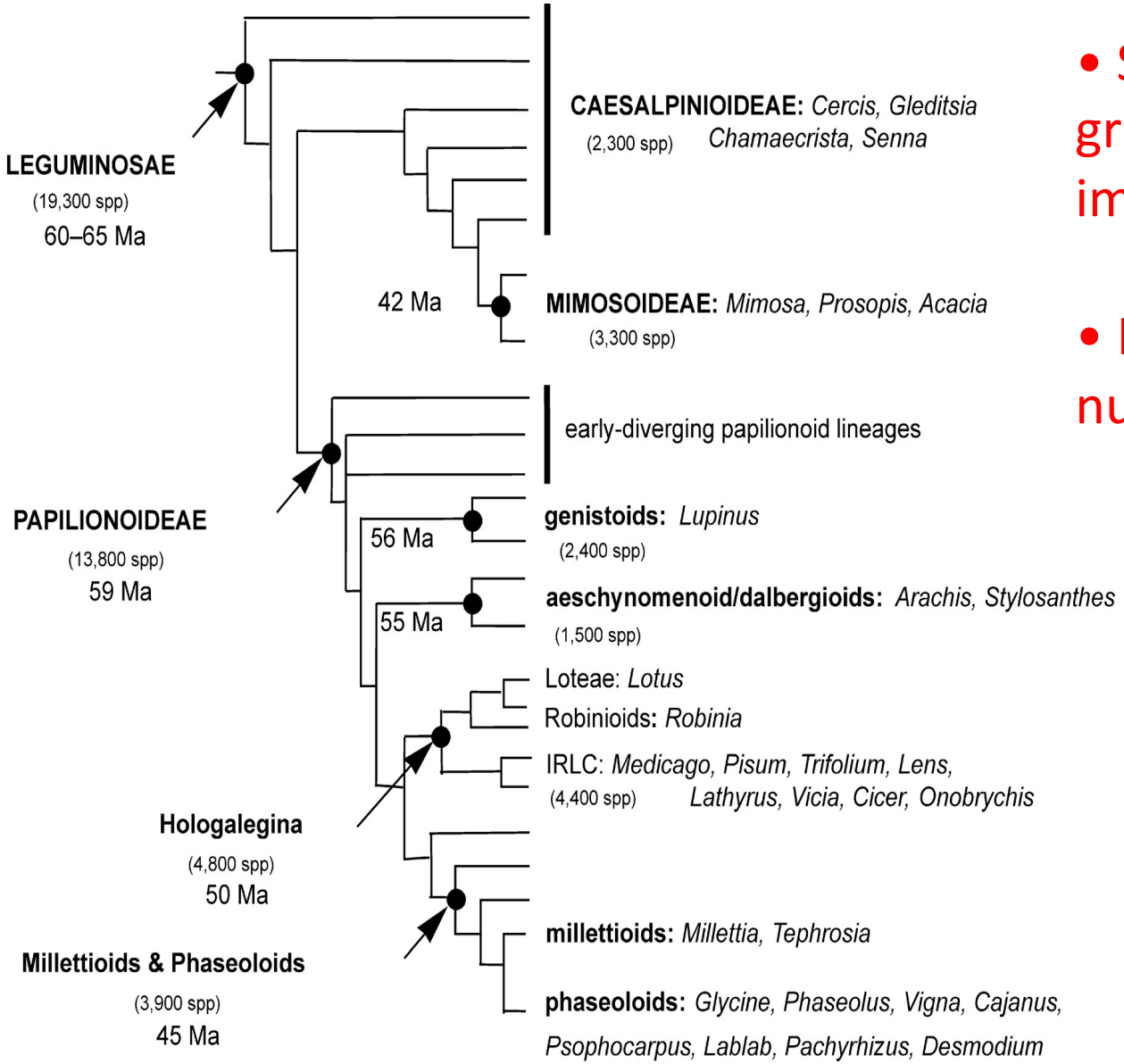
2016: The Year of the Pulse

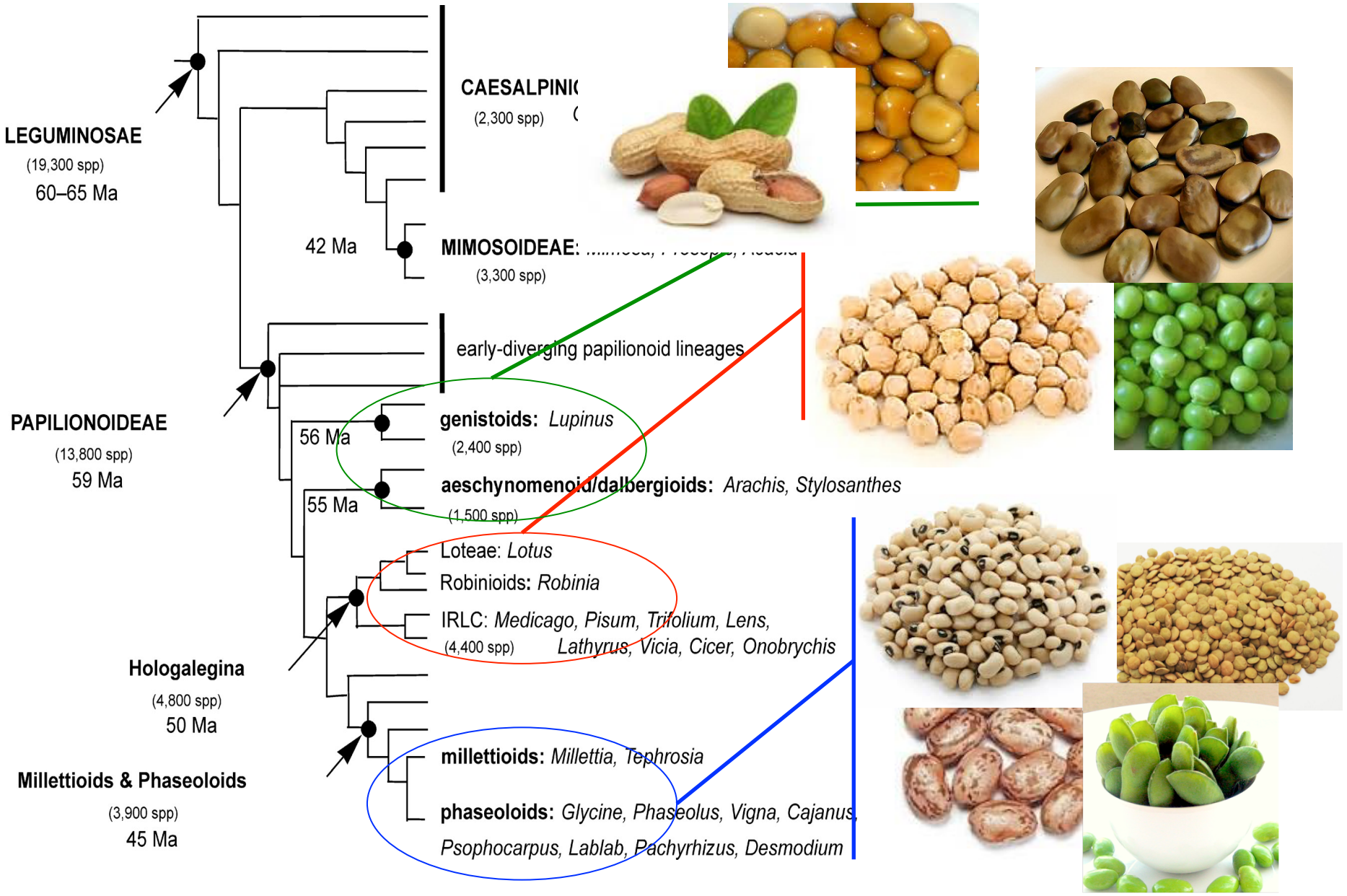
What’s a Pulse?

