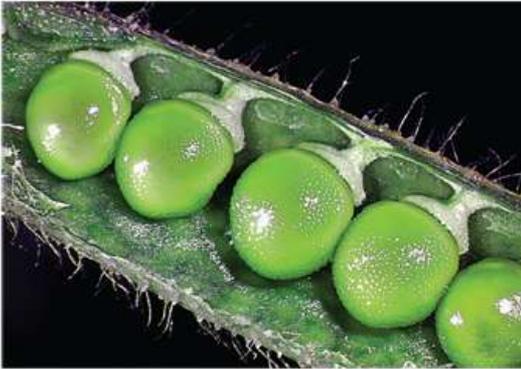


The Legumes - Fabaceae



(a)



(b)



Figure 13.1 (a) Flowers of the hyacinth bean resemble sailboats, a shape common to many species in the legume family. (b) Peas (seeds) in an opened pod.

Legume Introduction

- Second only to the grasses in their importance to humans and our domestic animals.
- Every major civilization has been based on a legume as well as a cereal grain.
- Legumes are by definition all members of the Fabaceae or Leguminosae (old name for this group).
- This is a large family with perhaps 18,000 species.

Legume examples

Foods

- peas
- peanuts
- soybeans
- kidney & pinto beans
- green beans
- fava beans
- lima beans
- chick-peas (Garbanzo beans)
- black-eyed peas
- lentils

Forage

- alfalfa
- red clover
- white clover
- sweet clovers
- vetches
- cowpeas

Trees

- carob
- mesquite
- locust (honey & black)
- mimosa



What is a legume?

- Dicots
- Distinctive flowers and pods
- Flowers are usually bilaterally symmetrical, “papilionoid” like a butterfly with wings
- Fruit is a legume (dry dehiscent fruit - two lines of dehiscence) with one row of seeds
- Seeds rich in oil (up to ca. 50%) and protein (e.g., 15-50%)



Legume Fruits

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Legume seeds

- Important food staple worldwide
- Rich in both oil and protein
 - Higher in protein than any other food plants
 - Close to animal meat in protein quality
 - Often called "poor man's meat"



Figure 13.3 Beans, peas, and lentils are the seeds of legumes. They come in a wide variety of shapes, sizes, and colors.

What is a Pulse?

Pulse: from the Latin *puls* meaning thick soup or potage, pulses are the edible seeds of plants in the legume family.

Three groups of Legumes

Faboideae

- Flowers zygomorphic and papilionoid, with standard (banner), 2 wings, 2 fused keel petals.
- Stamens 10, diadelphous, 9 united + 1 free



Three groups of Legumes

Caesalpinioideae

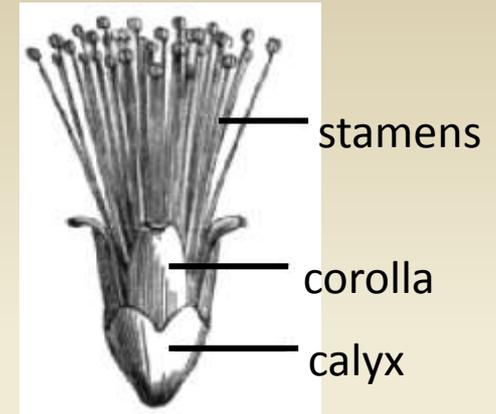
- Flowers winged, but somewhat irregular
- Banner is usually located interior to the wings
- 10 stamens that are free and often unlike
- *Cercis* (Redbud), *Caesalpinia*



Three groups of Legumes

Mimosoideae

- Inflorescence a “ball of stamens”
- Flowers actinomorphic
- *Mimosa*, *Acacia*



an individual flower



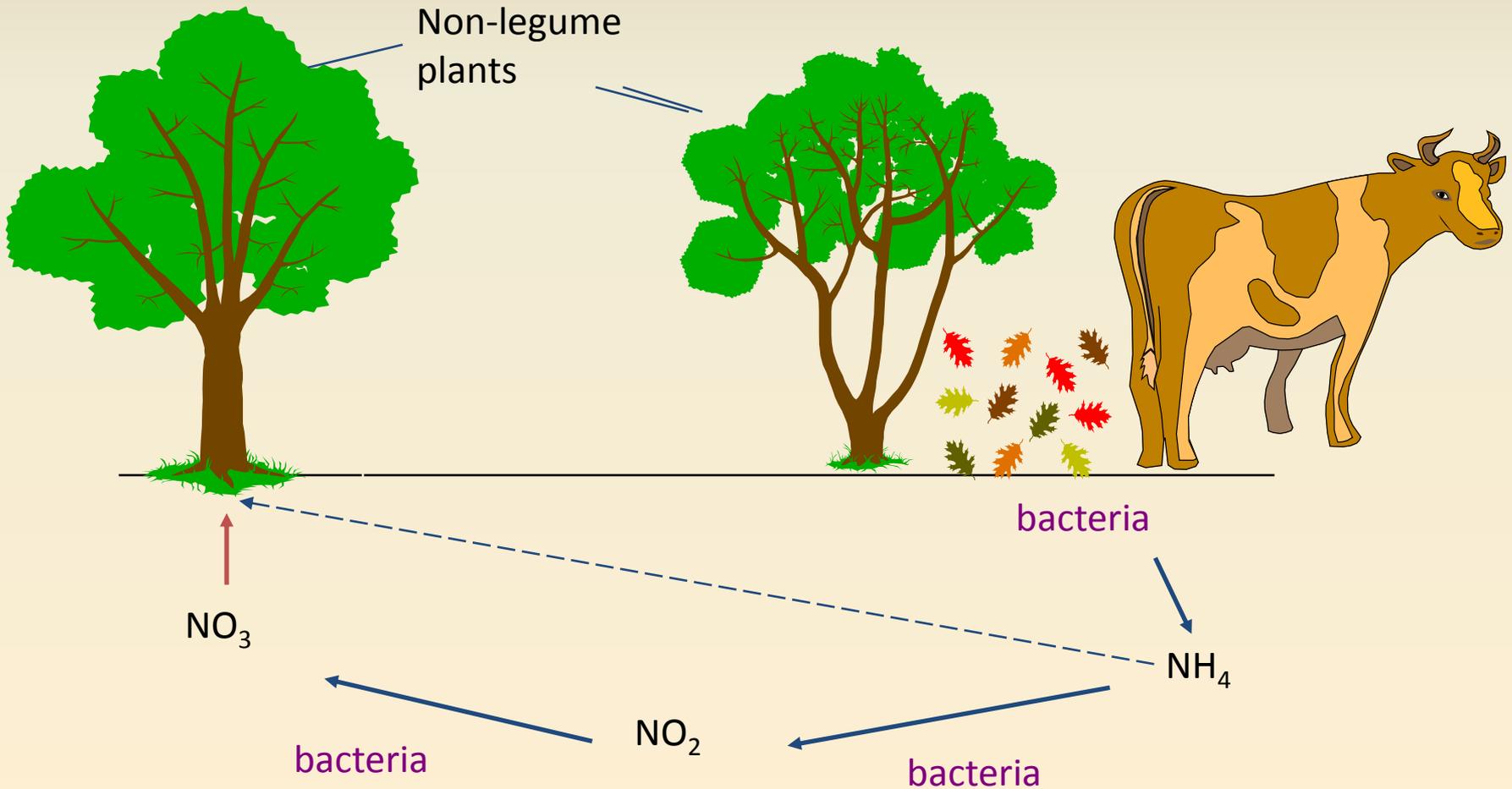
Nitrogen

- Nitrogen
 - essential elements for all living organisms
 - major component of amino acids, proteins, nucleic acids
- Nitrogen gas (N_2) about 79% of the air
 - most living organisms cannot use this form of nitrogen.
 - N_2 gas has triple bond, hard to break
- Most flowering plants must absorb nitrate or ammonium nitrogen through the roots.

Non-legume plants

- Can not fix nitrogen
- Must rely on the nitrogen compounds present in the soil
- During decomposition microorganisms break down proteins and other nitrogen-containing molecules into ammonium NH_4^+

Nitrogen Cycle (without legumes)

