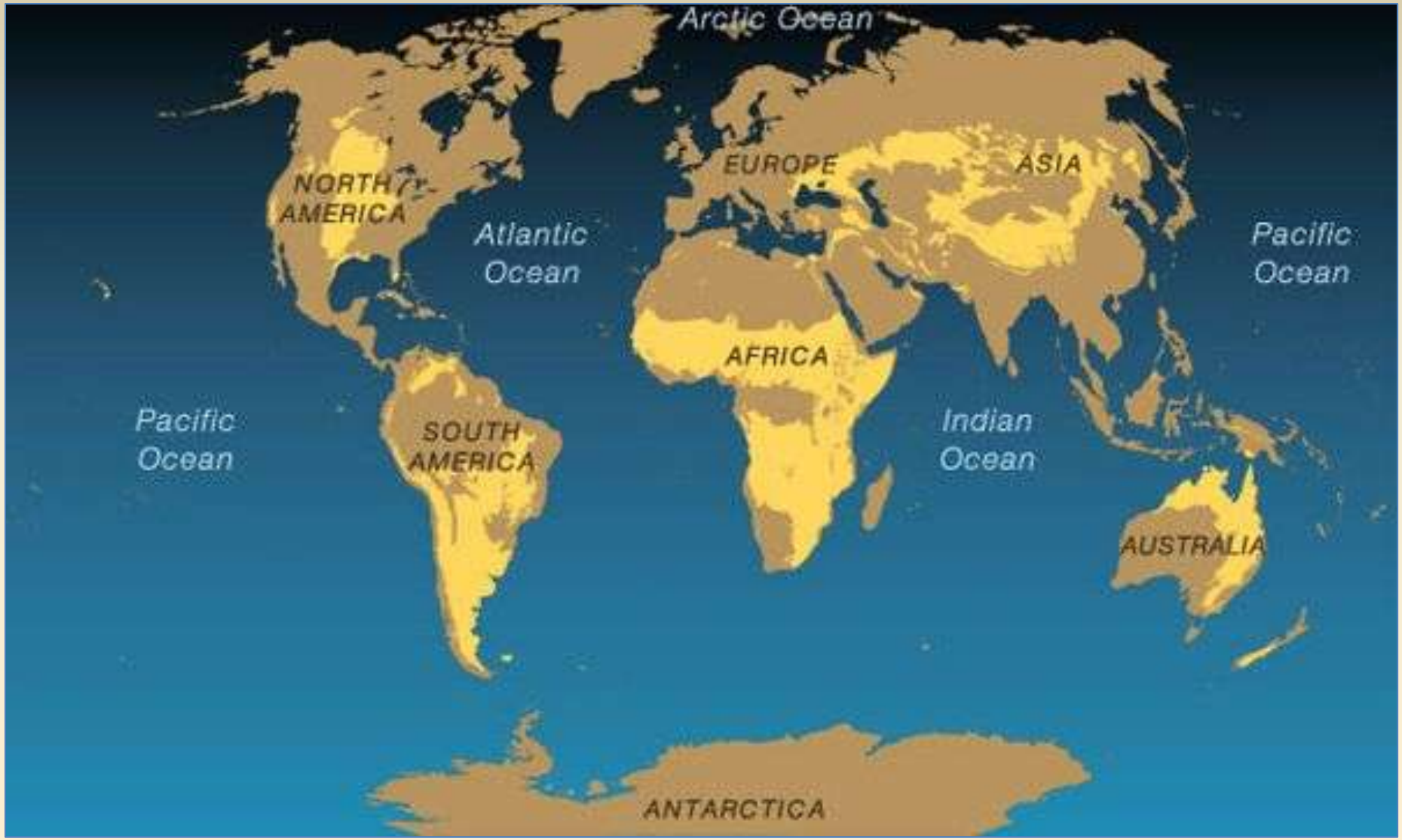
The Grasses

Figure 12.4 Wheat, one of the most widely cultivated cereals in the world.

Grasslands – Prairies, Steppe, Savanna

Grasslands of the World



Ceres - Cereals

Ceres (Greek Demeter) - ancient Roman goddess of the harvest, who presided over grains and the fertility of the earth.

Important features of cereals - sturdy plants, easy to grow, starch and protein content, dryness of grains for long storage, free from bitter tastes.

Grains - 10-16% protein, the rest is fiber and starch.

Grass Family - Poaceae

- 70% of farmland dedicated to this group
- More than 50% of the world's calories
- 9,000 species worldwide
- only about 35 species cultivated
- 3 major grains (wheat, rice, corn)
- Sugarcane, barley, sorghum, oats, rye
- Required for the formation of civilization?

Annual World Crop Production

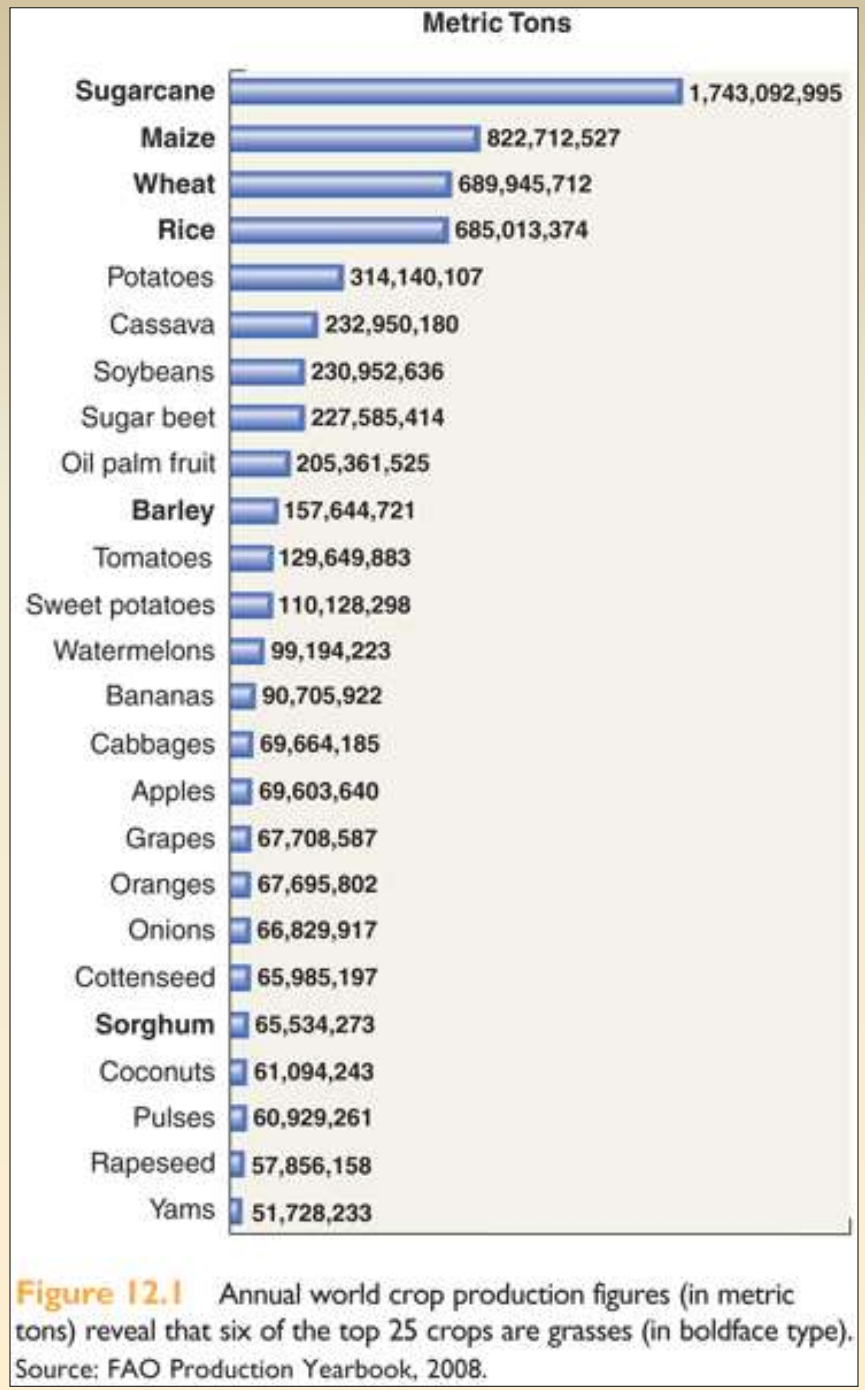


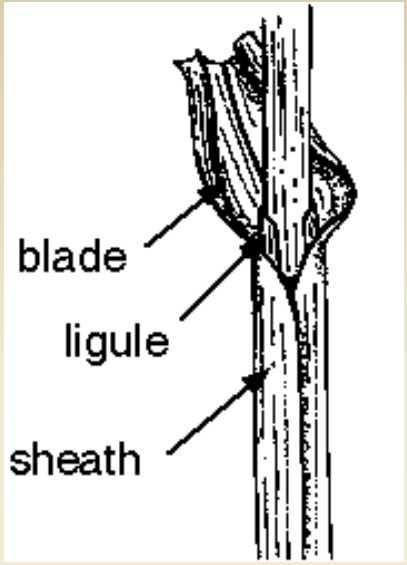
Figure 12.1 Annual world crop production figures (in metric tons) reveal that six of the top 25 crops are grasses (in boldface type).
Source: FAO Production Yearbook, 2008.

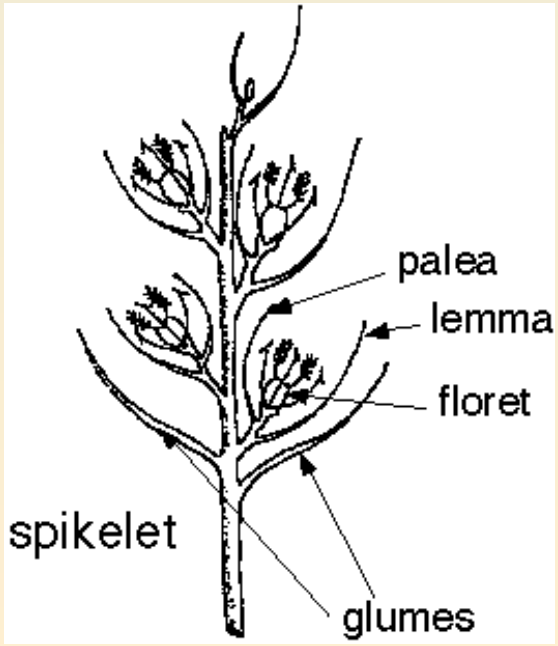
Grass family - Poaceae

- **Genera : 600 - 650**
- **Species: 7500 - 10,000**
- cereal crops (food & sugar)
- grazing/pasture/forage crops
- ornamentals
- building materials
- source for matting
- biofuels

What is a grass?