Legumes are the 3rd largest family of flowering plants



- Second only to grasses in agricultural importance
- Keystone family for nutrition

Pulses are legumes of which we eat the seed



Why legumes?

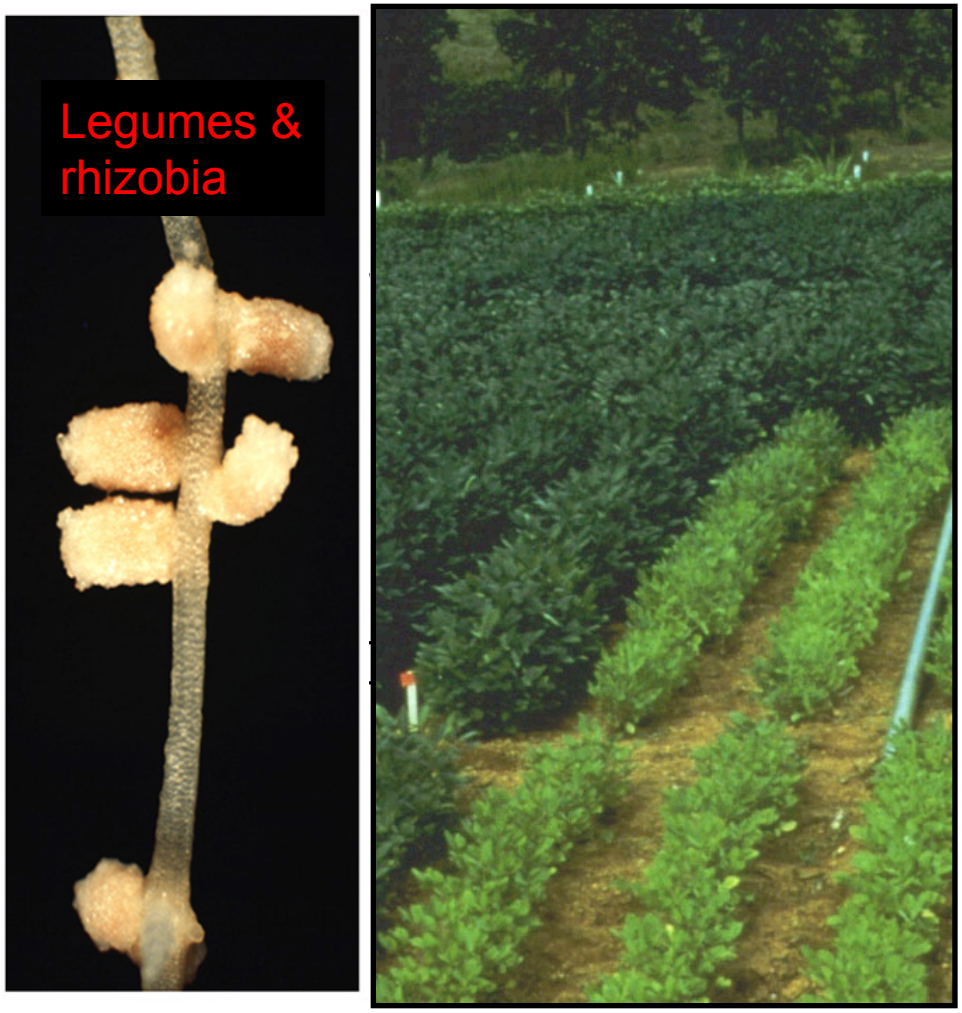
A key source of humankind's protein nitrogen

- High Protein content of seed
- Enrich soil in vital nitrogen

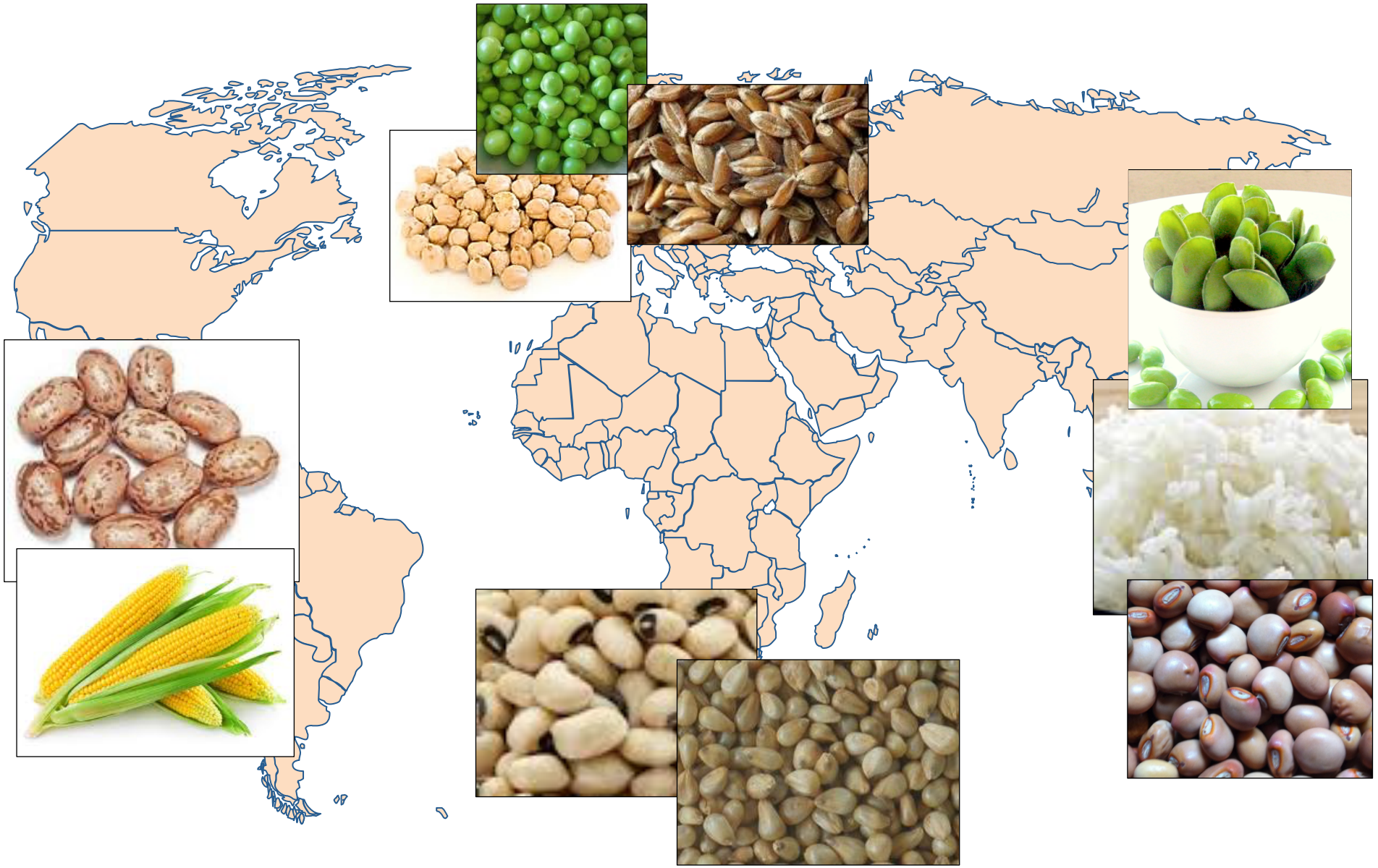
Of particular importance in food insecure regions of the world

In non-legume systems, in the developed world, nitrogen derives primarily from industrial processes that depend on fossil fuels.