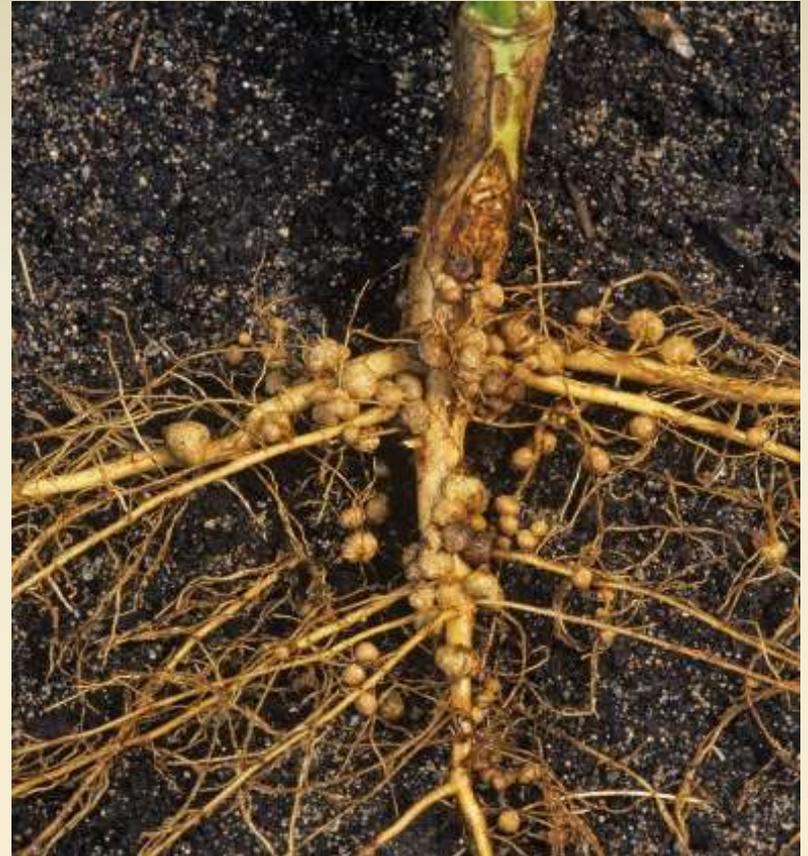


Nitrogen-fixing bacteria

- Certain bacteria and cyanobacteria have ability to reduce nitrogen (N_2) gas to ammonium NH_4^+
 - cells can convert NH_4^+ to compounds
 - called **Nitrogen-fixation**
 - organisms are called nitrogen-fixing
 - have special enzyme Nitrogenase that can break the triple bond of N_2

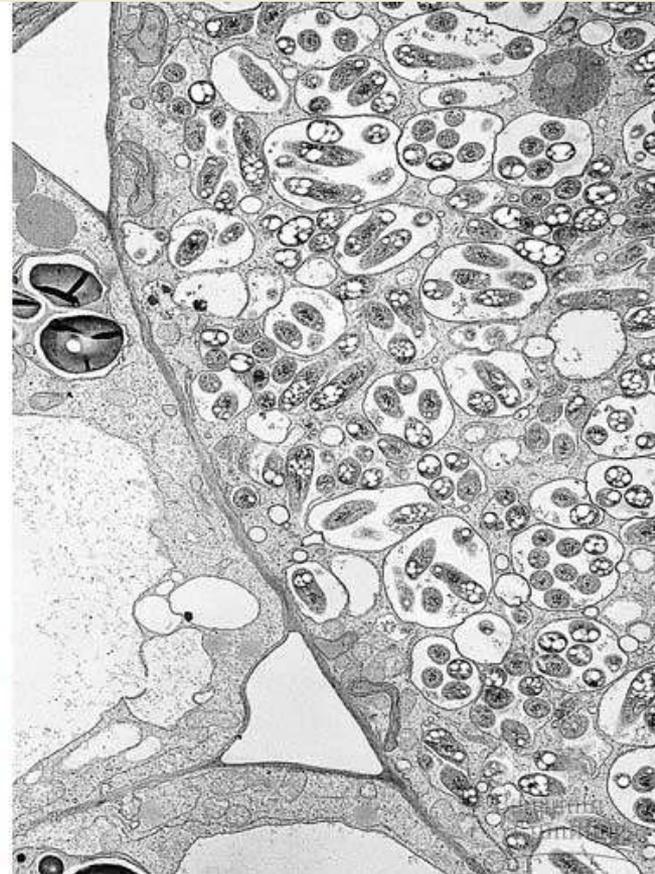
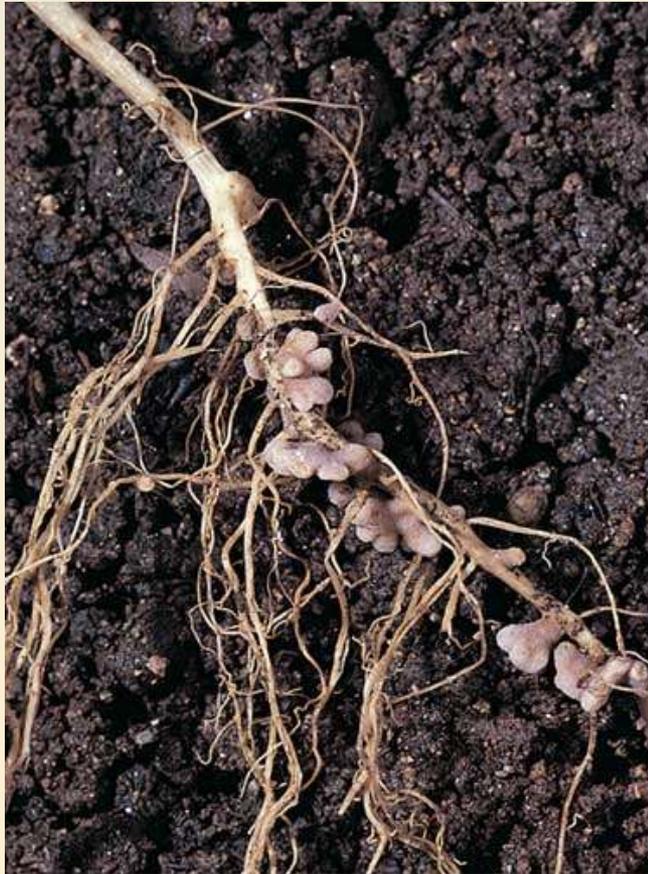
Nitrogen Fixation in Legumes

- The roots of most legumes form associations with bacteria that can fix atmospheric nitrogen.
- These *Rhizobium* species live in nodules on the roots.
- They provide “free” fertilizer.

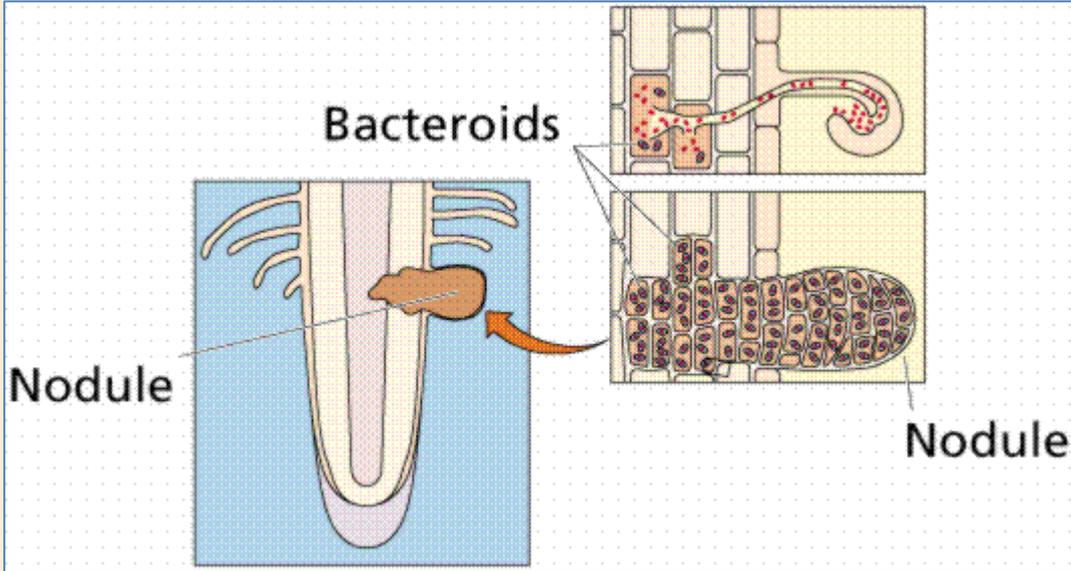
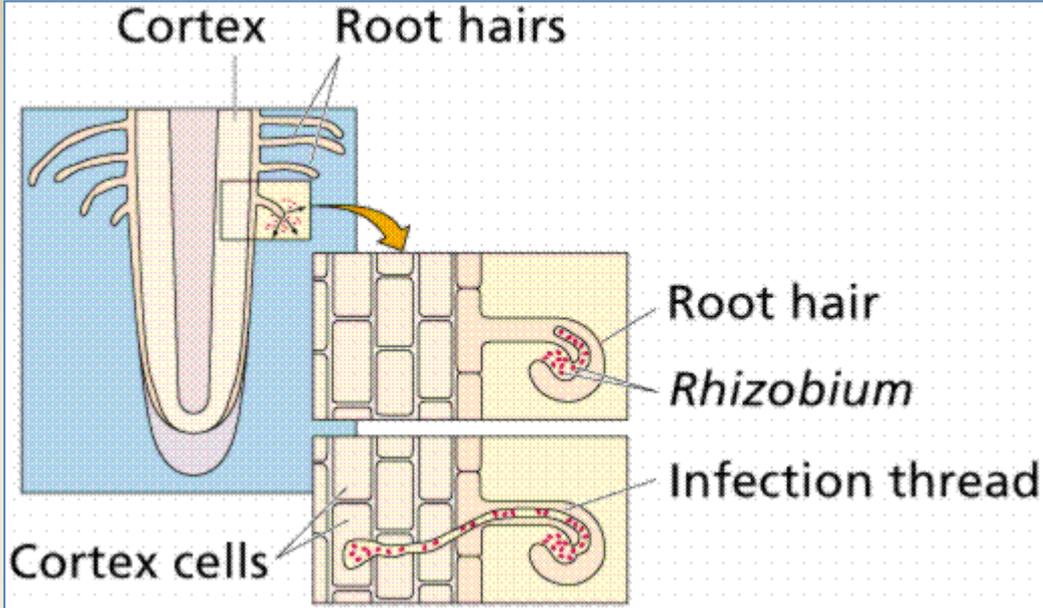