- Monocots, parallel-veined leaves
- Perennial or annual herbs (bamboos get woody and big)
- Stems erect, ascending, prostrate or creeping, round. Called culms.
- Leaves with open sheath, ligule, and blade, sheath encloses the stem
- Inflorescence spikes, racemes, panicles
- Flowers (florets) in spikelets, subtended by glumes
- Fruit a grain (caryopsis)





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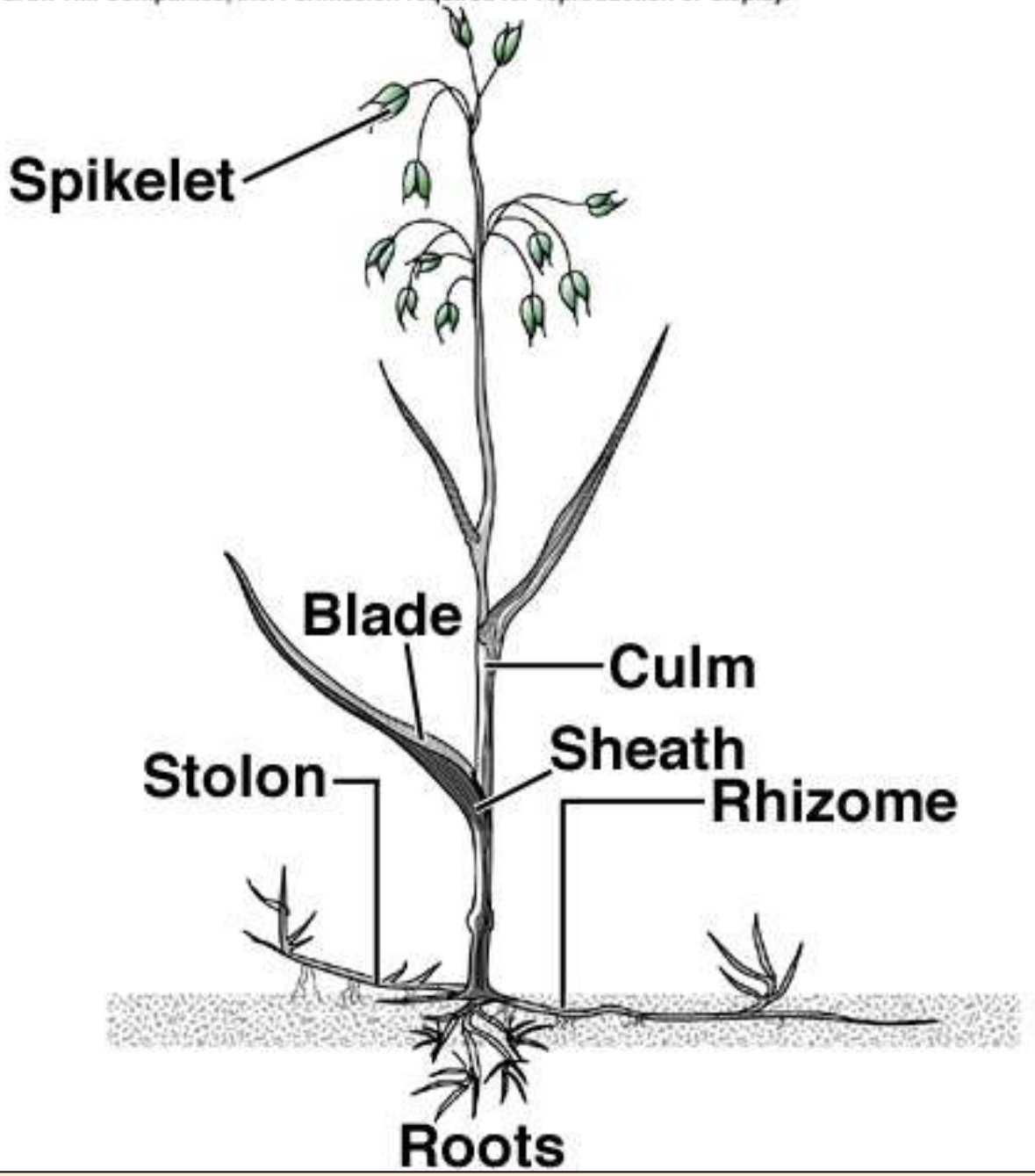
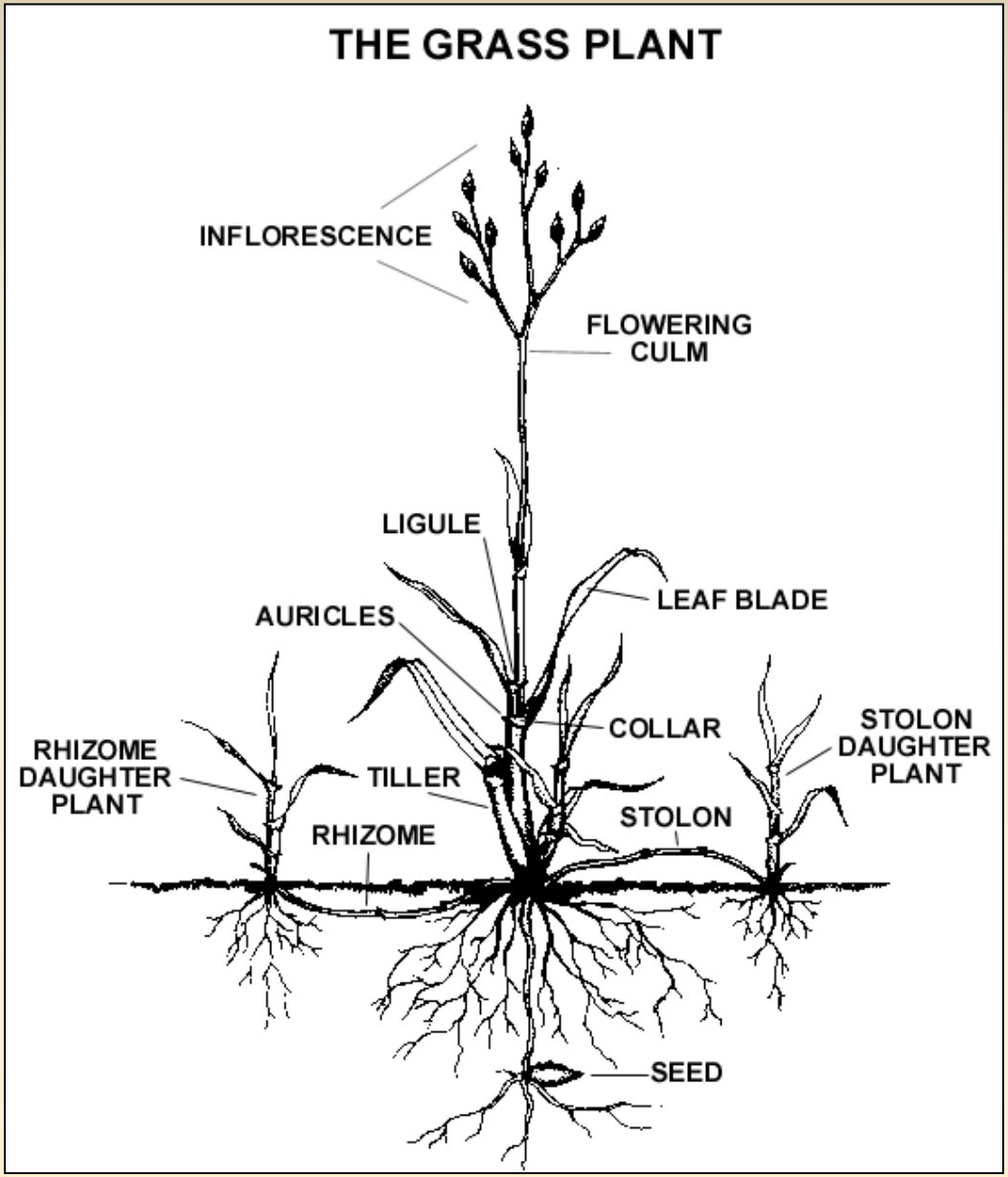
Typical Grass Plant