Nitrogen drives agricultural costs, is among the world's most significant pollutants and major contributor to greenhouse gases.



Humans co-domesticated legumes and grasses



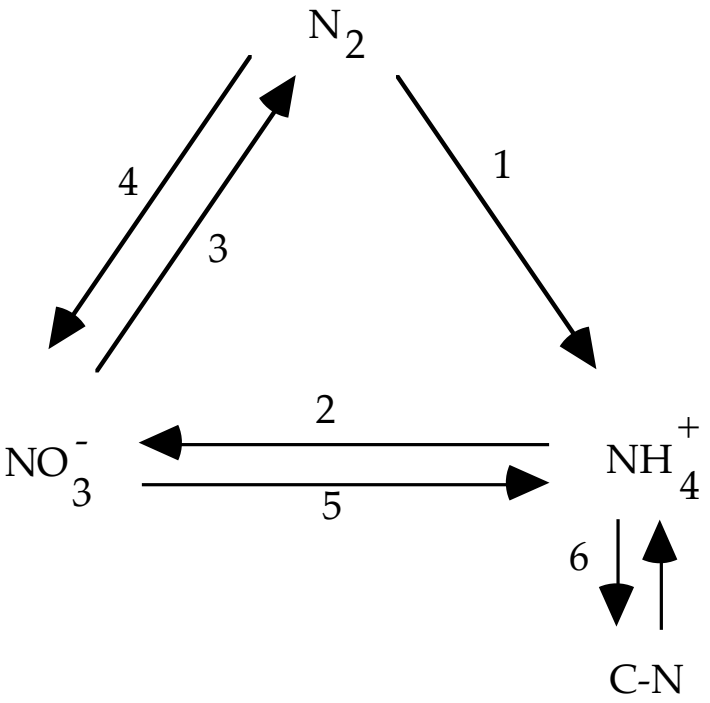
A soybean field experiment: +/- Rhizobium

Nitrogen, an **essential** plant nutrient

Reduced forms of nitrogen (NO_2^-, NO_3^-, NH_4^+, urea) are essential for the synthesis of many important biological molecules, including:

- amino acids (proteins).
- nucleic acids (DNA and RNA).

Nitrogen cycle

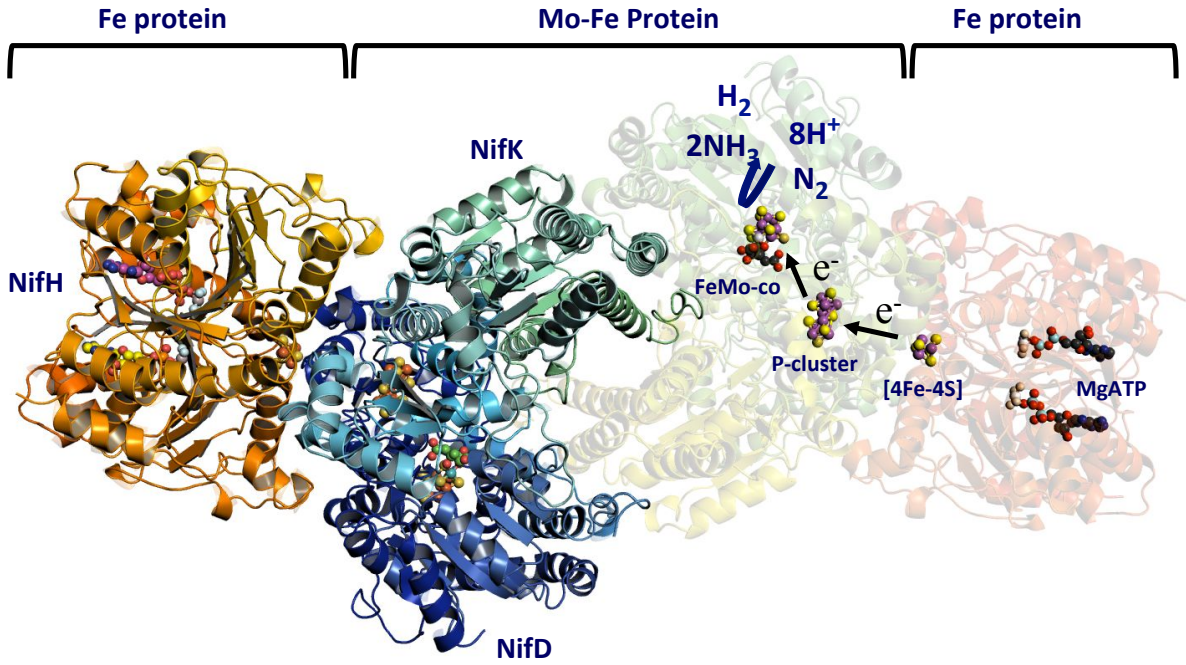


- **1 = biological nitrogen fixation.**
- **2 = nitrification** (aerobic process that uses ammonia (NH_4^+) and nitrite (NO_2^-) as an energy source.
- **3 = denitrification** (anaerobic process that uses nitrate (NO_3^-) and nitrite as an electron acceptor).
- **4 = lightning** (abiotic N_2 reduction).
- **5,6 = nitrogen assimilation.**

Only prokaryotes (bacteria) can conduct biological nitrogen fixation

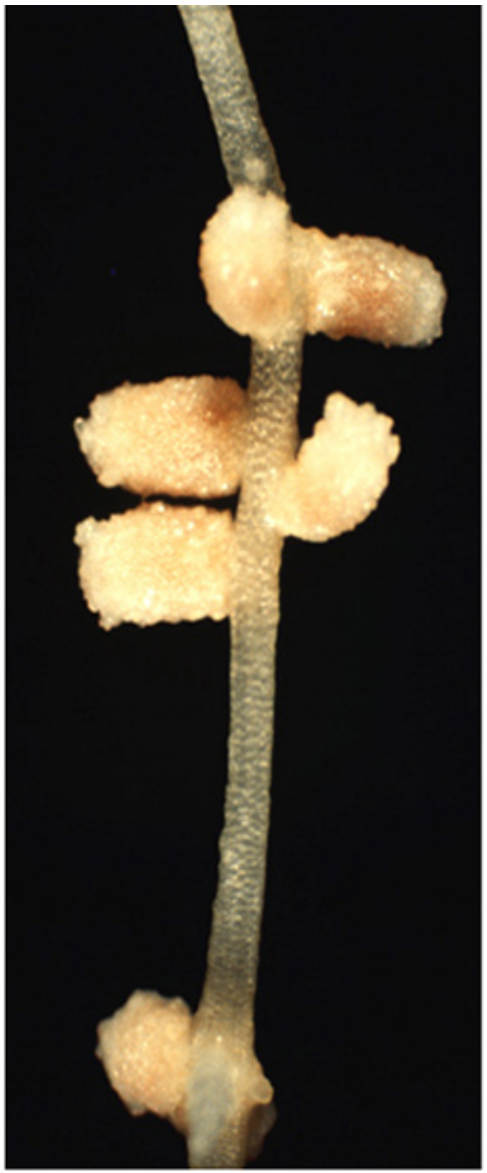
Higher organisms (all eukaryotes) are dependent on **external** sources of NO_2^-, NO_3^-, and NH_4^+