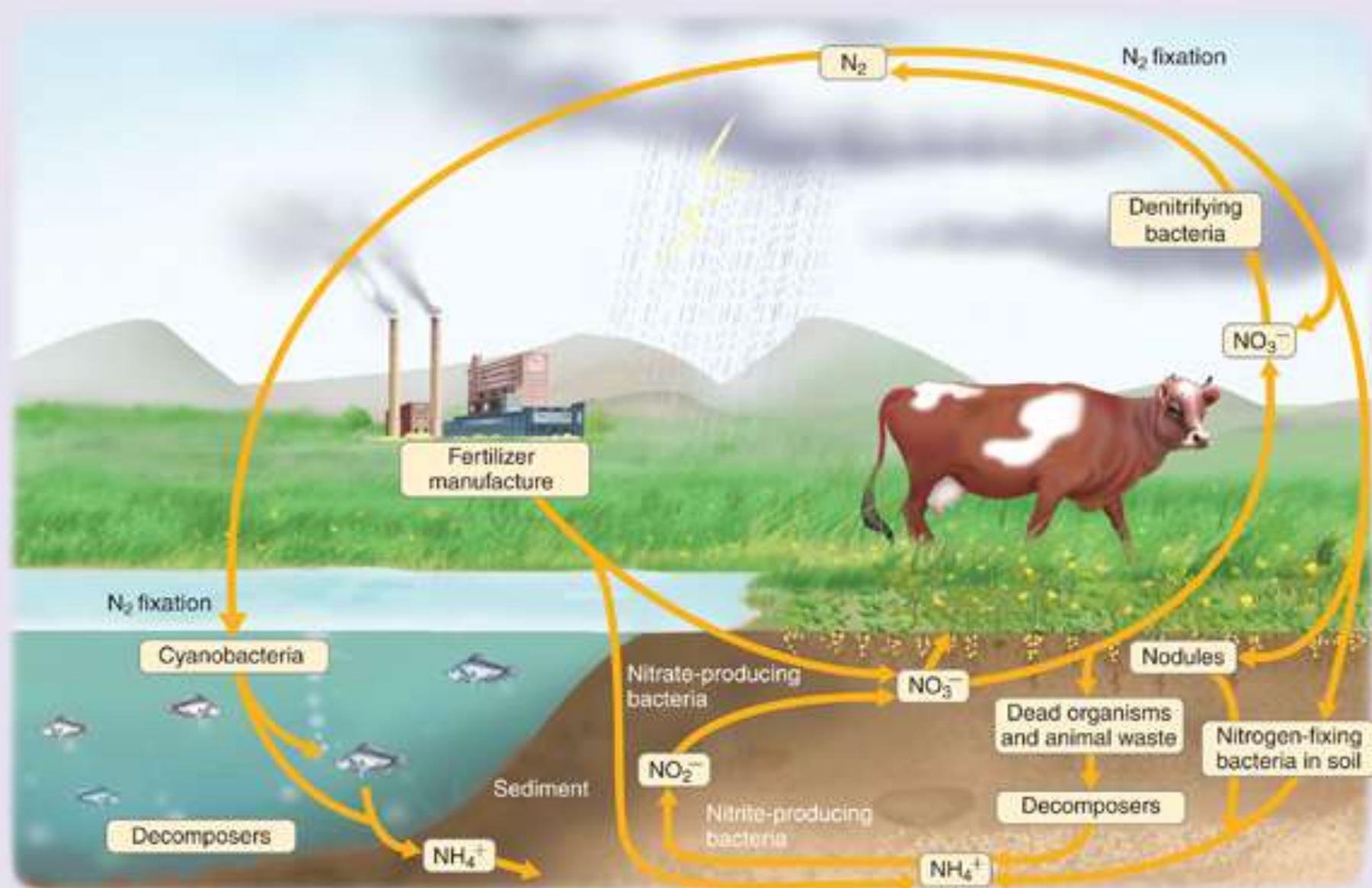
Root Nodules

- *Rhizobium* bacteria form symbiotic relationships with roots
- Legume produce nodules with *Rhizobium* inside, site of nitrogen fixation



Formation of Root Nodule





Box Figure 13.1 The nitrogen cycle. Nitrogen is cycled through the environment via the actions of microorganisms. Nitrogen-fixing cyanobacteria and bacteria, free-living or associated with legumes, convert nitrogen gas into ammonium (NH_4^+). Bacteria and other microorganisms decompose dead organisms and animal wastes, releasing ammonium. Other bacteria convert ammonium into nitrite (NO_2^-) and nitrate (NO_3^-).

Soil Inoculant



Legumes as fertilizer

- Because of nitrogen fixation in root nodules, legumes enrich the soil
 - Farmers often rotate legumes with crops that deplete soil nitrogen (soybean & corn)
 - "Green manure" crops plowed sometimes
 - Reduces need for fertilizers - even in poor soils
- *Azolla* water-fern also has a symbiotic association with a nitrogen-fixing cyanobacterium, used to fertilize rice paddies.

Nutritional Aspects

Nutritional value of legumes

- Legumes rich in protein (nitrogen).
- Many are in the 20-30% range.
- Legumes also contain some fats but usually less starches than cereal grains.



Split
Peas

Nutrition Facts	
Serving Size 1/3 cup (65g)	
Servings Per Container	
Amount Per Serving	
Calories 80	Calories from Fat 0
<hr/>	
% Daily Value*	
Total Fat 0g	0%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 0mg	0%
Total Carbohydrate 14g	5%
Dietary Fiber 5g	20%
Sugars 2g	
Protein 5g	
<hr/>	
Vitamin A 0%	• Vitamin C 0%
Calcium 0%	• Iron 4%
*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:	
	Calories: 2,000 2,500
Total Fat	Less than 65g 80g
Saturated Fat	Less than 20g 25g
Cholesterol	Less than 300mg 300mg
Sodium	Less than 2,400mg 2,400mg
Total Carbohydrate	300g 375g
Dietary Fiber	25g 30g
<hr/>	
Calories per gram:	
Fat 9 • Carbohydrate 4 • Protein 4	

Nutritional value of legumes

- Amino acid composition different from that of cereal grains.
- Legume seeds have more of some amino acids than cereal grains. Need to combine with grains to get complete protein
- Seeds of almost all legumes are toxic if eaten uncooked because of proteins or peptides that inhibit digestive enzymes.

Important points

- Legumes fix nitrogen
- Legumes rich in protein
- Legumes easily stored and harvested

Maize and Beans - Complementary

- Traditional staples in Central and South America
- *Nutritionally complementary*
 - Beans rich in amino acids deficient in corn and vitamin niacin
 - Corn rich in amino acids deficient in beans
- *Ecologically complementary*
 - Poly-cropping
 - Crop rotations
 - Well adapted to low inputs



Essential amino acids

- Not manufactured by body
- Must be consumed in diet

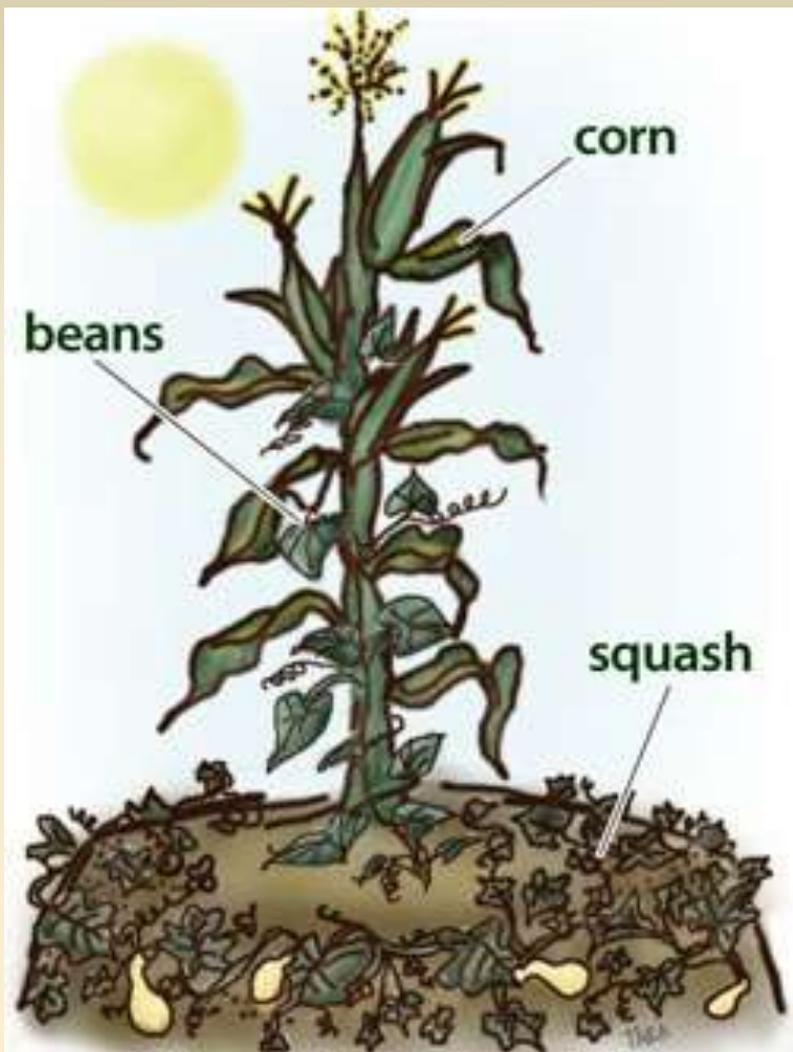
Red: low in grain, high in beans

Green: high in grain, low in beans



- isoleucine
- leucine
- tryptophan
- lysine
- methionine
- phenylalanine
- threonine
- valine
- histidine

