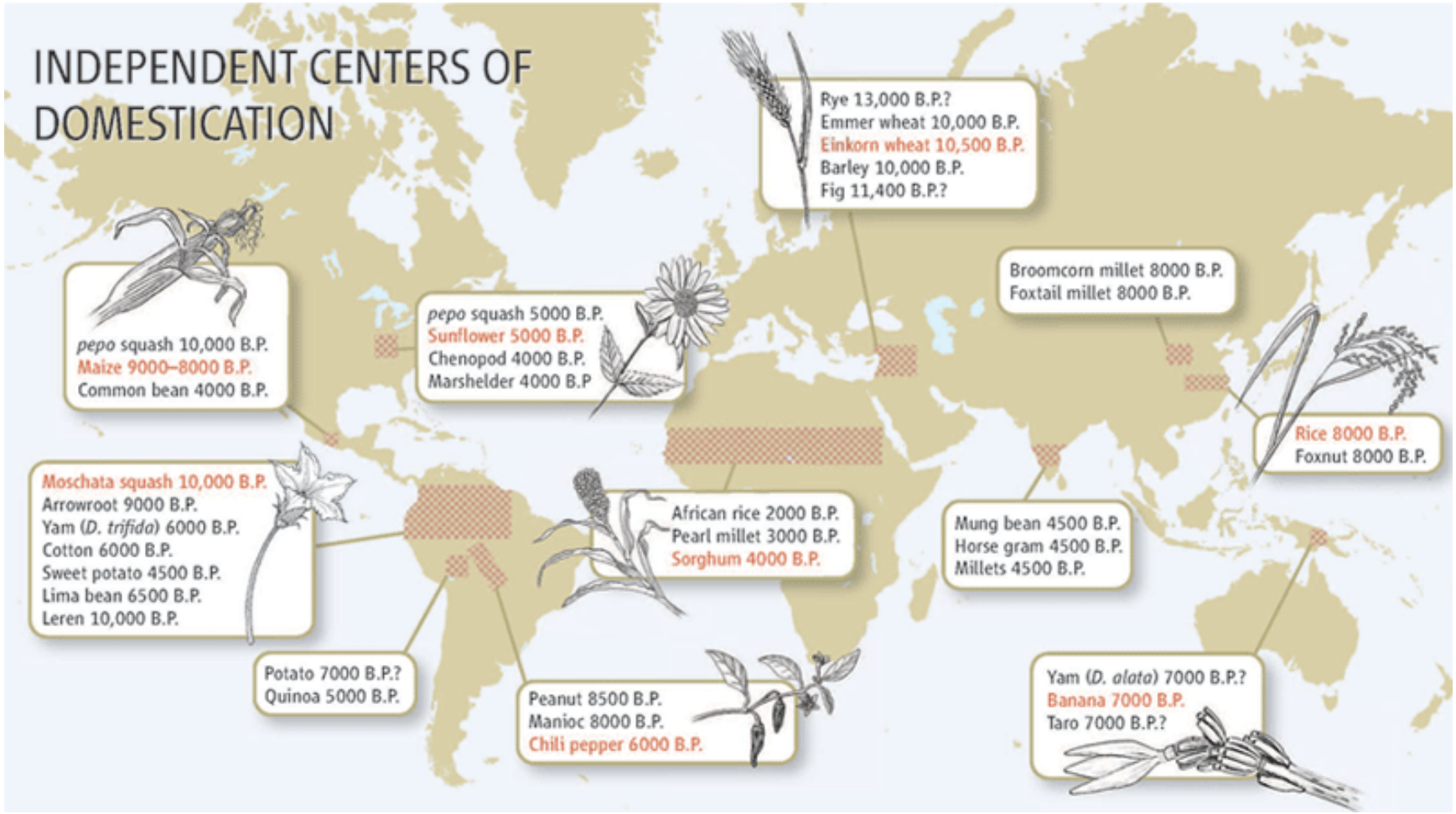
Why did agriculture develop when and where it did?

Where: Places where the most easily domesticated/most desirable native plants were; not necessarily the most productive areas for agriculture



From Diamond et al., 2002

When did agriculture arise?



How are these dates for the origins of agriculture determined?

- Radioactive carbon dating (^{14}C)
- Dating using genetic tools—number of genetic differences between wild variety and domesticated form (we'll spend more time on this in next class)
- What do you think about these dates (i.e., what is assumed)?

Why farm? What are its advantages and disadvantages?

What are the hypotheses for why agriculture arose when it did? (of course, not mutually excusive as agriculture arose multiple times over period of 8000 years…)

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- Climate change: Evidence that agriculture did not arise anywhere until after the last Ice Age. Warmer, wetter, more stable climate in Holocene. Also increase in CO2 levels—why would this be helpful for agriculture?