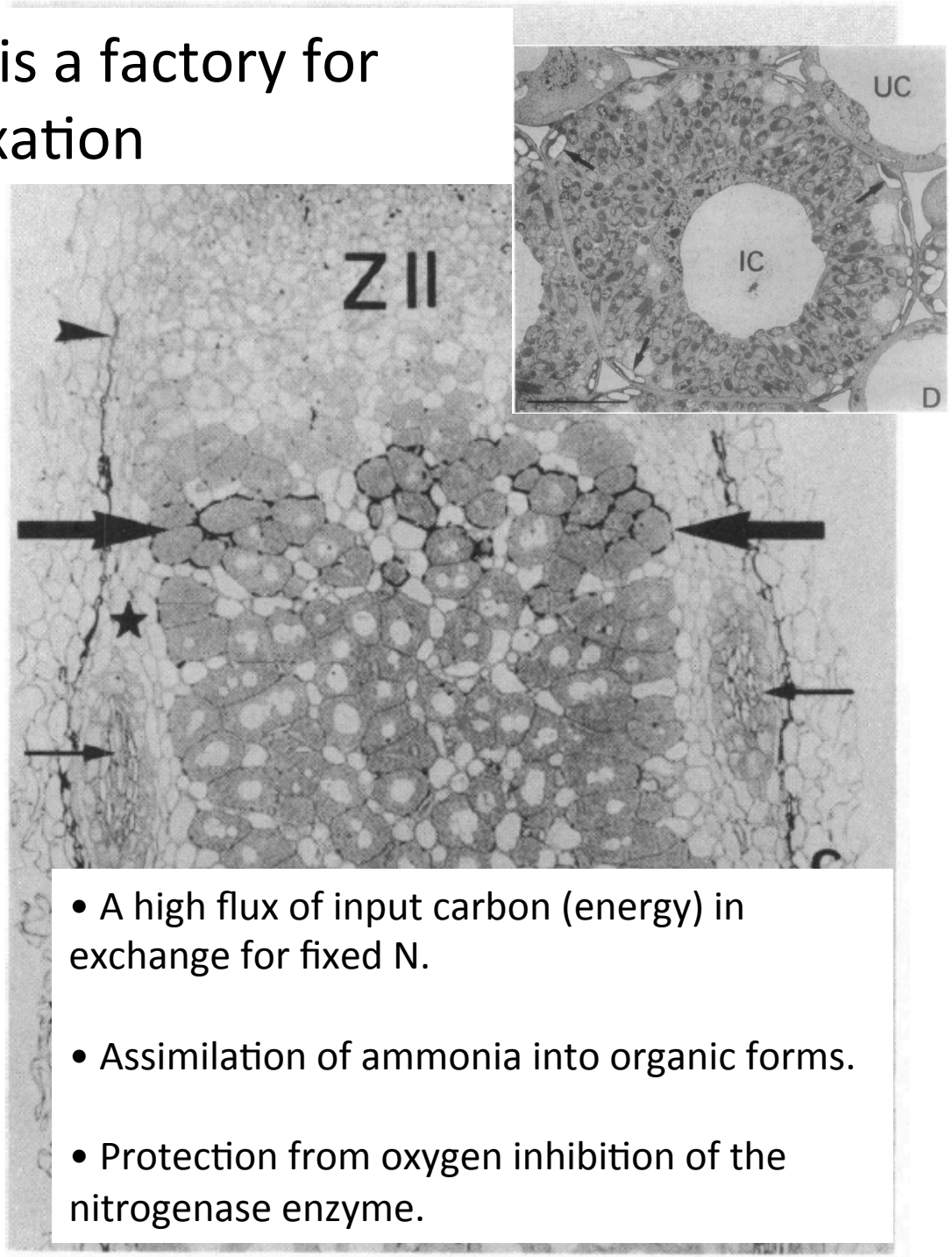
Molybdenum containing nitrogenase



$N_2 + 8H^+ + 16MgATP + 8e^- \rightarrow 2NH_3 + H_2 + 16MgADP + 16P_i$

The legume nodule is a factory for nitrogen fixation



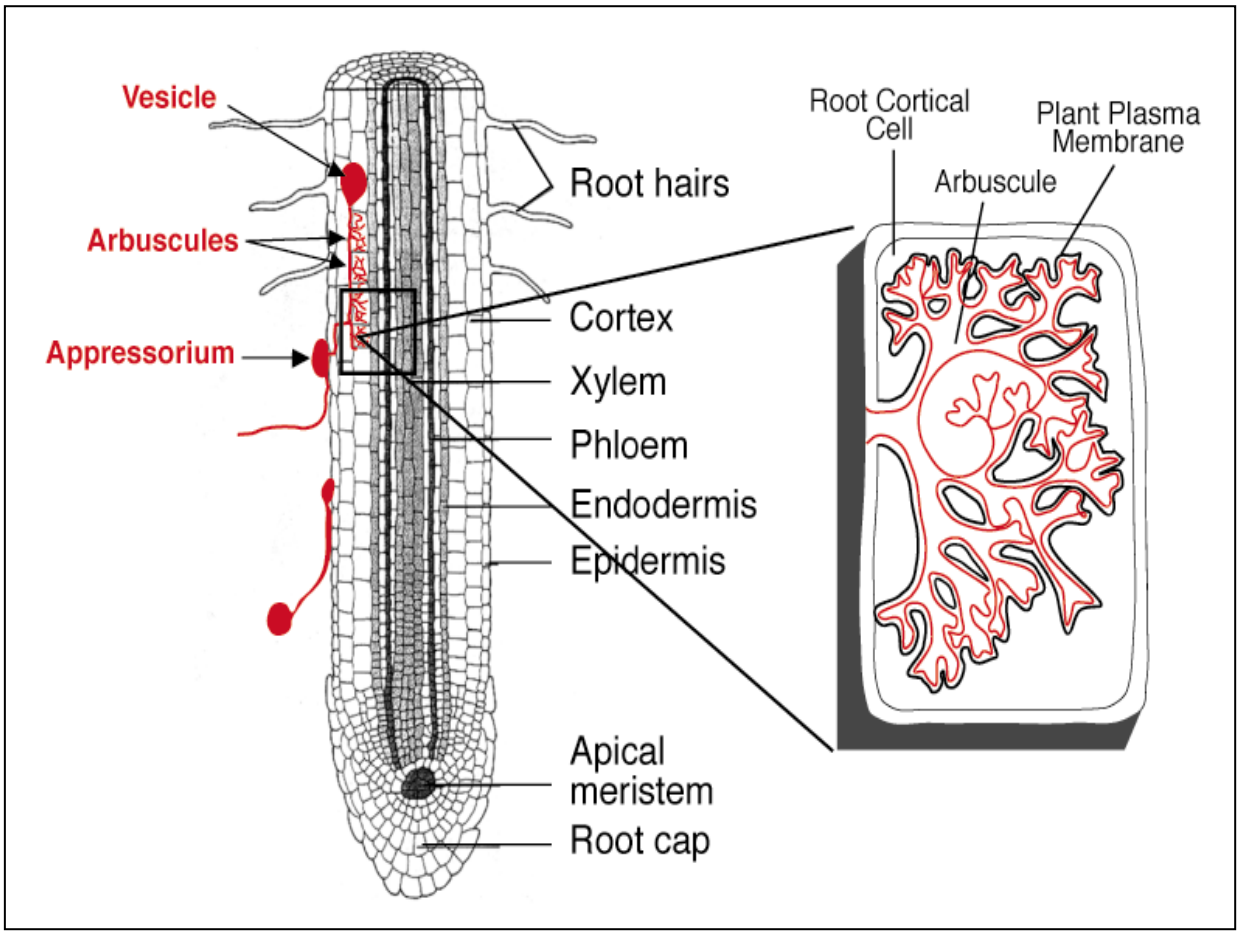


- A high flux of input carbon (energy) in exchange for fixed N.
- Assimilation of ammonia into organic forms.
- Protection from oxygen inhibition of the nitrogenase enzyme.