Companion Planting – the 3 Sisters – corn, beans, squash



*Direct-Sow, Easy-to-Grow:
The Ancient **Three Sisters** Method*



A Poisonous Legume



Abrus precatorius – Precatory Bean



Abrin – toxin, one of most toxic substances known

1 crushed seed can be fatal if ingested

Domestication of legumes

- At first, wild small-seeded legumes consumed.
- Lentils are one of oldest domesticated legumes
- By 6000 B.C., lentils, peas, vetch (*Vicia* sp.), bitter vetch (*Vicia ervilia*), and garbanzos were already cultivated.
- In Africa *Vigna* by 2000 B.C.
- In the Americas, *Phaseolus coccineus* in Tamps., Mexico, by 5000 B.C. wild harvested.

Domestication of legumes

- By 4000 B.C., *P. vulgaris* and *P. lunatus* were cultivated in Peru.
- Many domesticated legumes have lost the ability to reseed themselves.
- Pods of cultivars are indehiscent (hold their seeds).

Domestication of legumes

centers of origin

- Near East and Europe: peas, broad beans, lentils, and garbanzos.
- New World: common beans, lima beans, and peanuts
- South East Asia and China: soy beans, mung beans (*Vigna aureus*) and adjuki bean (*Vigna mungo*).
- Africa: black-eyed pea, pigeon pea.

Legumes – Changes Under Domestication

1. Annual habit, selfing breeding system
2. Less seed scattering
3. Greater seed size
4. Synchronous fruiting
5. Loss of dormancy



- question: which came first, domestication or loss of dormancy?

Recent studies – no common set of “domesticated genes”

Beans



Black Turtle Beans, Cannellini Beans, Flageolet Beans, French Navy Beans, Great Northern, Green Split Peas, light Red Kidney Beans, Pinto Beans, Cranberry Beans, and Yellow Split Peas.

Beans and peas -- Pulses

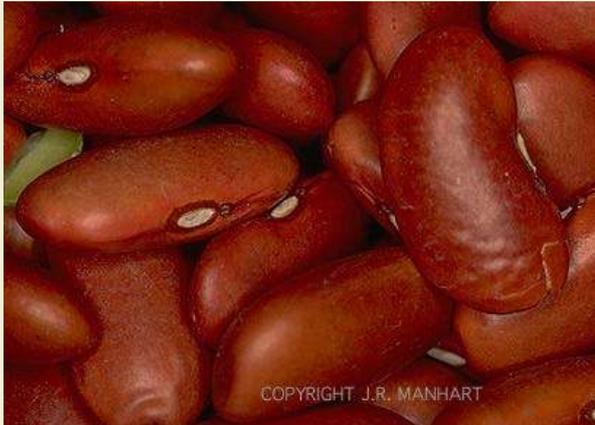
- Some of the oldest and most common food crops
- Good source of protein average about 25% for beans and 21% for peas
- Traditionally cultivated for dry seeds
- Some varieties today have edible pods
- Beans warm season annuals
- Peas grown during the cooler seasons

Common Edible Beans & Peas

- Black-eyed peas
- Butter beans
- Chick peas
- Fava (broad) beans
- Green beans
- Green peas
- Kidney bean
- Lentils
- Lima beans
- Mung beans
- Navy bean
- Pinto beans
- Snow peas
- Split peas
- Wax bean

Beans, Beans, Beans

Selection for the variations in the seed in color and size have produced a bewildering number of variants, several of which have widespread use in our country.



Kidney bean



Black bean



Pinto bean

Common beans - *Phaseolus vulgaris*

- Kidney beans, pinto beans, navy beans, black beans, green beans, wax beans, and snap beans are all *Phaseolus vulgaris*.
- Domesticated in Mexico and South America.
- Domesticated several times.
- Fossil cultivated beans go back 7000 years in Mexico and almost as far in Peru.

Navy Beans – *Phaseolus vulgaris*

- Frequently served to sailors at sea
- Small in size and compatible in flavor and texture.
- Baked beans, soups, salads, casseroles, or ethnic dishes



Pinto Beans – *Phaseolus vulgaris*

- “Pinto” means painted in Spanish
- Get their name from their mottled beige and brown skin
- Staple in the diets of Mexico and the American Southwest.
- Found in stews, chili, refried beans, and dips



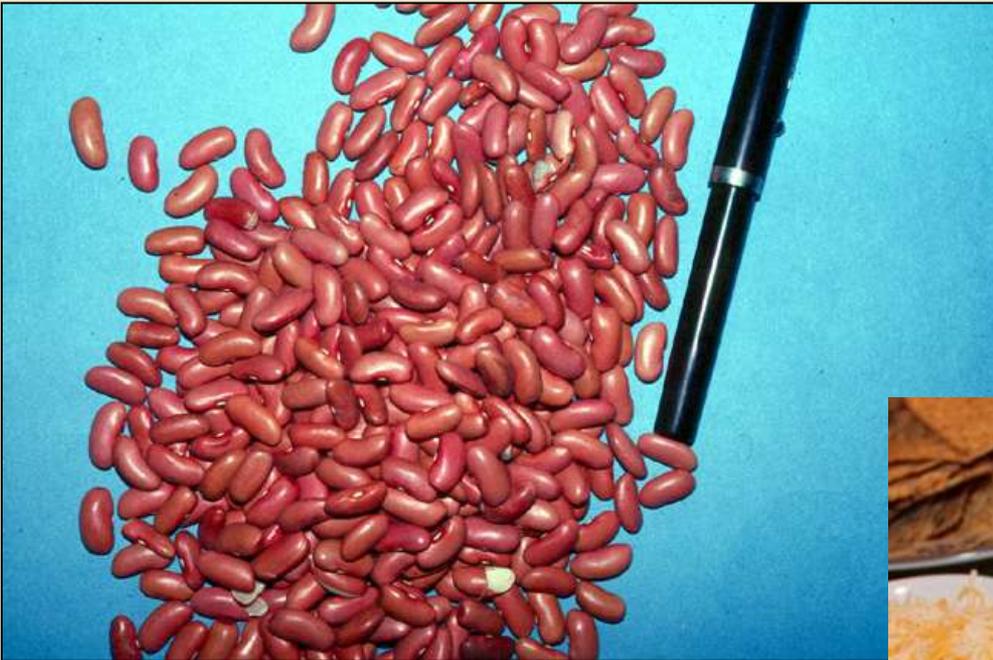
Black Turtle Beans – *Phaseolus vulgaris*

- Medium to small, with a shiny black coat or skin, small white eye or spot , a creamy white interior,
- Pleasant “earthy” flavor
- Color retained when cooked.
- Native to South and Central America
- Popular in southern U.S.
- Served with rice, in salads, dips, stews, and thick soups, especially in Cuba, Puerto Rico, Brazil, and Spain.



Kidney beans – *Phaseolus vulgaris*

- Common in chili
- Most consumed legume in the U.S.



Butter beans, Lima bean, *Phaseolus lunatus*

- Usually tropical perennials
- Independently domesticated in Mexico and South America
- Oldest cultivated from Peru (7000-10,000 years old).
- Cultivated from Canada to Argentina in 1492
- Some varieties with toxic cyanide unless cooked properly (not in the U.S. and Europe)



Peas (*Pisum sativum*)

- “Peas” actually a variety of different kinds. Green peas, lentils, black-eyed peas, chick peas, snow peas.
- An extremely old crop from the Near Eastern center. Go back at least 9000 years.
- They may have also come from Ethiopia and Central Asia.



Peas - *Pisum sativum*

- In the Middle Ages in Europe, dried peas made up a major part of the diet of peasants.
- Still very important there, especially in Eastern Europe.
- People didn't eat "green peas" until about the 1700's.
- Peas are the fourth most important legume crop world wide.