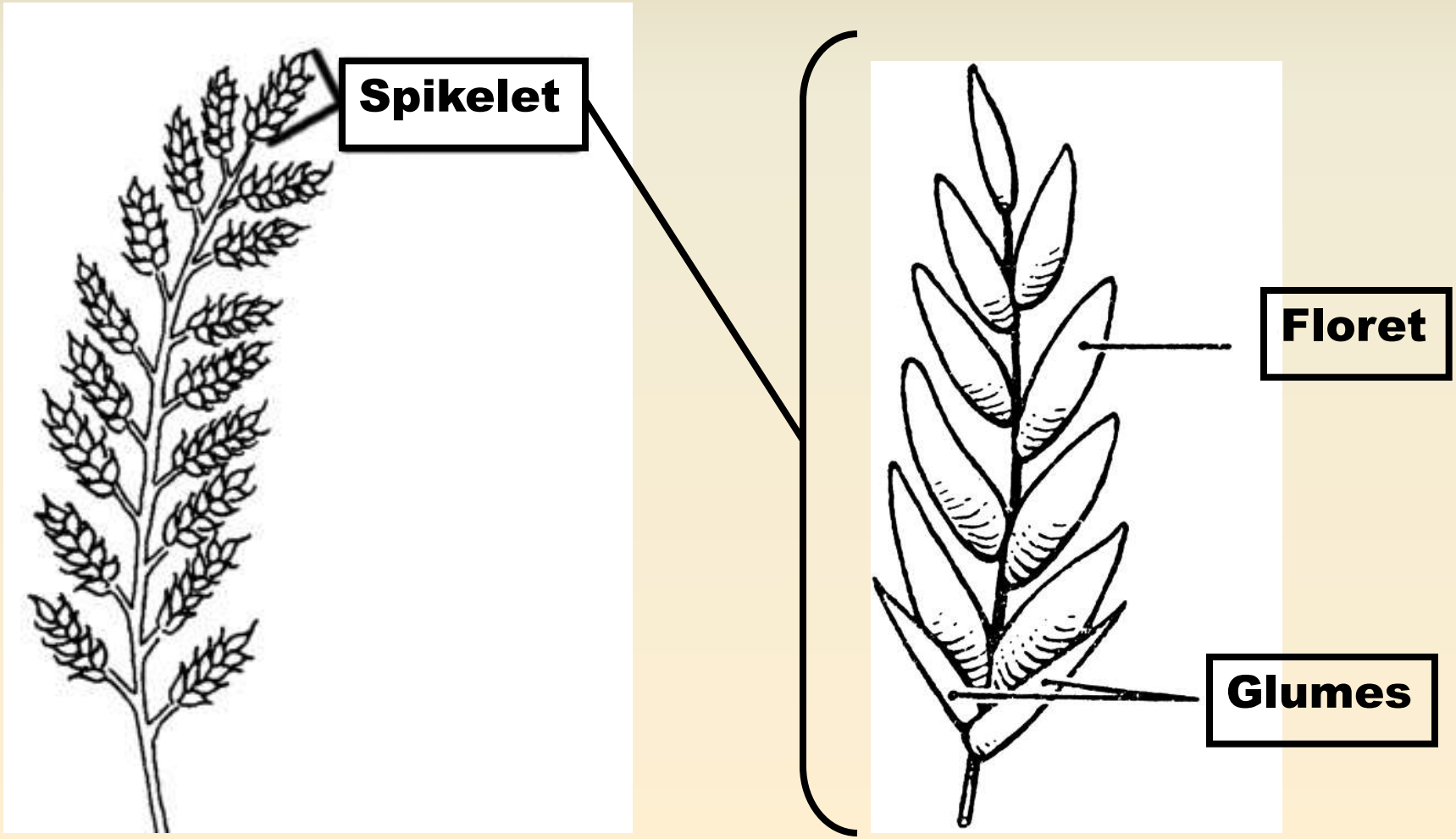
Grass vegetative structure

- Fibrous roots
- Leaves sheathing at base, wrap around stem
- Produce clones (tillers) from above-ground runners (stolons) or below-ground rhizomes



Grass Inflorescence - Spikelets

The **spikelet** is the basic unit of grass inflorescence, subtended by two sterile **bracts** known as **glumes**. The glumes define the spikelet, they and everything above them make up the spikelet



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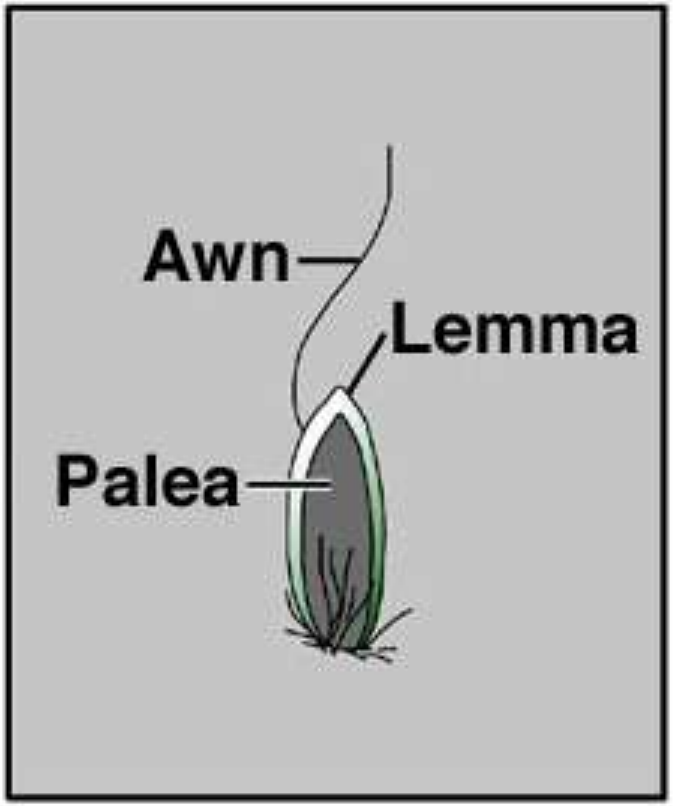
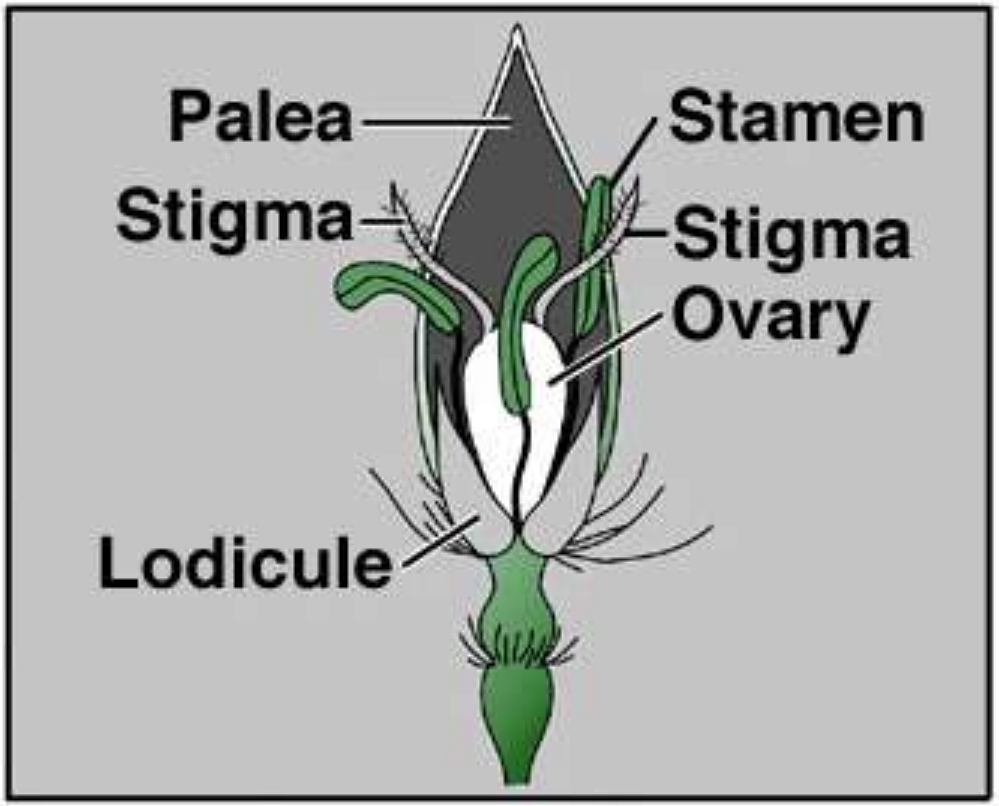
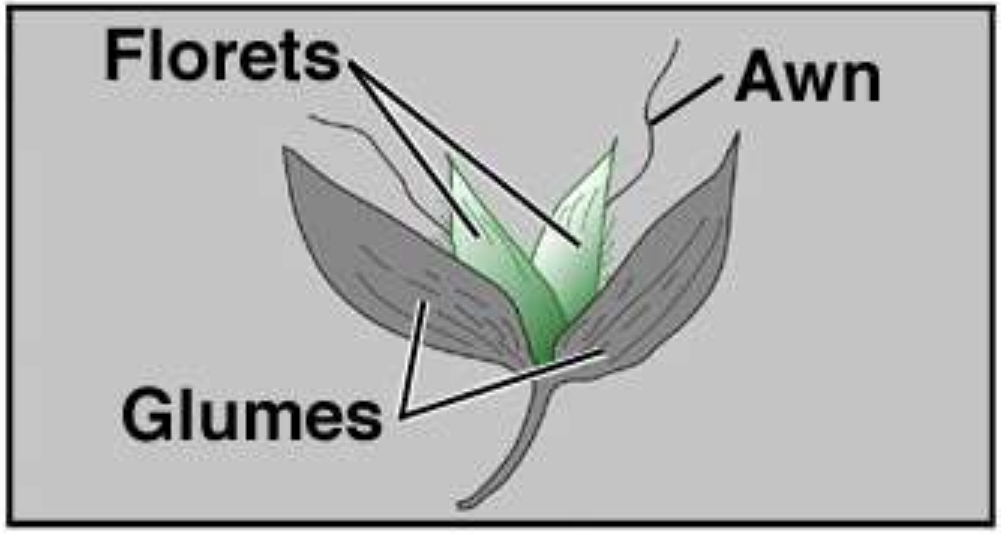
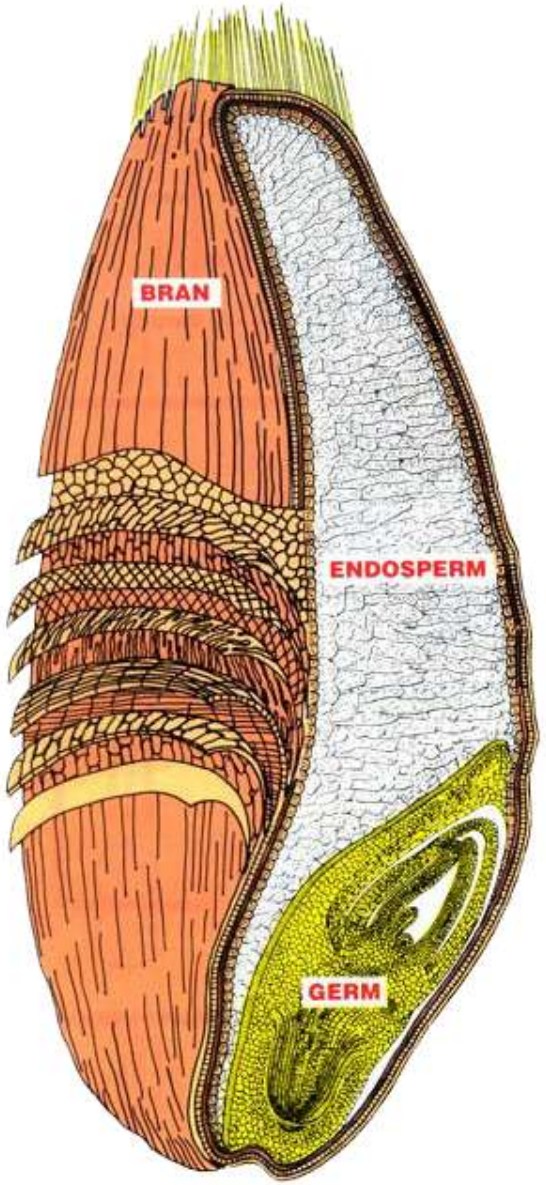