Nitrogen fixation in legumes arose from a more ancient pathway for mycorrhizal associations.

nitrogen

phosphate

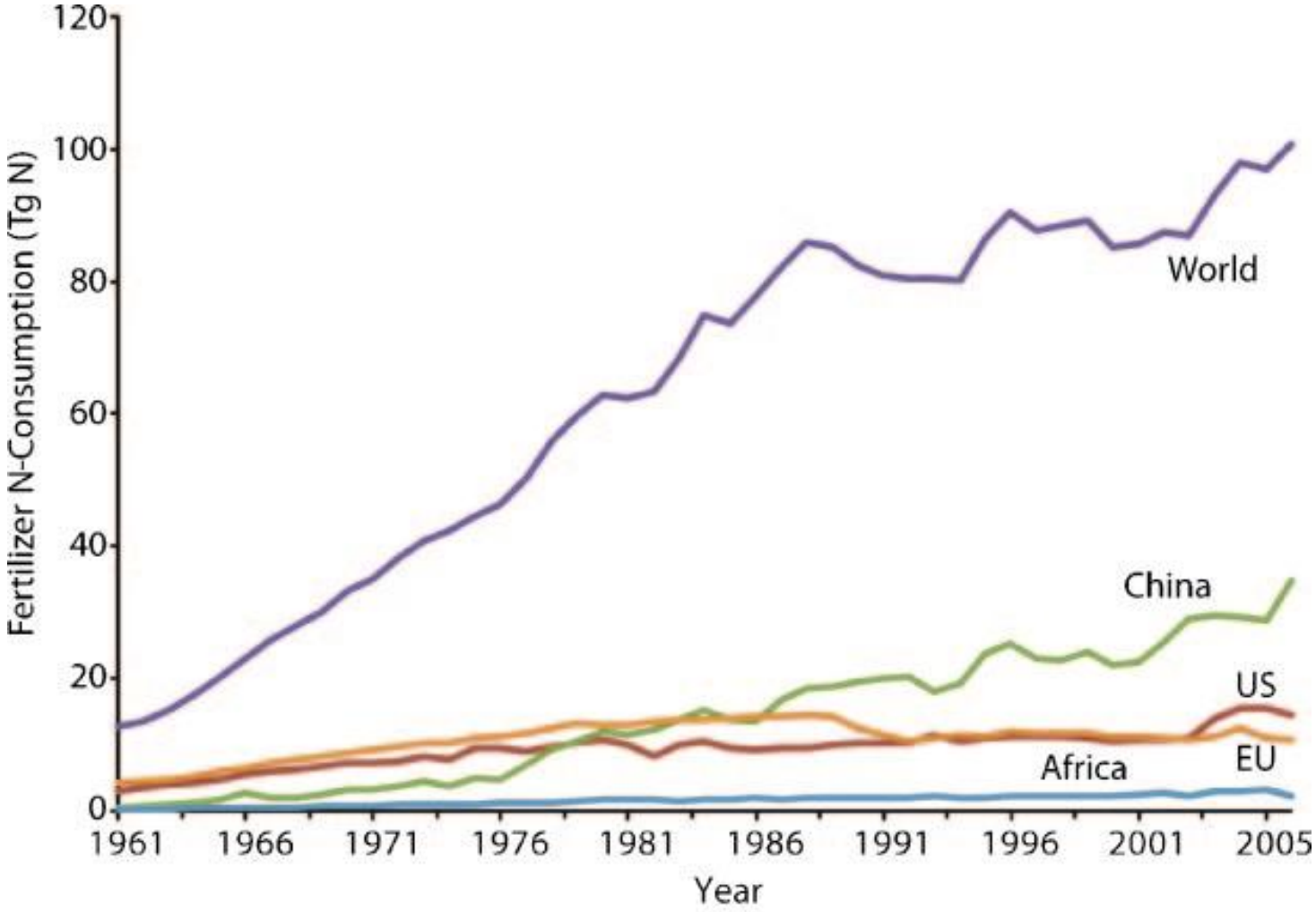


Significance of Symbiotic Nitrogen Fixation:

- One of the major sources of reduced nitrogen in the biosphere.
- Crop rotations with legumes have been an important mechanism for increasing nitrogen in agriculture since at least Ancient Rome and China.
- In the Midwestern United States, alfalfa and Rhizobium fix > 1 million tons of nitrogen/year.
- Using this resource, farmers could reduce nitrogen input by an estimated 14%.

Industrial Source of Ammonia: Haber-Bosch Process

- ~100 atmospheres of N_2 and H_2
  (Large inputs of energy [fossil fuels])
- at 600°C
- ≤ 30% of cost of agriculture in US

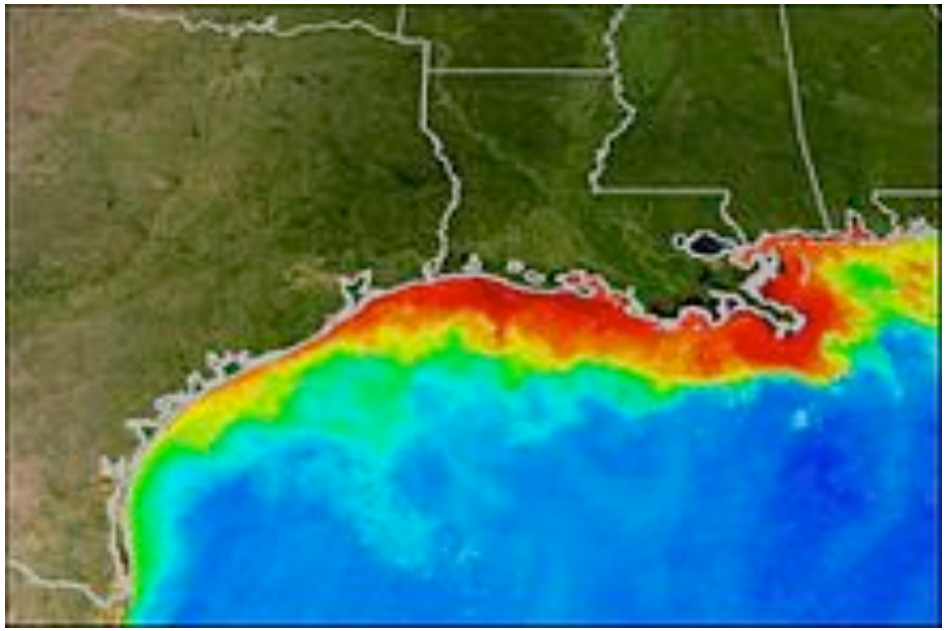


Robertson GP, Vitousek PM. 2009.
Annu. Rev. Environ. Resour. 34:97–125

"China feeds 22% of the world's population with only 7% of the world's arable land – a seemingly remarkable feat, until one takes into account that China also uses 35% of the world's fertilizers."