XVII, 3. *M. Leguminosae.*

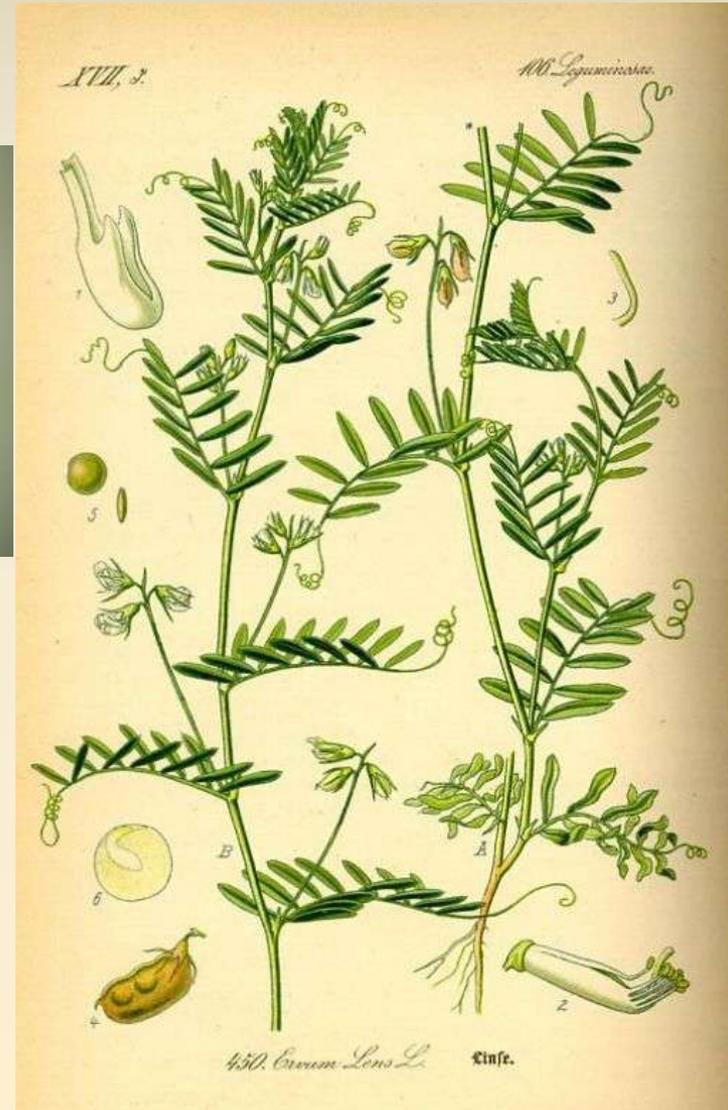
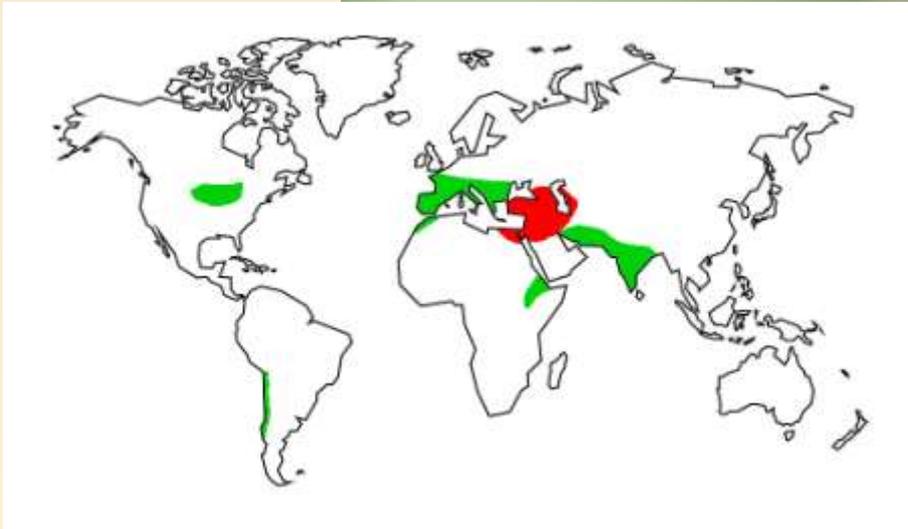


Pisum sativum L. Bredt-Erbse.



Lentils - *Lens*

Lens culinaris – genus name refers to shape of seeds



Lentils - *Lens culinaris*

- Among the most ancient of cultivated crops.
- 8000-9000 years in the Near East.
- Lentils found in archaeological sites before that, but as is the case for cereal grains, it is difficult to sort out what is cultivated and what is not.
- By 2200 B.C., they appear in Egyptian tombs.



Lentils - *Lens culinaris*

- Lentils especially high in protein.
- Lentils drought resistant.
- Lentils particularly important in India today. Many different kinds of "dhal".
- In the U.S. mostly cultivated in Washington and Idaho in the Palouse Prairies.



Broad Beans – *Vicia faba*

- Native to North Africa, southwest and south Asia,
- Extensively cultivated elsewhere.
- Among the most ancient plants in cultivation, 8,800 years.
- Major food of old Mediterranean civilizations, particularly for the Romans and Ancient Greeks
- Favism – type of anemia, common in Mediterranean people, aggravated in susceptible individual by *Vicia* alkaloids



Fava Beans – with tomato, bacon, in salads



Garbonzos, Chick-Peas – *Cicer arietinum*



Hummus



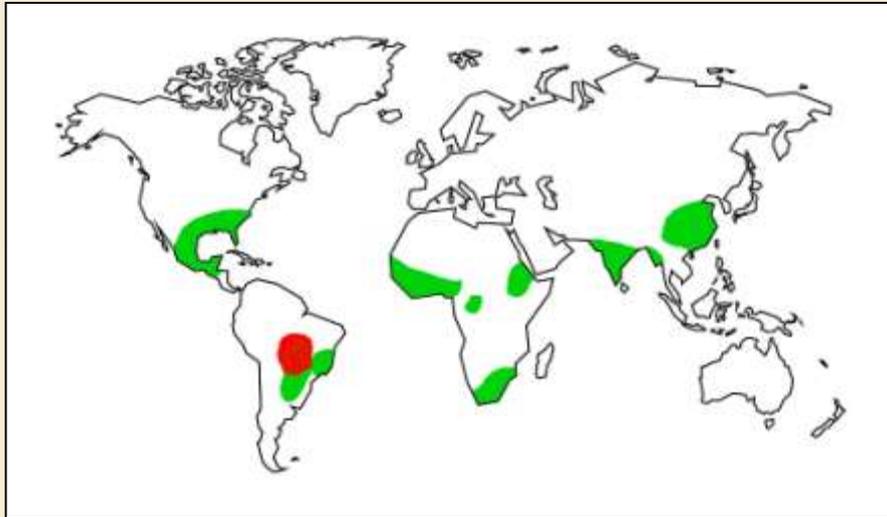
Falafel



Peanuts

Peanut

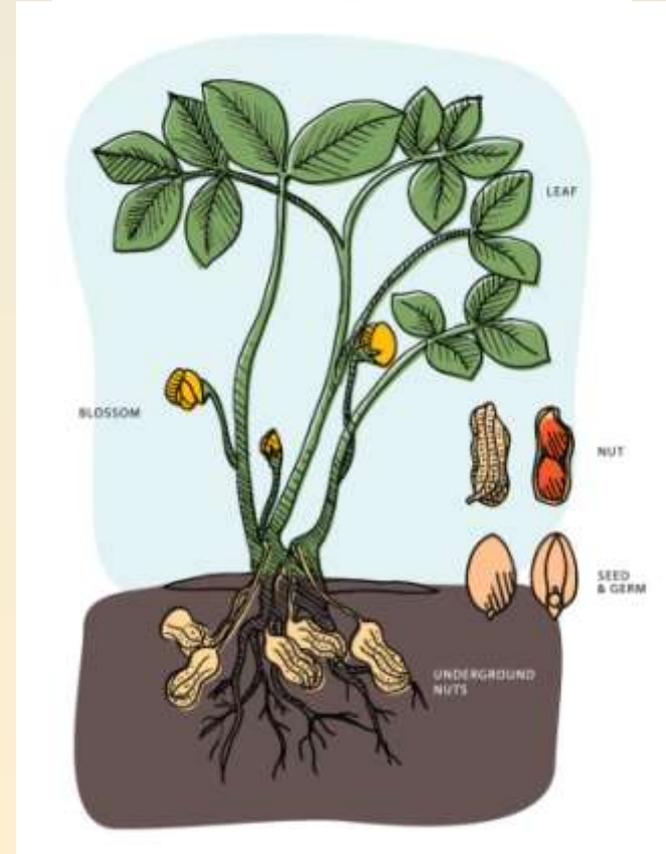
- *Arachis hypogaea*
- peanut, ground nut, goober
- central South America



Arachis hypogaea L.