Grass Flower Parts

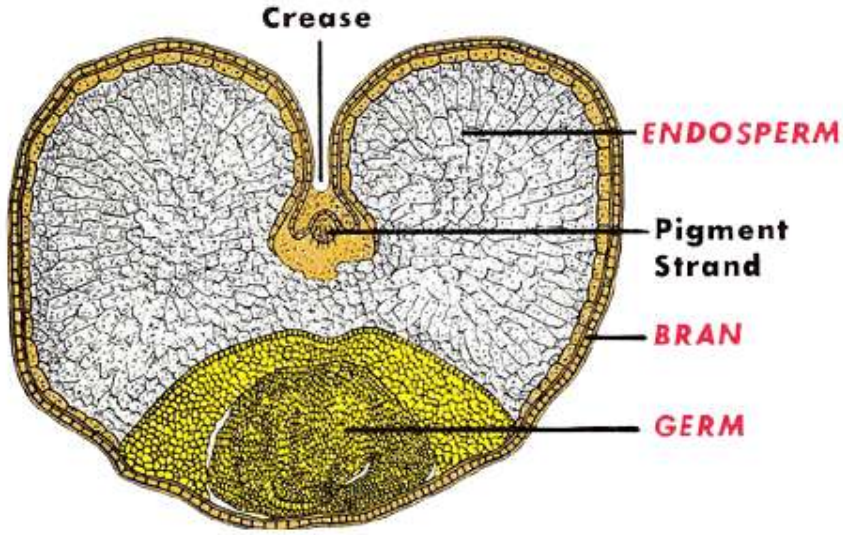


Grain Structure - Wheat



Bran

Fine white flour



Two Major Kinds of Grasses

Cool Season Grasses – C3 Pathway

- Initial compound in photosynthesis is a 3-carbon compound (3-PGA)
- No specialized anatomy, bundles small
- Photosynthesis less efficient at high temperatures
- Better adapted for cooler, temperate climates
- Frost tolerant, green up early and grow fast in spring
- e.g. Rye, Fescue, Bluegrass, Wheat

Warm Season Grasses – C4 Pathway

- Initial product of photosynthesis is a four carbon compound (oxaloacetate)
- Specialized thick walled bundle sheath cells, where most of the photosynthesis takes place (Kranz Anatomy)
- More efficient under high heat and light conditions than C3
- Common in tropics and other warm areas.
- Grow fast in warm summer months
- e.g. Corn, Sorghum, Millet, Sugarcane, Prairie Bluestems, many weeds

Major Grass Grain Crops

- Wheat (C3)
- Corn (Maize) (C4)
- Rice (C3)
- Barley (C3)
- Sorghum (C4)
- Oats (C3)
- Millet (C3 & C4; different species)
- Rye (C3)
- Triticale (wheat & rye hybrid; C3)

Wheat - *Triticum*

Wheat

-Most widely-cultivated cereal.

-Does best in temperate grassland biomes. (i.e., on the cool & dry side). C3

-Origin is Near-East ca. 10,000 years ago.

-Top producers: U.S., Canada, Ukraine, China, India, Argentina, France.

-Relatively better nutritionally than corn & rice (more protein & other nutrients).

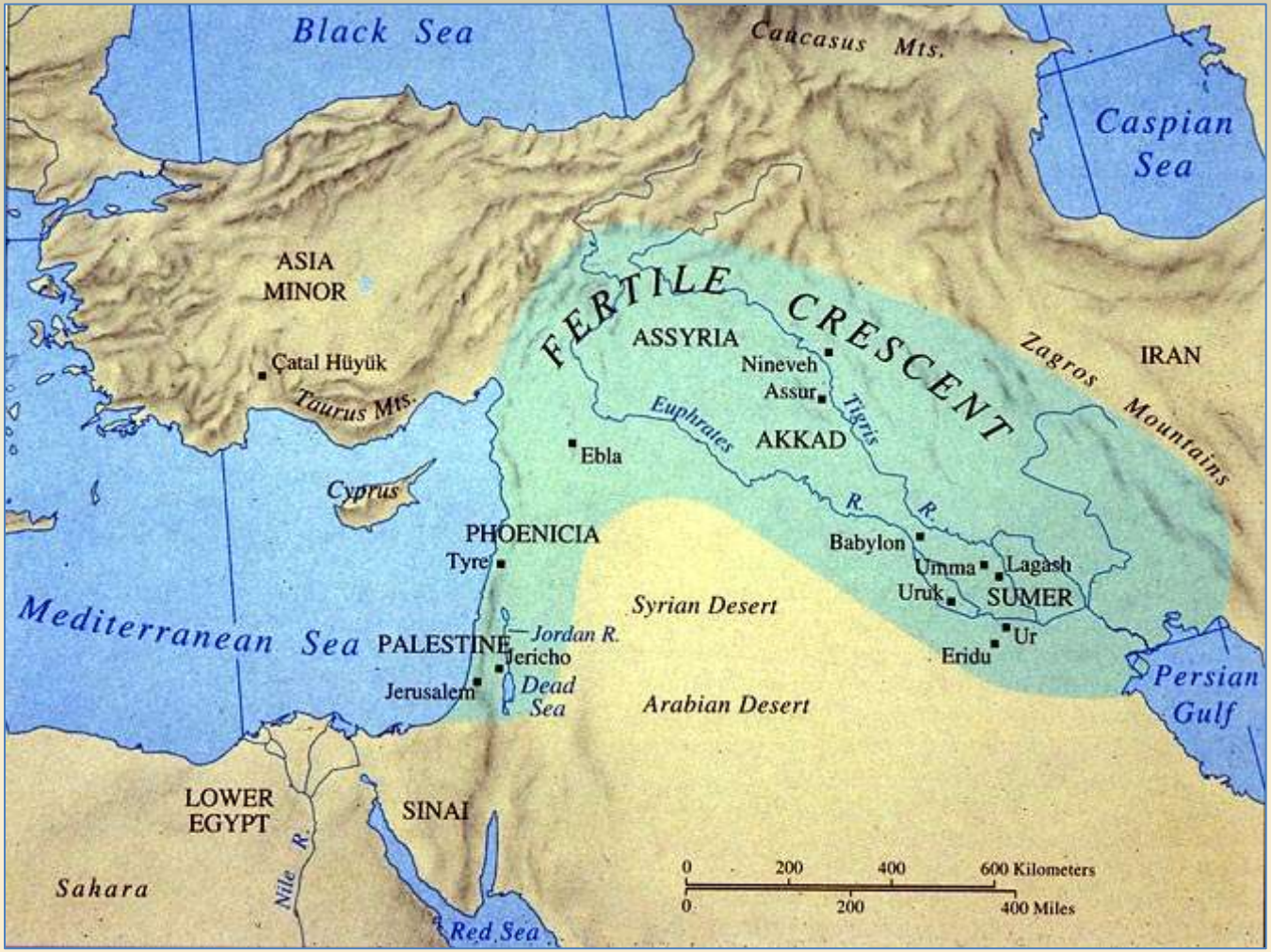
-Susceptible to many diseases.