"In 2008, China lost more fertilizer-nitrogen to volatilization than all nitrogen fertilizer consumed in Africa."

An estimated 8% of China's energy-related CO2 emissions are attributable to nitrogen fertilizers."



Fertilizing the Nitrogen Cycle

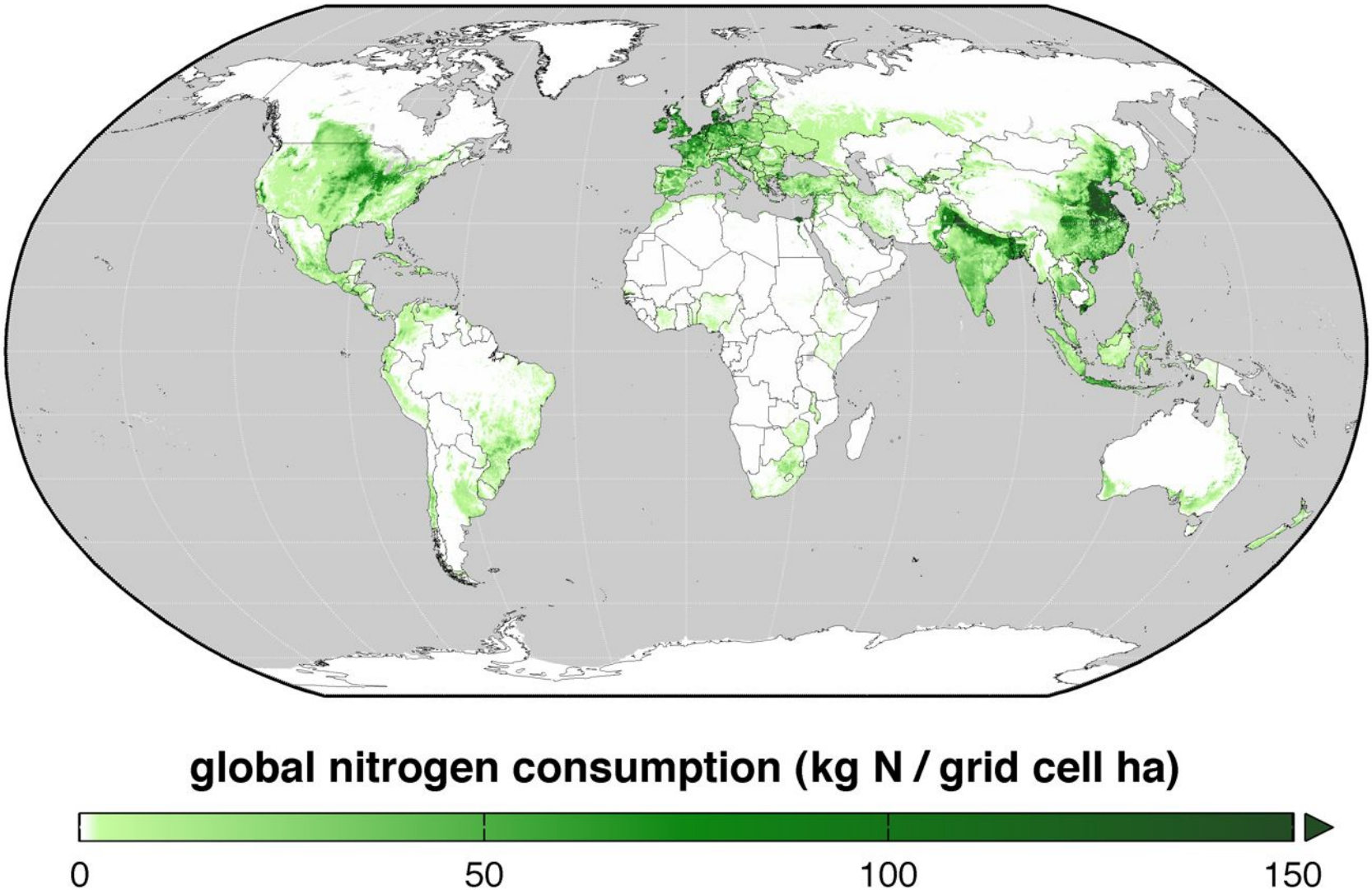
Annual releases of fixed nitrogen caused by human activity

Source	Millions of tons
Fertilizer	**80**
Nitrogen-fixing crops	40
Fossil fuels	20
Biomass burning	40
Wetland drainage	10
Land clearing	20
Total human releases	**210**
Total natural fixed-nitrogen prod^{n}*	140

*Terrestrial sources only; marine sources have not yet been reliably estimated.

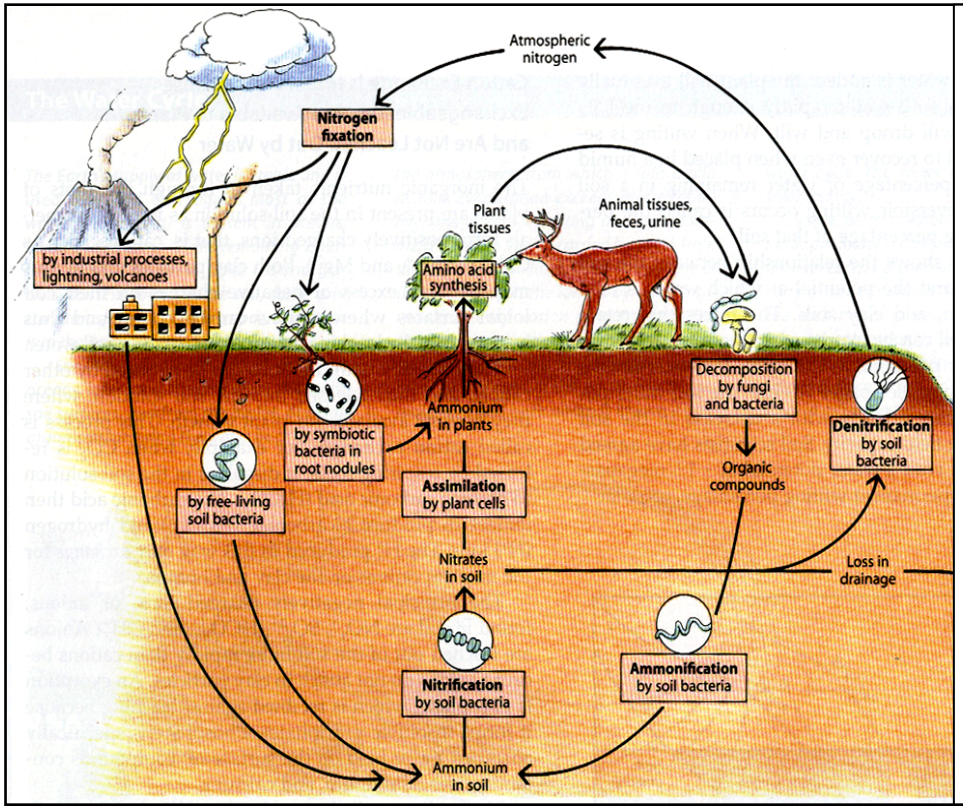
Source: World Resources Institute, "Global Nitrogen Glut" www.wri.org/wri/wr-98-99/nutrient.htm.

The Nitrogen Fertiliser Problem



Mueller et al 2012, *Nature* **490**: 254-257

What is the quantitative impact of N-fixation on organic N in agriculture?



N14 and N15 – Stable Nitrogen Isotopes

In the atmosphere, natural abundance of N15 is 0.37%, compared to 99.63% N14.