Peanut - *Arachis hypogea*

- Also called goobers and groundnuts
- Unusual plant
- After pollination the flower stalk grows downward pushing the developing fruit into the soil
- Fruit matures underground - typically with two seeds (peanuts)



The Underground Crop

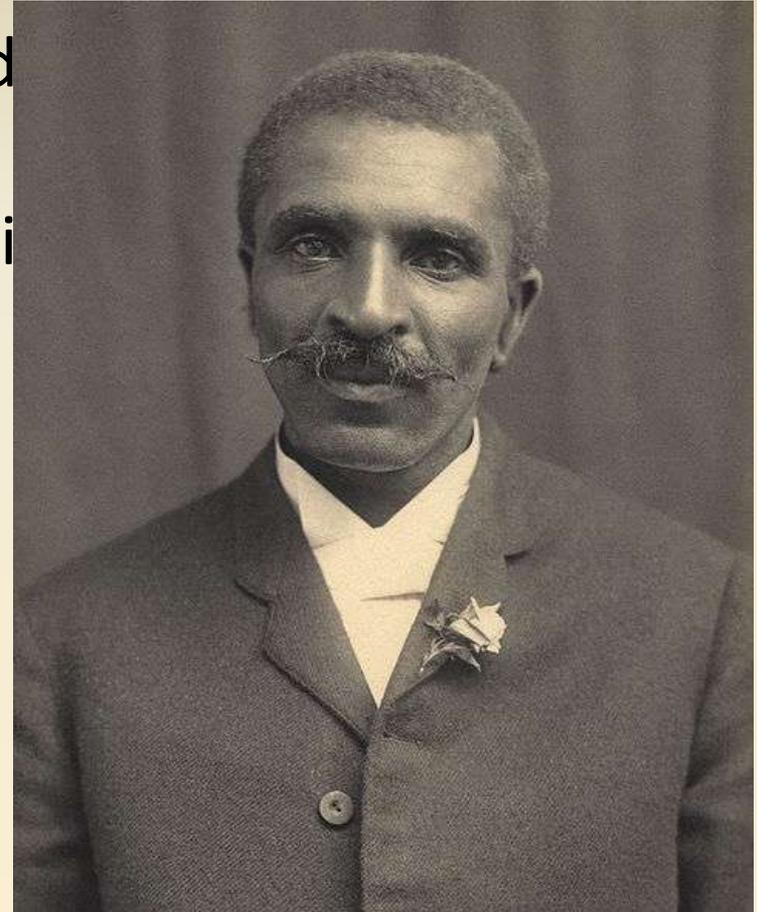


Peanut - *Arachis hypogaea*

- Originated in Peru; > 15,000 varieties
- Flowers above ground, after pollination the flower stalk pushes the fruit into the soil, fruit matures underground into a pod. Seed has two large cotyledons.
- Seed contains 45%-50% oil, 25%-35% protein.
- 50% of U.S. crop used for peanut butter.
- Promoted by George Washington Carver to reinvigorate southern agriculture after the Civil war.

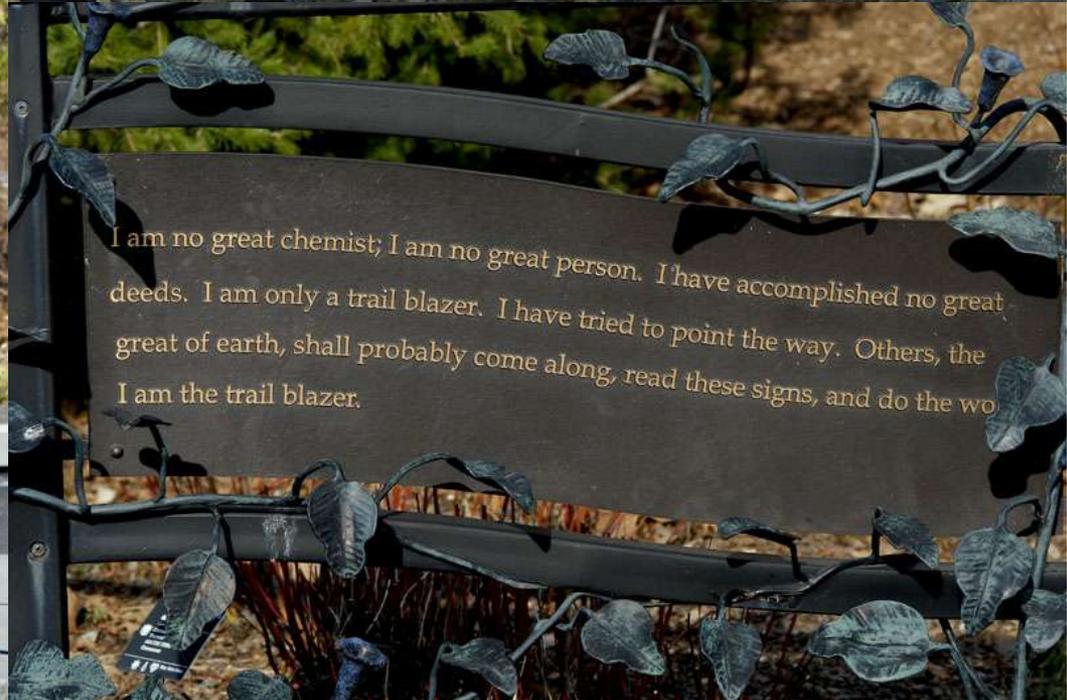
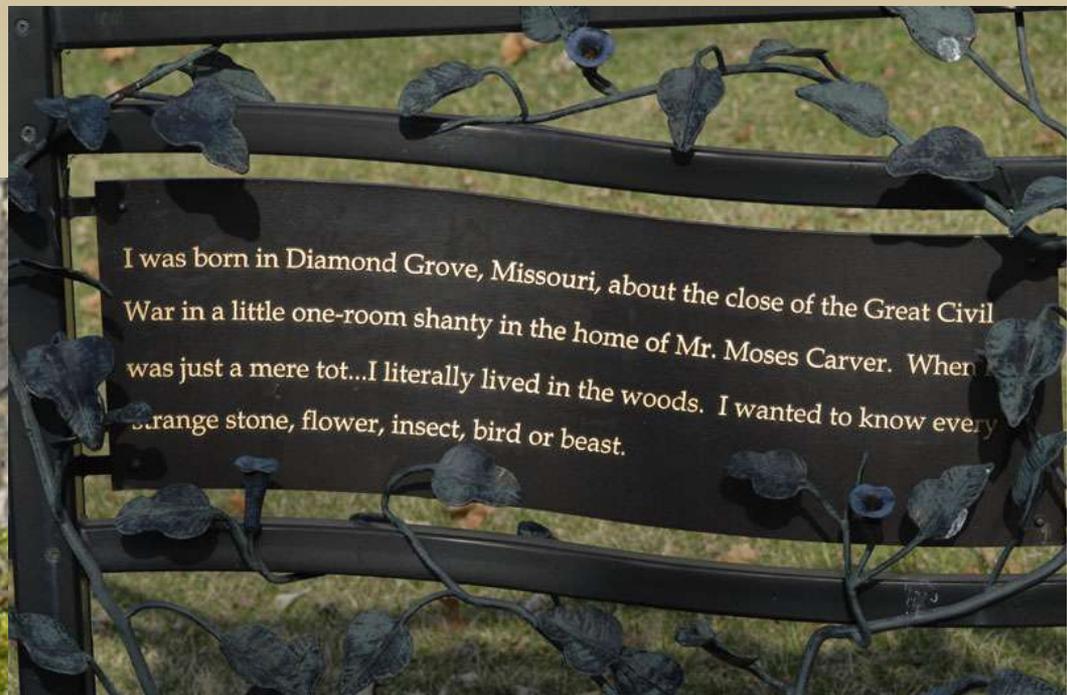
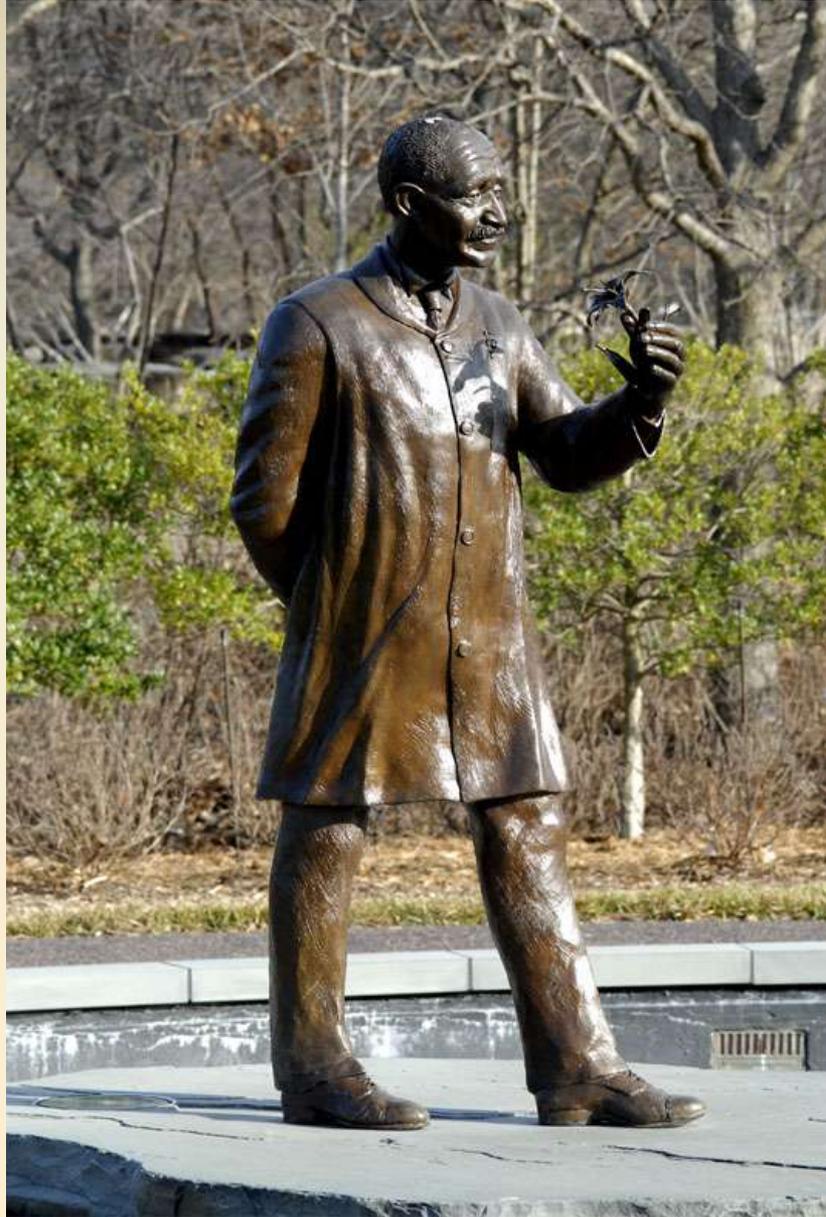
George Washington Carver - (1864-1943)