-13% protein, with low tryptophan & lysine

-missing Vit A, B12, C, iodine

-leavened (raised wheat) bread discovered by Egyptians ca. 4000 years ago

The Near East – Fertile Crescent

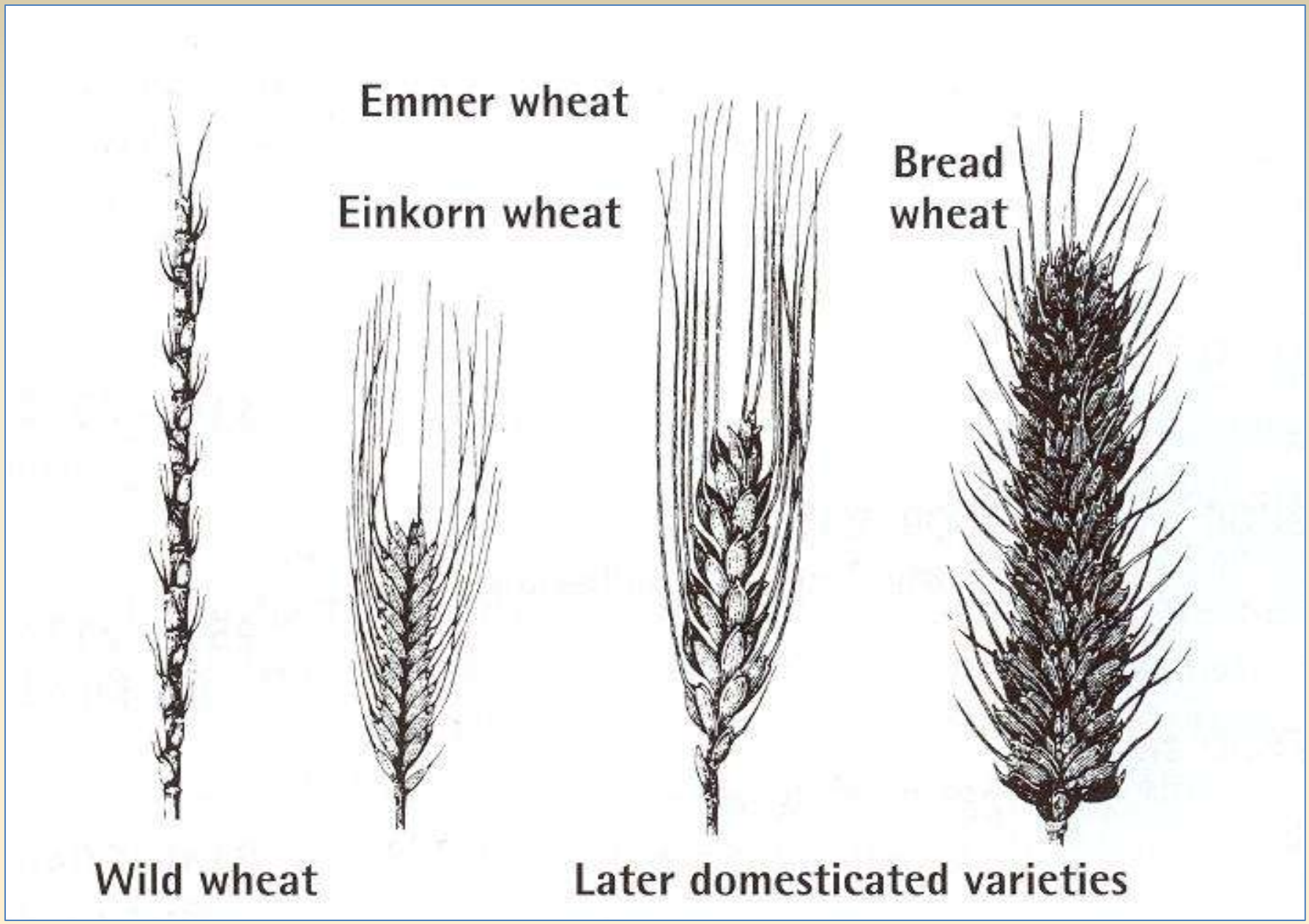


The Fertile Crescent region of Southwest Asia is the center of domestication for three cereals (einkorn wheat, emmer wheat and barley) four legumes (lentil, pea, bitter vetch and chickpea) and flax.

Wild and Domesticated Cereals

Domesticated forms have larger seeds with hulls and a non-shattering rachis

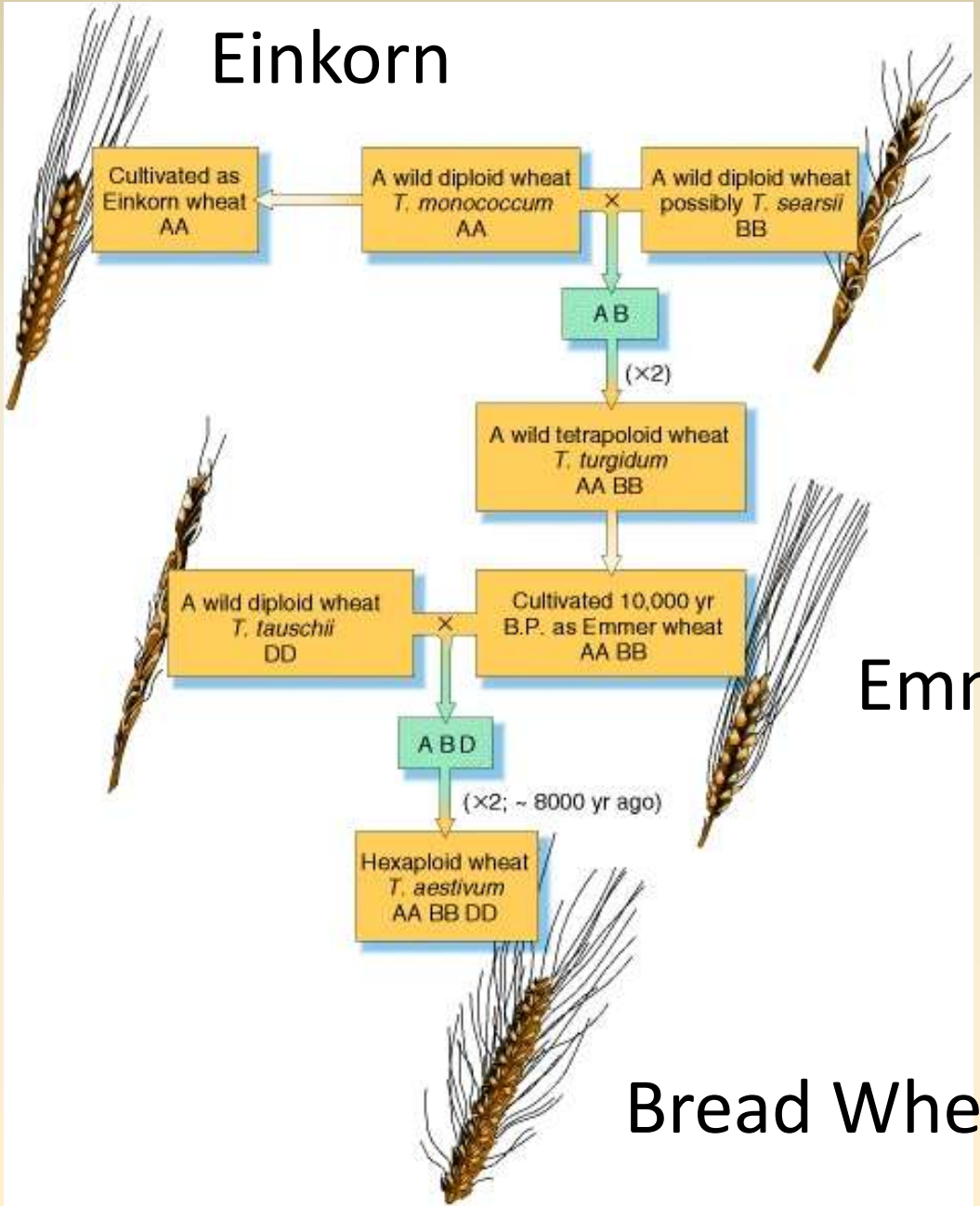
The Wheat Story



Einkorn - *Triticum monococcum*

- One of first wheat species grown for food, wild forms still exist.
- Cultivated in the Stone Age (10,000 BC) in the Near East and SW Europe.
- Diploid, 2n=14, chromosomes are derived from a single genome (designated AA).
- Seeds do not thresh free of the chaff
- Rachis of the spike is brittle and breaks apart at maturity

Hexaploid – 6 sets of chromosomes



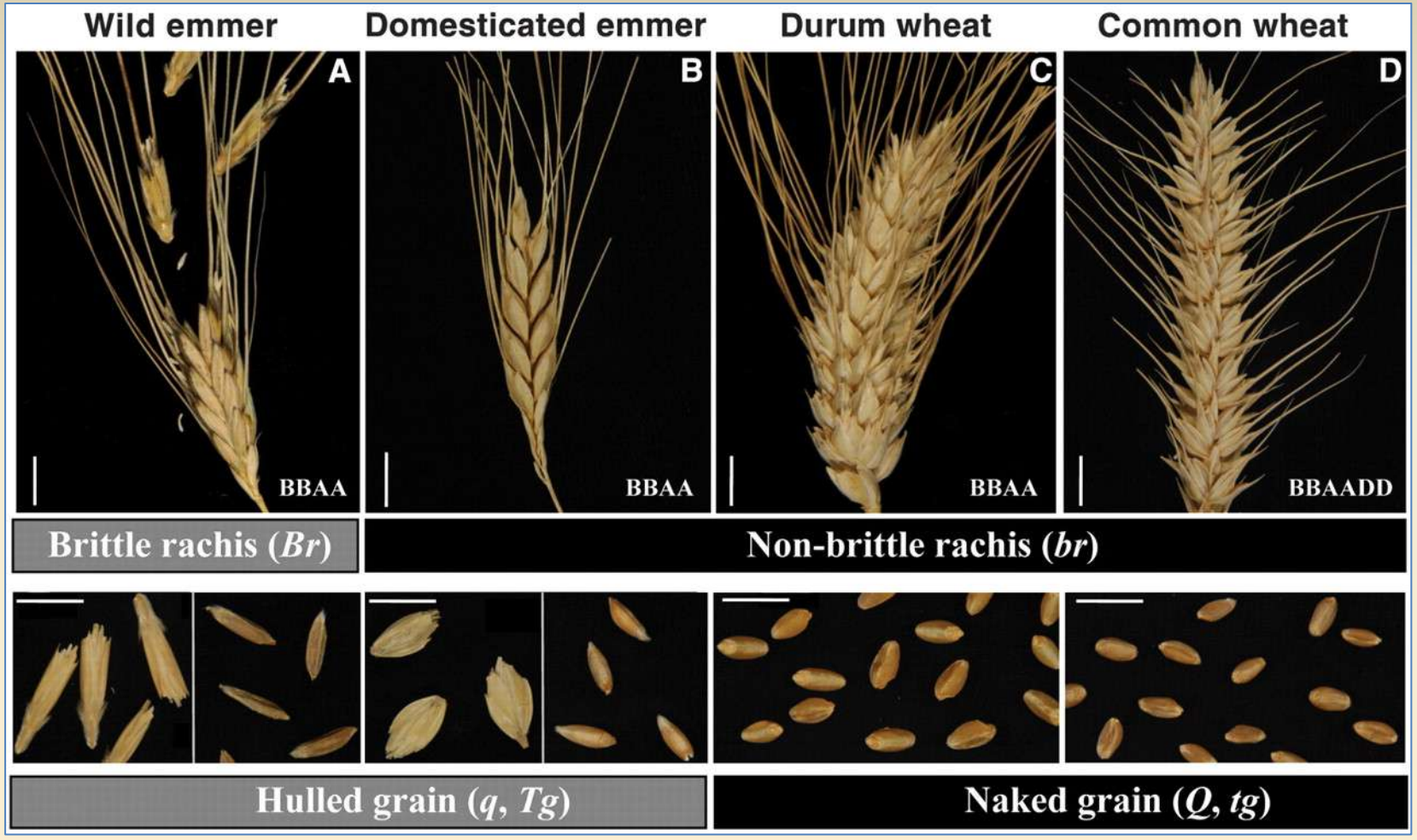
Emmer wheat was widely cultivated in the ancient world, but is now a relict crop in mountainous regions of Europe and Asia.