- Nitrogenase creates organic N with the same N15:N14 ratio as in air.

In the soil biologically available N is depleted in N15 relative to the air.

- Organic N derived from soil nitrogen has N15:N14 ratios the same as soil.

N-fixing plants have increased N15:N14 ratios, relative to non-N fixing plants. The "nitrogen derived from the atmosphere" (%Ndfa) metric.

From: Raven P., R. Evert, and S. Eichhorn, 1999. *Biology of Plants*, 5th Ed. Worth Publishers.

Nitrogen fixation can be highly variable in agricultural situations

Table 1. Distributions of %Ndfa of farmers' crops of legumes in northern Pakistan (source: Rupela et al. 1997).

Species	Number of crops surveyed	Level of %Ndfa				
		0-20	21-40	41-60	61-80	81-100
		% crops in each category				
Lentil	40	0	0	8	50	42
Chickpea	86	0	3	8	43	45
Mung bean	40	15	15	35	25	10

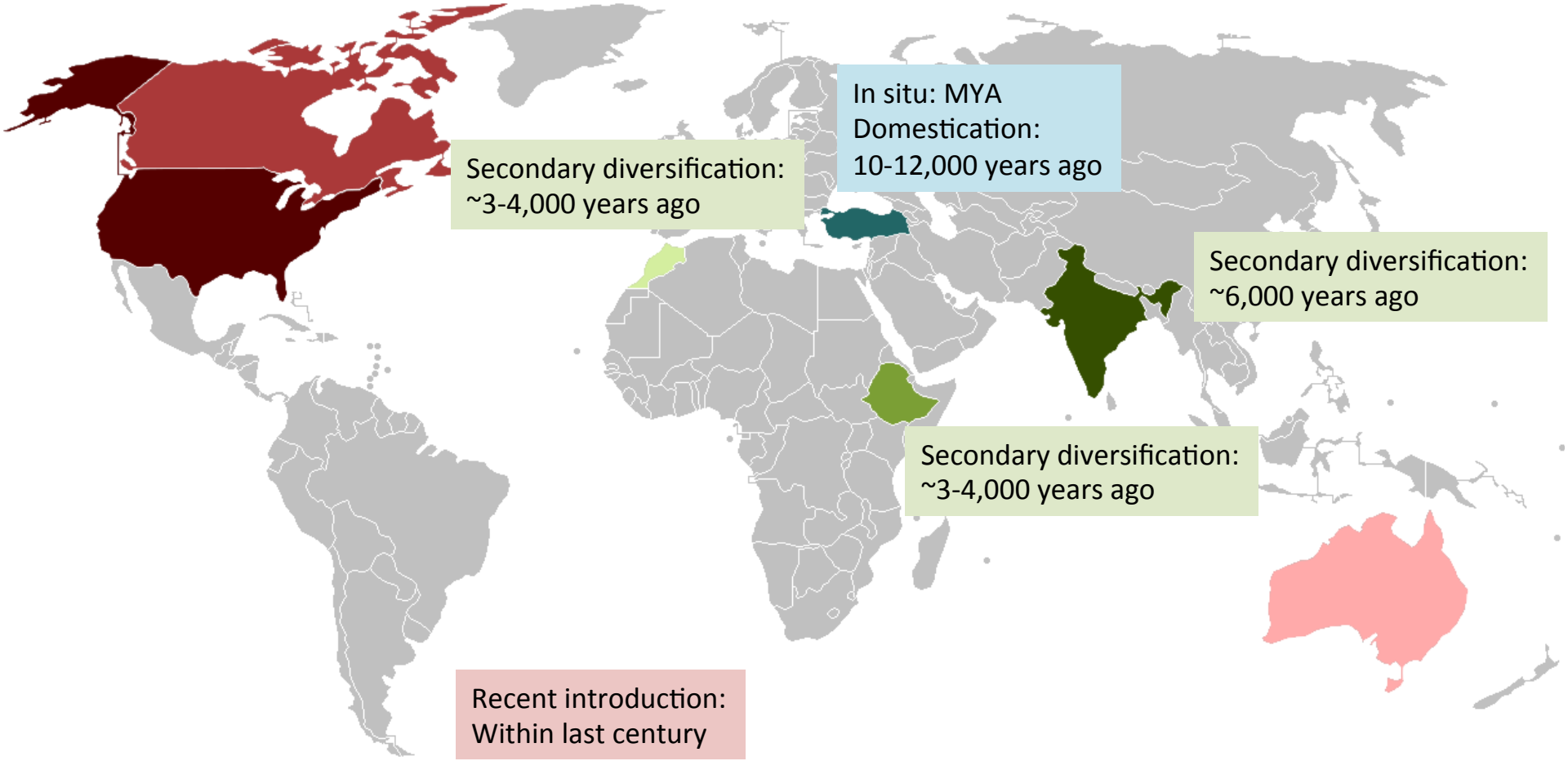
Chickpea is among the world's most important pulse legumes and critical to food security in much of the developing world

- Stagnant yields
- Susceptible to pathogens, pests and abiotic stress

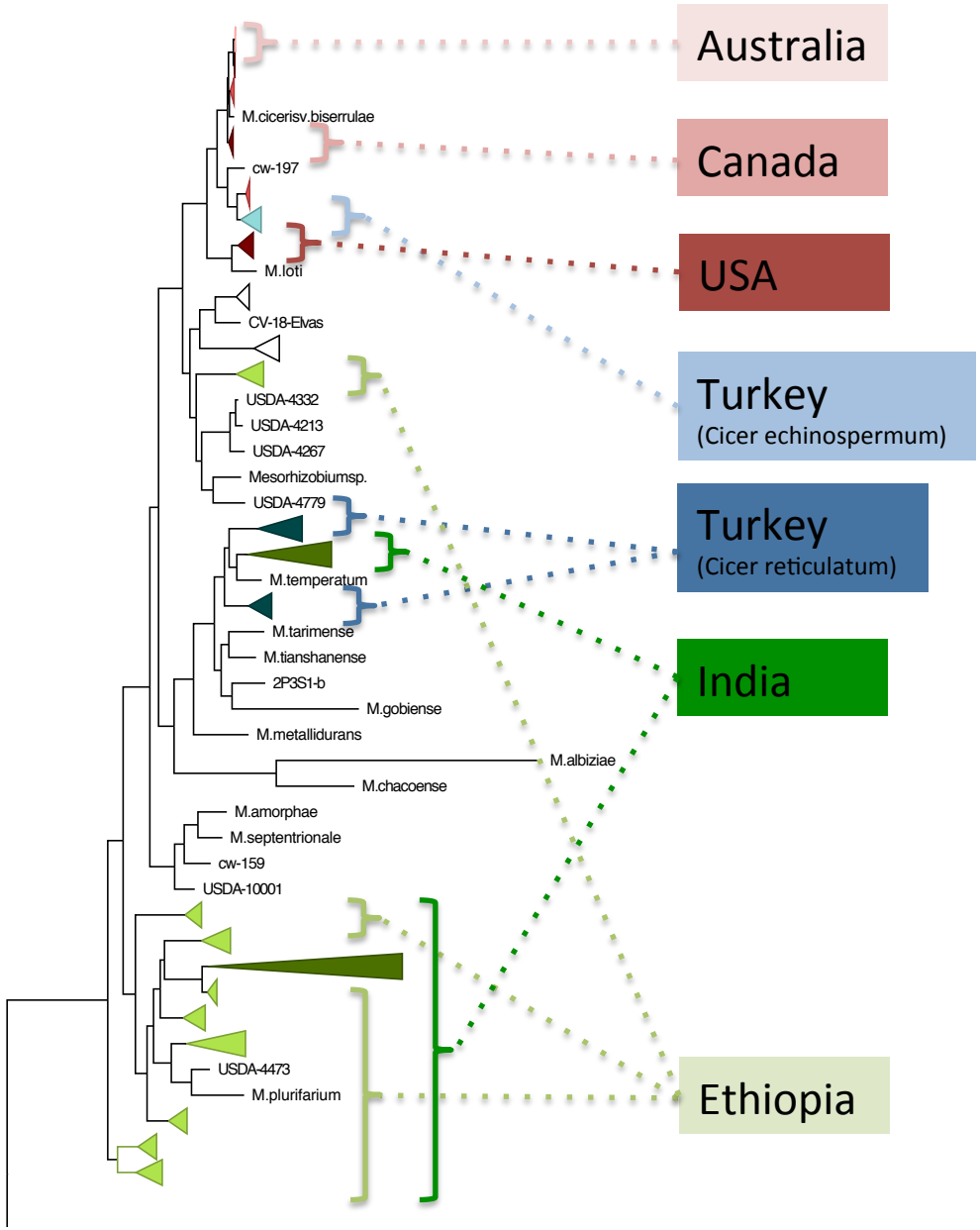
- Drought
- Heat
- Pests and Disease
- Nitrogen fixation
- Nutrition
- Soil adaptation
- Agronomic traits
- *Domestication*