- American botanist, chemist, and inventor.
- Born into slavery in SW Missouri
- College professor, Tuskegee, Alabama
- Revolutionized Southern Agriculture
 - crop rotation methods
 - agricultural products
- Philanthropist and Role model



George Washington Carver

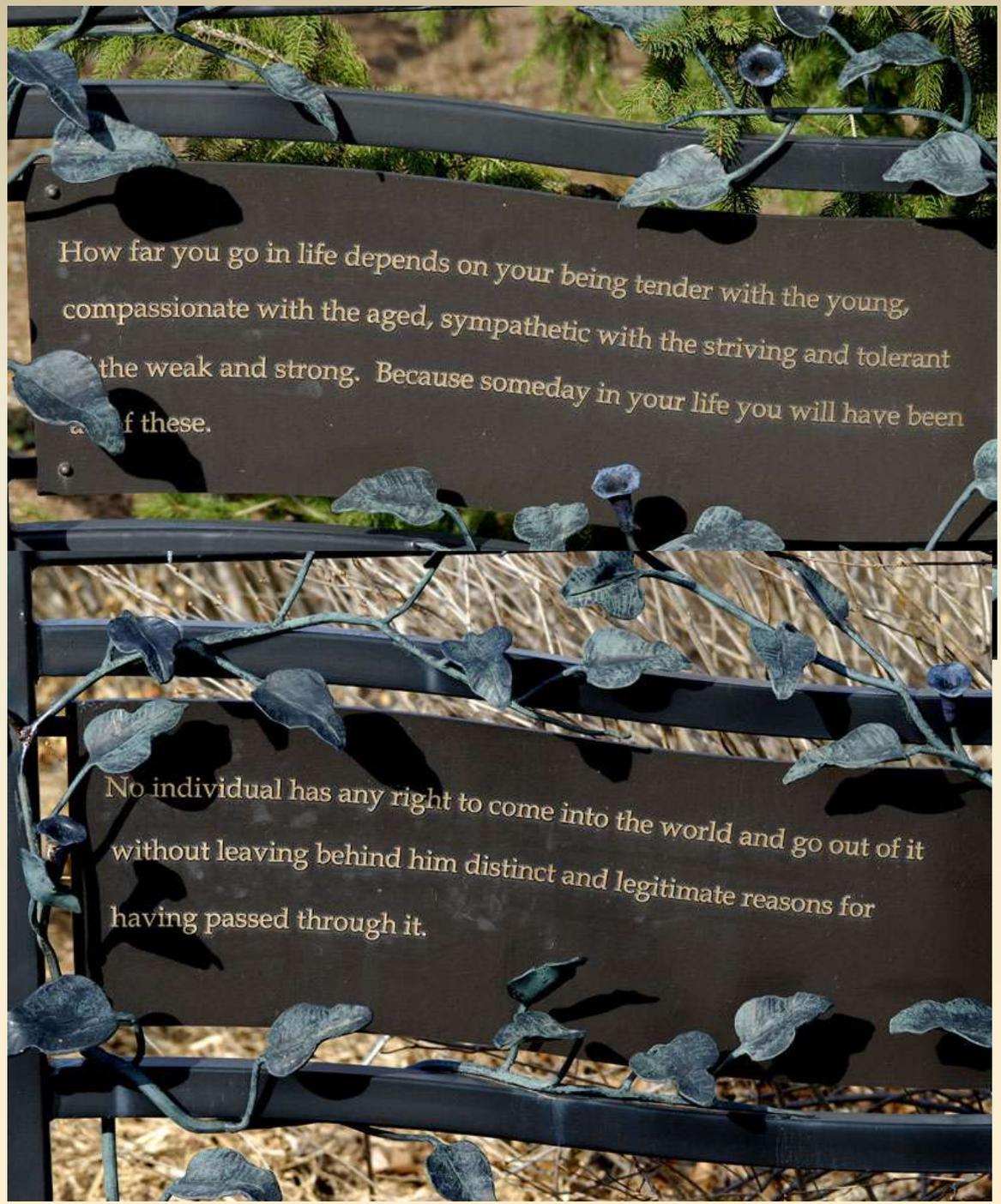
MBG



G.W. Carver

"Ninety-nine percent of the failures come from people who have the habit of making excuses."

"There is no short cut to achievement. Life requires thorough preparation - veneer isn't worth anything."



Versatility of the peanut

- George Washington Carver (1864-1943)
 - Developed over 300 food and industrial uses for the peanut
 - Encouraged its cultivation in the South
 - Revitalized Southern agriculture exhausted by years of cotton cultivation
 - Also introduced other soil-enriching legumes like soybean

Peanut oil

- Found in margarine, shortening, salad dressing, and cooking oil
- Soaps, cosmetics, and shaving cream
- Industrial products such as plastics and paints
- Pressed cake that remains after the extraction of oil is used as a high protein livestock feed

Peanut Production

- US is the world's third largest producer, after China and India. The
- US is one of the world's leading peanut exporters
- In 2012, 49% of US peanuts production, in pounds, occurred in Georgia.
- In 2012, the US produced over 6.7 billion pounds of peanuts



Soybean - *Glycine max*

- Relatively new to the West but used in the Orient for centuries
- Domesticated in northern China at least 3000 years ago
- Although soybeans were introduced to Europe quite early, they never became popular.
- In Pennsylvania by 1804. Benjamin Franklin was sent a sample of seeds and both he and Thomas Jefferson grew them.
- Until 1940's never common in the United States.

Soybean harvest



soybeans



Soybeans - *Glycine max*

- About 38% protein and 18% fats and oils.
- Higher protein content than beef
- The amino acid content is especially good.
- Serve as a source of edible oils.
- In the Orient, soybeans are eaten in many different ways.
- Converted to miso, tofu, soy milk, soy sauce, curd, cheeses, and greens (sprouts).

Soybean Products



Oriental Foodstuffs: Miso, Tofu, Tempeh, Soy Milk, Soy Sauce

Soybean Oil – widely used

Soy proteins – added to many products

Soy lecithin – widely used in chocolate products

Non-food uses - inks, plastics, cleaners



Soymilk

- 32 mg DHA Omega-3 per serving
- 7 grams of heart-healthy soy protein
- Excellent source of calcium
- 100% cholesterol-free
- Low in saturated fat
- Free of dairy, lactose, gluten, casein, egg and MSG
- Verified Non-GMO
- No artificial colors, flavors or funny business



Nutrition Facts

Serving Size 1 Cup (240mL)
Servings Per Container 8

Amount Per Serving

Calories 100 **Calories from Fat 40**
% Daily Value*

Total Fat 4g **7%**

Saturated Fat 0.5g **3%**

Trans Fat 0g

Polyunsaturated Fat 2.5g

Monounsaturated Fat 1g

Cholesterol 0mg **0%**

Sodium 125mg **5%**

Potassium 370mg **10%**

Total Carbohydrate 7g **2%**

Dietary Fiber 2g **6%**

Sugars 5g

Protein 7g **14%**

Vitamin A 20% • Vitamin C 35%

Calcium 40% • Iron 6%

Vitamin D 30% • Vitamin E 20%

Riboflavin 30% • Vitamin B6 25%

Folate 10% • Vitamin B12 50%

Phosphorus 10% • Magnesium 10%

Zinc 10%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:
Calories: 2,000 2,500

Total Fat Less than 65g 80g

Sat Fat Less than 20g 25g

Cholesterol Less than 300mg 300mg

Sodium Less than 2,400mg 2,400mg

Potassium 3,500mg 3,500mg

Total Carbohydrate 300g 375g

Dietary Fiber 25g 30g

Protein 50g 65g

Calories per gram:

Fat 9 • Carbohydrate 4 • Protein 4

We work hard to keep the information on this website up-to-date, but please check the label on your product for the most current nutrition facts.

Soy milk

- raw soy beans soaked overnight then drained.
- beans pulverized as boiling water poured over them.
- resultant mash will have the consistency of mashed potatoes.
- mash is ladled into boiling water, like dumplings, and allowed to boil gently for about 10 minutes.
 - CRUCIAL STEP: certain enzyme in the bean is broken down during this time. If the enzyme is not destroyed, the Soy protein will not be humanly digestible.
- resulting slurry is filtered. The liquid is Soy Milk, and the pulp is called Okara.
 - Okara is good for mixing with flour to make bread, feeding to the pigs, or fertilizer.

Tofu



- Excellent source of protein
- Low in calories and sodium
- Cholesterol-free
- Great source of calcium and iron



Tofu - soy curd

- Boil soymilk for 5 to 10 minutes. Cool down to about 170 to 180 degree F.
- Prepare coagulant
 - Calcium sulfate or magnesium chloride
- Pour the prepared coagulant solution slowly into the soymilk while gently stirring the soymilk.
- Transfer coagulated dispersion into a mold lined with cheesecloth.
- Store in cold water, change soaking water daily.