- Hulled wheat – has strong husks (glumes), that enclose the grain.
- Has to be pounded to release the grain.
- Tetraploid, 2n=28

Durum Wheat - Macaroni

- Tetraploid, artificially <u>selected from emmer</u>
- Hardest of all wheats
- High protein content, strength, make durum good for **pasta**.
- Low in gluten needed to form a glutinous web necessary for bread to rise

Wheat spikes showing (**A**) brittle rachis, (**B** to **D**) nonbrittle rachis, (A and B) hulled grain, and (C and D) naked grain.



Durum – Macaroni wheat, tetraploid, artificially selected from emmer

Bread Wheat - *Triticum aestivum*

- Hexaploid, AABBDD, six sets of chromosomes, 2n=42
- Firm stems tend not to shatter when harvested.
- Glumes open readily to release the grain, easily threshed
- High in gluten protein
- Bread wheat is more widely cultivated than any other crop
- World trade is of greater monetary value than all other cereals combined.

Types of wheat

- Bread wheat (*T. aestivum*) :
  - This has a high gluten content and hard grain. It is used to make flour from which bread is made. **Gluten** (type of wheat proteins) good for baking qualities (elasticity).
  - 95% of world production.
- Durum wheat (*T. durum*):
  - Unsuitable for bread making, but is used to make pasta.
  - 5% world production

Types of wheat (cont.)

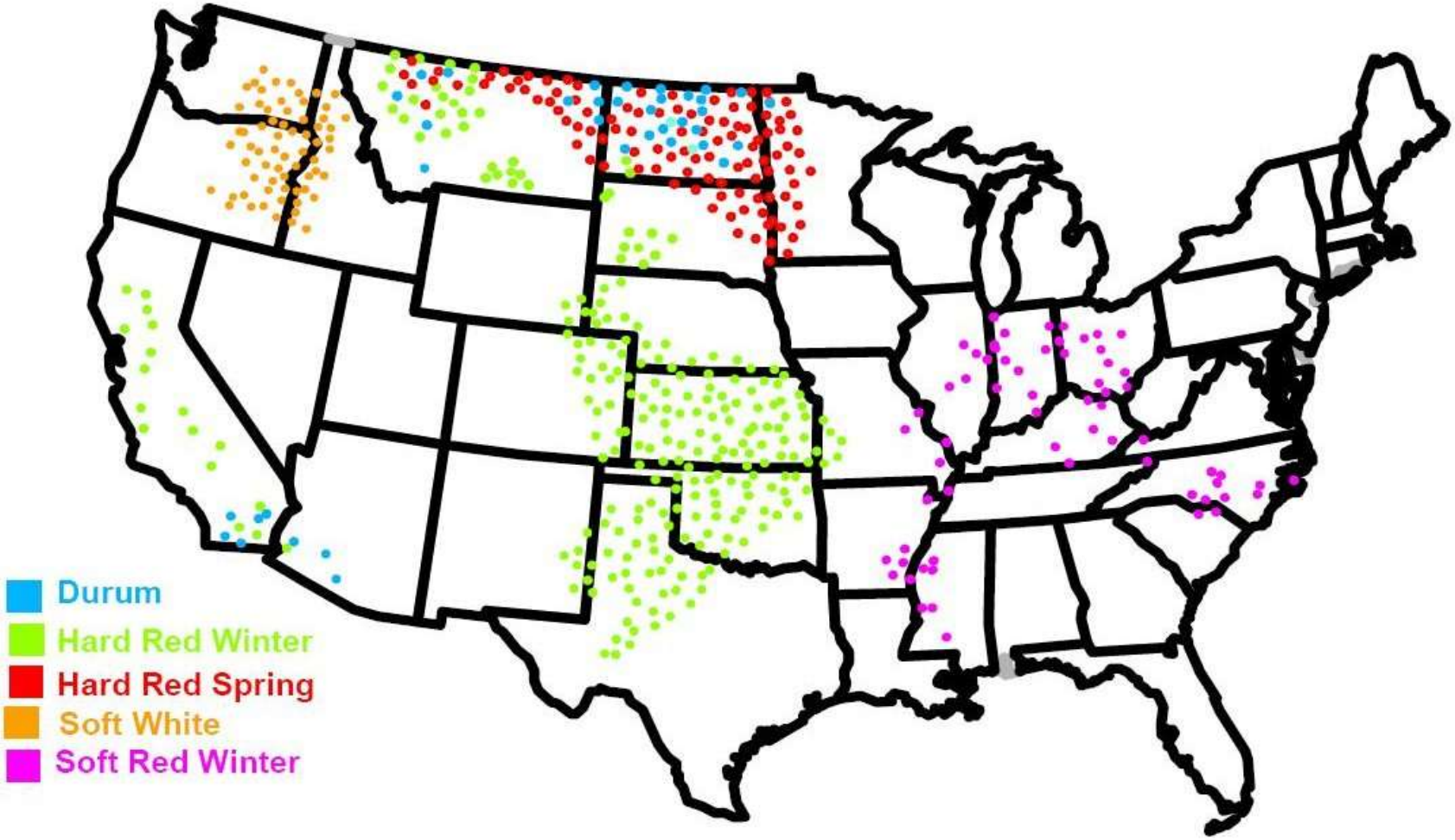
Spring wheat: Northern U.S. & Canada; planted in spring, harvested in fall.

Winter wheat: rest of U.S.; planted in fall, harvested in early summer.

Hard wheat: higher protein content, used for bread.

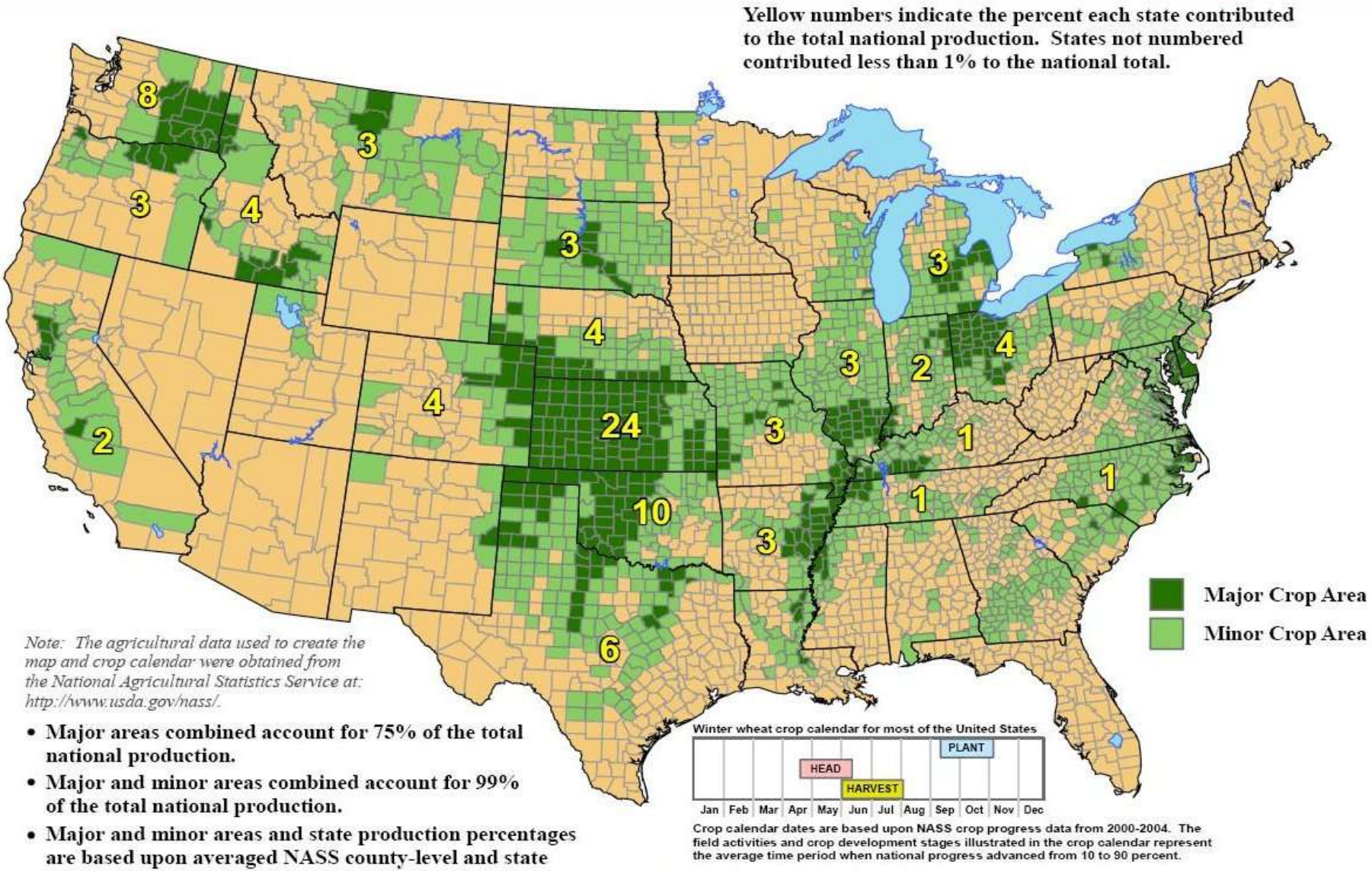
Soft wheat: better for pastries.

Major US. Wheat Growing Regions



Source : US. Wheat Associates

United States: Winter Wheat



Note: The agricultural data used to create the map and crop calendar were obtained from the National Agricultural Statistics Service at: http://www.usda.gov/nass/.