Chickpea originated in Mesopotamia

Harness the genetic potential of chickpea (and its microbes) at its center of origin and sites of longstanding cultivation

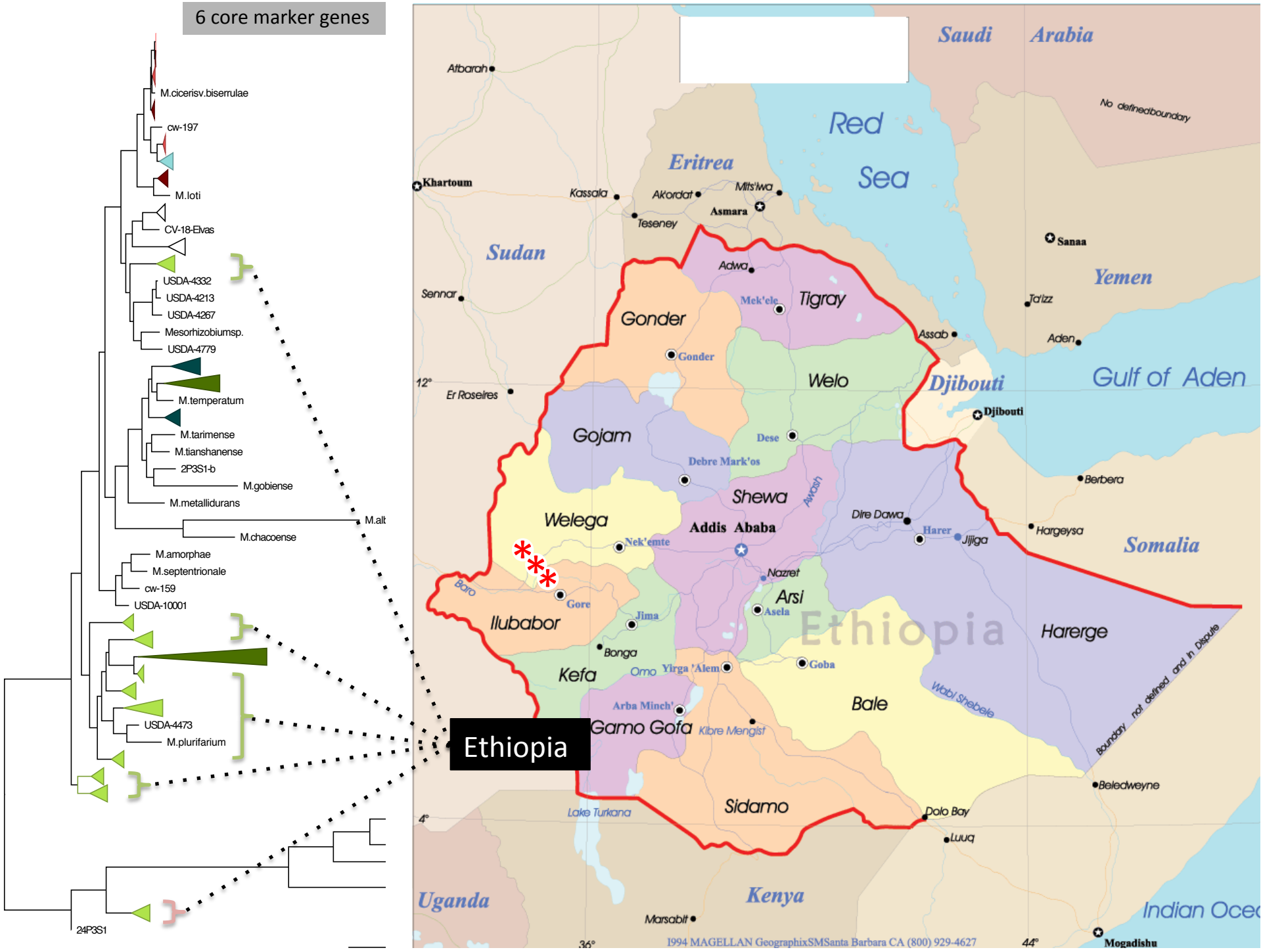


Focus on chickpea's nitrogen-fixing symbiont: *Mesorizobium* 1,200 genomes from a global survey



Pakistan

India


6 core marker genes
M.cicerisv.biserrulae
cw-197
M.loti
CV-18-Elvas
USDA-4332
USDA-4213
USDA-4267
Mesorhizobiumsp.
USDA-4779
M.temperatum
M.tarimense
M.tianshanense
2P3S1-b
M.gobiense
M.metallidurans
M.alt
M.chacoense
M.amorphae
M.septentrionale
cw-159
USDA-10001
USDA-4473
M.plurifarium
24P3S1
Ethiopia
Saudi Arabia
Red Sea
Eritrea
Sudan
Yemen
Gulf of Aden
Djibouti
Somalia
Uganda
Kenya
Indian Ocean
Atbarah
Khartoum
Kassala
Ak'ordat
Mits'iwa
Asmara
Teseney
Sanaa
Ta'izz
Aden
Assab
Adwa
Mek'ele
Tigray
Gonder
Sennar
Er Roseires
Welo
Dese
Djibouti
Berbera
Hargeysa
Gojam
Debre Mark'os
Shewa
Awash
Welega
Addis Ababa
Dire Dawa
Harer
Jijiga
Nek'emte
Nazret
Baro
Gore
Arsi
Asela
Ilubabor
Jima
Harerge
Bonga
Kefa
Omo
Yirga 'Alem
Goba
Wabi Shebele
Arba Minch'
Bale
Gamo Gofa
Kibre Mengist
Boundary not defined and in Dispute
Beledweyne
Sidamo
Lake Turkana
Dolo Bay
Luuq
Marsabit
Mogadishu
12°
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1994 MAGELLAN GeographixSMSanta Barbara CA (800) 929-4627


3
90P4S2 +P
5
80P4S2 +P
4
45P4S1 +P
1
Untreated
6

Implement and deliver

Holster up & lets get cracking…