Other soybean foods

- **Miso** - (from Japan) prepared from soybeans, salt, and rice; fermented by fungi for a several months and then ground into a paste and used as a spread, in soups, etc
- **Tempeh**- (from Indonesia) fermented soybean cakes made by inoculating parboiled soybeans with a fungus and allowing it to grow for a few days. The fungal mycelium binds the soybeans together into a cake which can be sliced and cooked in various ways



More Soy Products

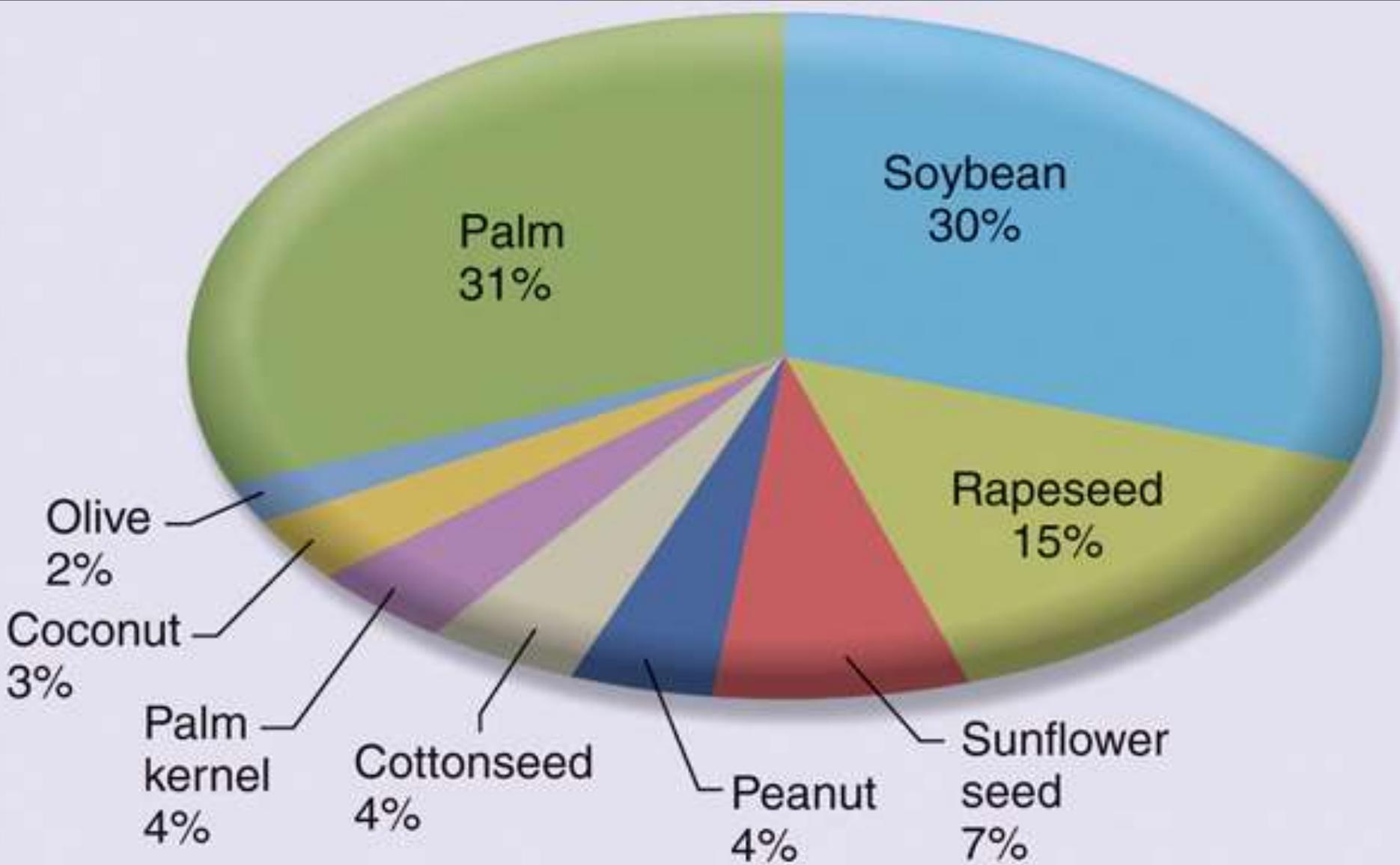
- Textured vegetable protein (TVP)
 - Produced by spinning the soy protein into long slender fibers
 - Picks up flavors from other substances
 - Made into imitation meats and used as meat extenders
- Lecithin - common food additive
 - Lipid extracted from soybeans
 - Stabilizes and extends the shelf life
 - Added to packaged foods - cake mixes, instant beverages, whipped toppings, and salad dressings

Soybean oil

- Food uses
 - Cooking oil, salad oil, margarine, shortening, and prepared salad dressings
 - Americans consume almost 6 gallons per year
- Industrial uses
 - Paints, inks, soaps, cosmetics, biodiesel fuel
 - Soybean-based "plastic" car body built by Henry Ford in 1940



Are GMOs 100% natural?



Box Figure 13.2 World consumption of major vegetable oils, 2008.

Carob

Ceratonia siliqua

- Cultivated in the Near East for thousands of years.
- Fruits have long been used to feed livestock.
- Carob currently used as a chocolate substitute and as a source of "locust gum".
- Used as cocoa substitute, a natural sweetener, caffeine free, low in calories and fats.



Tamarind

- Tamarinds (*Tamarindus indica*) have been used in tropical Africa and Asia for thousands of years.
- The sticky pulp surrounding the seeds has a sour taste and is the part used.
- Used in many types of sauces, drinks, candy



Bentley and Trimen, Medicinal Plants

Tamarind



Lead tree - *Leucaena leucocephala*

- Mimosoid tree native to Mexico and Central America
- Fast-growing , 30 ft/year
- Widely planted around world for forestation
- Highly invasive in many countries
- Forms dense thickets



These trees less than 2 years old

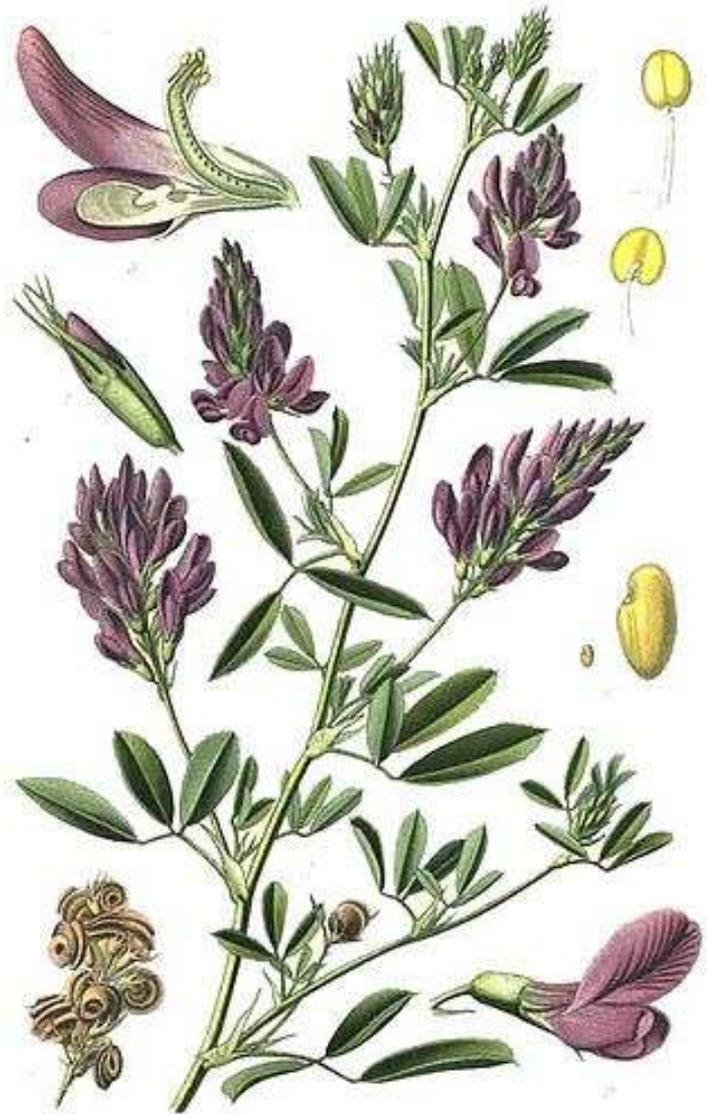
Alfalfa – *Medicago sativa*



Figure 13.10 Alfalfa (*Medicago sativa*) has been used as a forage since the days of the ancient Greeks and Romans.

Alfalfa – *Medicago sativa*

- Perennial forage legume
- Native to Persia
- The most cultivated forage legume in the world,
- Mostly northern and western US, 29 million acres in US alone
- Used as grazing, hay, silage
- Deep root system, resistant to drought
- Primary use is as feed for high-producing dairy cows
- GMO Round-up Ready approved by USDA



Pl. 75. Luzerne cultivée. *Medicago sativa* L.

End