- Changing availability of food—reduction in big game; agriculture would have improved predictability of food supply

- Religious shifts

- Farming as status symbol with hunter-gatherers

- Population pressure

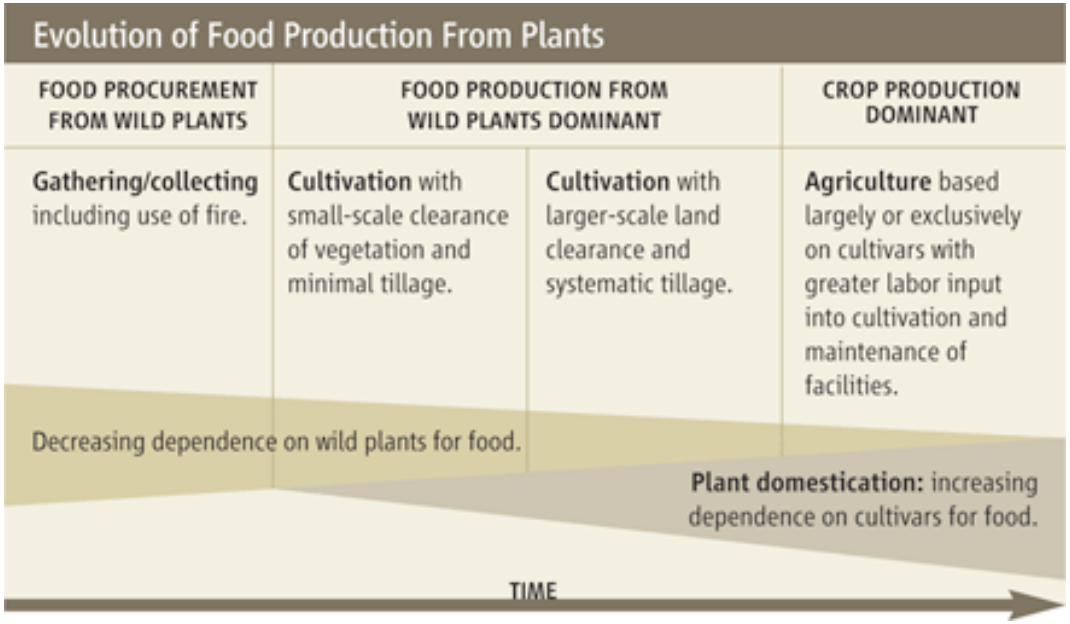
Was there an agricultural revolution or evolution?

Traditionally considered a revolution —How does this assumption reflect ideas about society?

Was there an agricultural revolution or evolution?

Traditionally considered a revolution-- Agriculture so beneficial that must have happened/developed quickly

Current data suggest a gradual shift, slow transition from strictly hunter-gather to cultivation of some wild species to partial and then full domestication



What is the evidence for evolution versus revolution?

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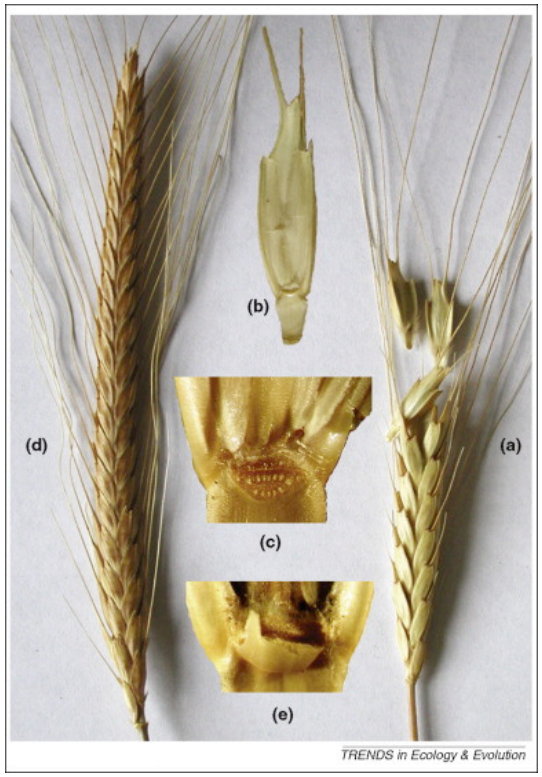
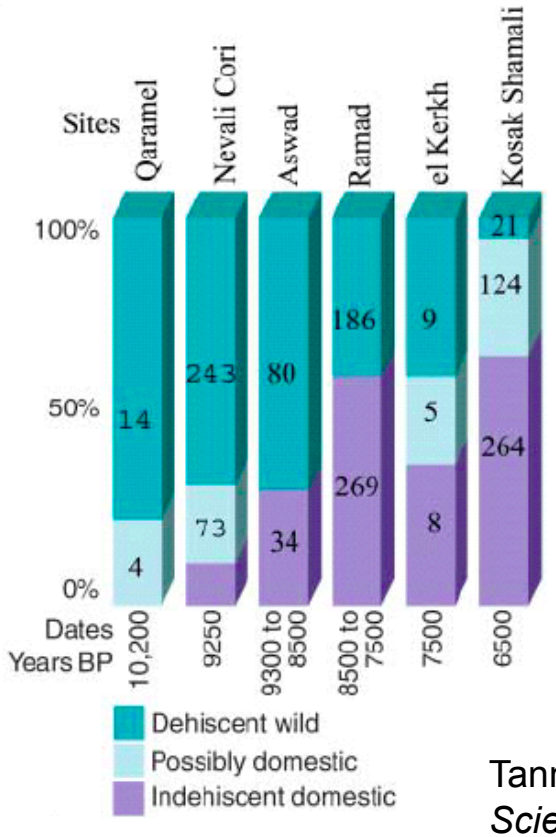
- Archaeological sites with lots of wild plant materials and evidence that they were using cereals for flour, but no evidence of domestication

What is the evidence for evolution versus revolution?

- Mix of both domesticated and non-domesticated spikelets at sites in Syria and Turkey. Trend over 3000 years towards greater percentage of domesticated spikelets





Tanno & Willcox, 2006. *Science* 311:1886