- **Major areas combined account for 75% of the total national production.**
- **Major and minor areas combined account for 99% of the total national production.**
- **Major and minor areas and state production percentages are based upon averaged NASS county-level and state production data from 2000-2004.**

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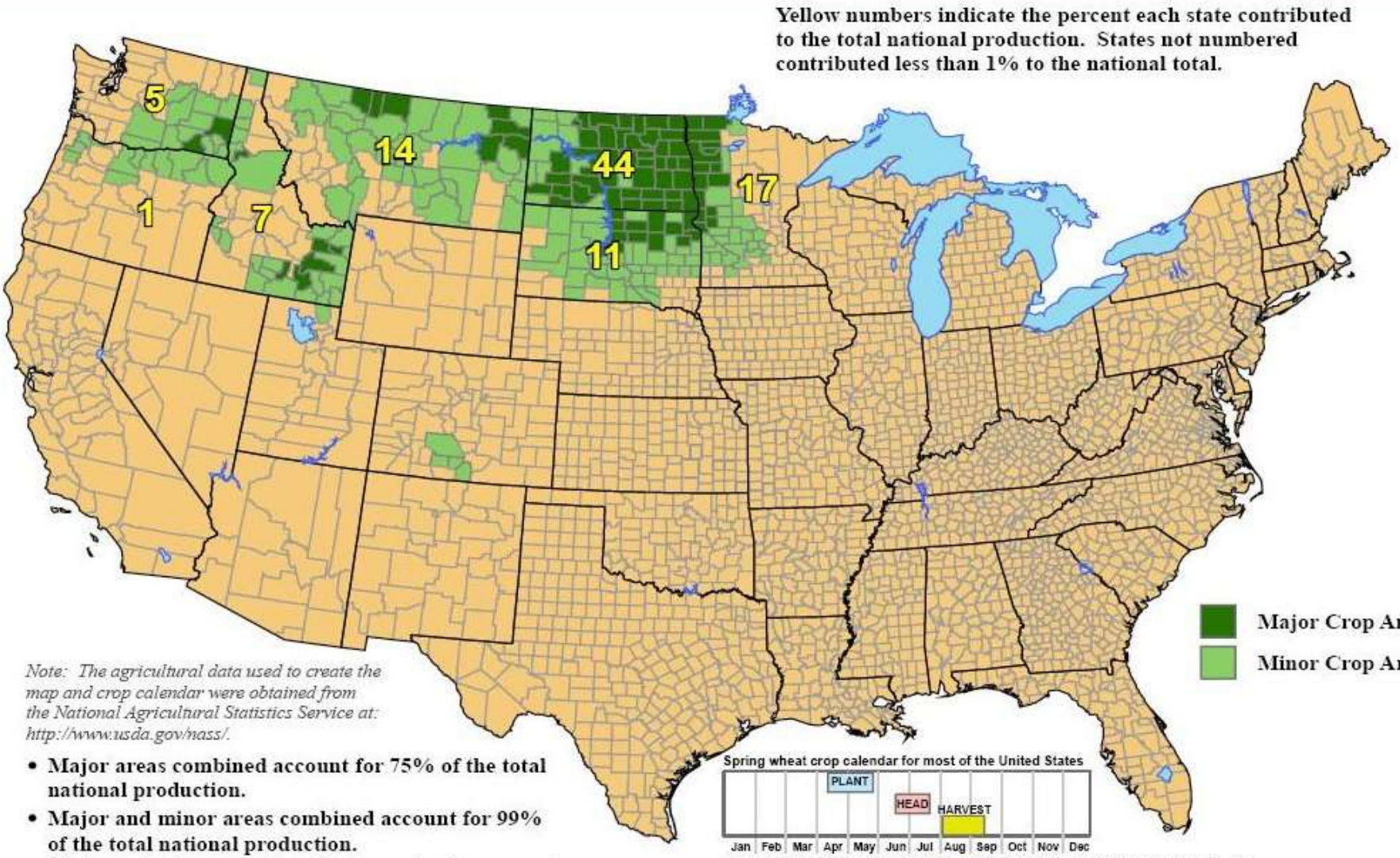
United States: Spring Wheat (excluding durum)



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Crop calendar dates are based upon NASS crop progress data from 2000-2004. The field activities and crop development stages illustrated in the crop calendar represent the average time period when national progress advanced from 10 to 90 percent.

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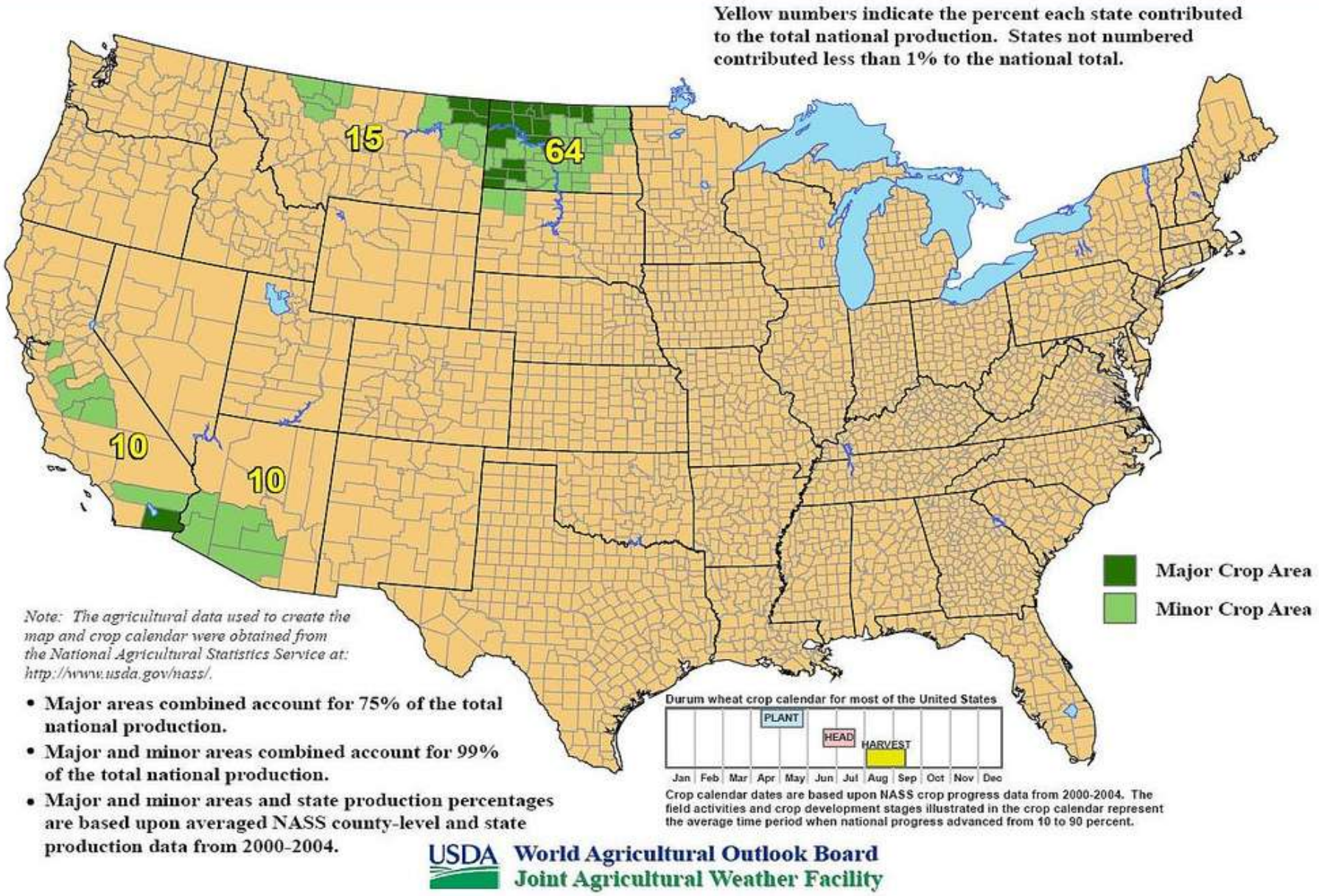
United States: Durum Wheat



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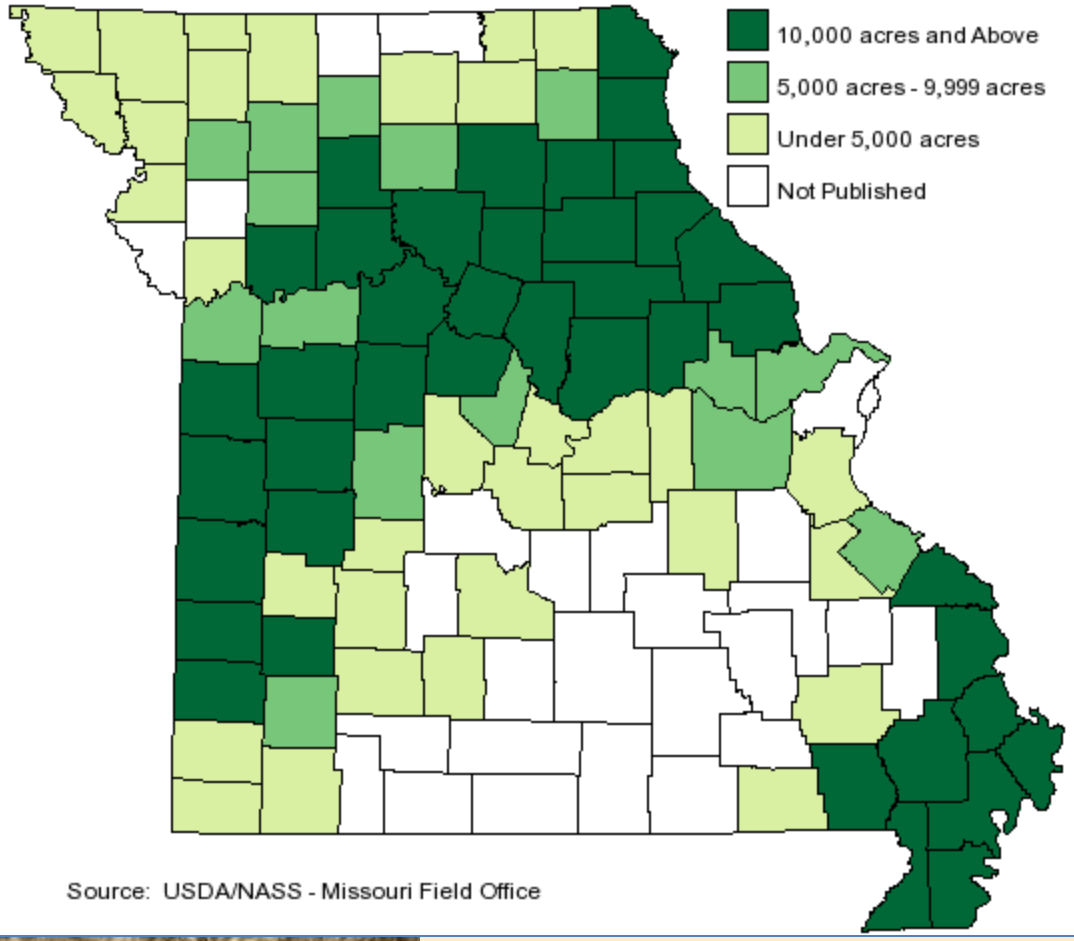
2008 Wheat Acres Planted

by County



Source: USDA/NASS - Missouri Field Office

Products Made From Wheat:

1. Croissant;
2. Wheat Flour;
3. Noodles;
4. Cracked Wheat;
5. Vermicelli;
6. Refined Wheat Flour;
7. Common Brown Bread;
8. Semolina (bran);
9. Pasta;
10. Cookie; and
11. Flat Bread

(Source: Saikat Basu)

Gluten – protein in wheat. Important for elasticity. Allows dough to rise.

Box Figure 12.1 Bread is the staff of life.

Leavening Agents – anything that makes bubbles - yeast, baking soda, baking powder, sour milk, beer, sourdough

Flatbreads

- Bread that does not rise
- Made with flour, water and salt, and then rolled into flattened dough, cooked.
- Many flatbreads are **unleavened**—made without yeast—although some are slightly leavened, such as pita bread.
- Nan, tortillas, frybread, arepa, matzoh, chapati, pizza, foccacia, Johnnycake

,

Making flour

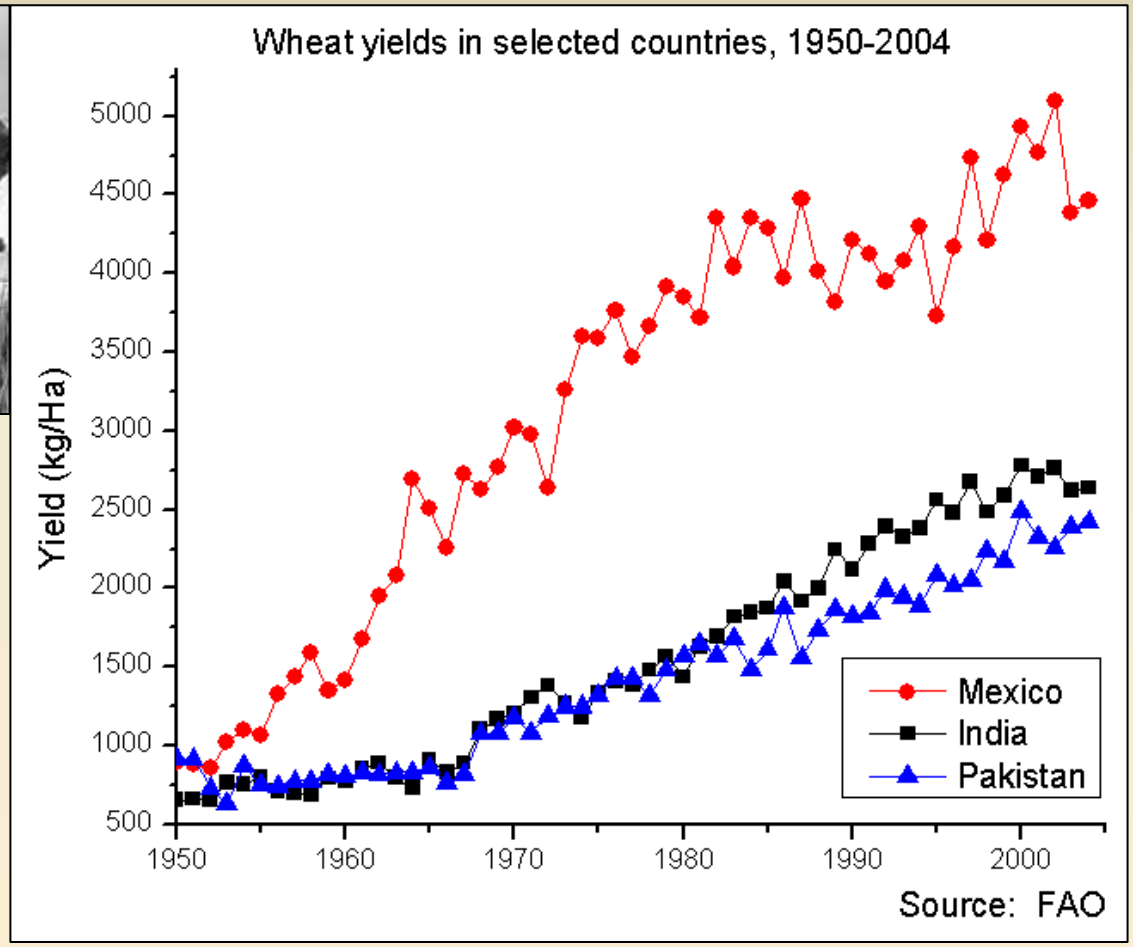
- Whole-grain (has germ & bran)
- White flour (only endosperm)
  - 83 percent of the nutrients are removed
  - Stores longer, because little oil to go rancid
- Milling
  - Stone milling more nutritious, more bran, but shorter shelf-life compared to steel-roller milling

Green Revolution – 1940s to 1960s

- High-yielding varieties
- Mechanization
- Fertilizer
- Pesticides
- Irrigation

Green Revolution

Norman Borlaug



Crop breeding, fertilizers, pesticides, technology

Borlaug's High Yielding Wheat Varieties

- Shorter, stronger stems
- Resist lodging, collapsing stems under weight of grain
- Hold up with heavy fertilizer application
- Rust disease resistant
- He developed similar high-yielding rice varieties

Puccinia graminis – Stem Rust

Losses are often severe (50 to 70%) over a large area and individual fields can be totally destroyed. Damage is greatest when the disease becomes severe before the grain is completely formed. In areas favorable for disease development, susceptible cultivars cannot be grown. Grain is shriveled due to the damage to the conducting tissue, resulting in less nutrient being transported to the grain. Severe disease can cause straw breakage, resulting in a loss of spikes with combine harvesting.

Farming/Wheat YouTube Videos

Discovery How Stuff Works : Wheat
https://www.youtube.com/watch?v=F4VoVLlyuS0
Harvesting Wheat by Hand
https://www.youtube.com/watch?v=DcDv545uA4c
Harvesting wheat by hand - Scythe
https://www.youtube.com/watch?v=KW1lxWRY5kE&playnext=1&list=PL1F1B0360104DF6A9&feature=results_video
Plowing a Field with Oxen - Old Sturbridge Village
https://www.youtube.com/watch?v=xuytRXRfyeI
Plowing with mules
https://www.youtube.com/watch?v=DpWfkV_rw_A
Jethro Tull's Seed Drill
https://www.youtube.com/watch?v=DqhdumfLtJw
Threshing and Winnowing
https://www.youtube.com/watch?v=iReC7WpveVs
From Milling Wheat to Loaf - The Story of Bread
https://www.youtube.com/watch?v=AbCjTONgM2c
2014 wheat harvest – wow…..
https://www.youtube.com/watch?v=WqCh3Dbu3Tg

Corn – *Zea mays*

Corn facts

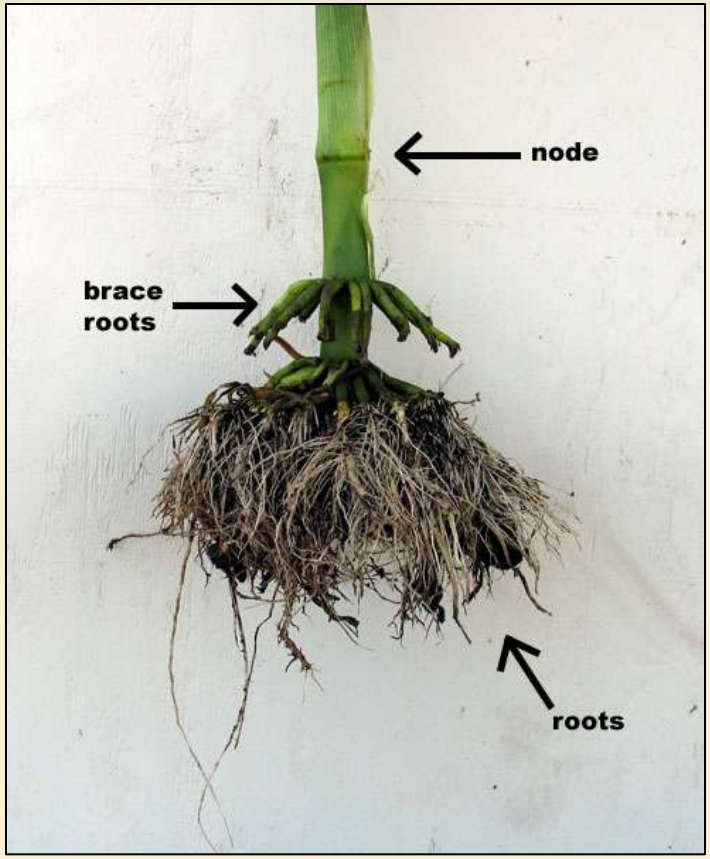
- Originated from Southern Mexico (sub-tropics), so from a warm climate.
- Corn is a C4 species. Corn likes it warm, and needs lots of sunshine. And requires lots of water, for a grass.
- Domesticated *ca*. 10,000 years ago.
- Modern corn has naked seeds, but can't disperse them due to husk covering, can't survive on its own.

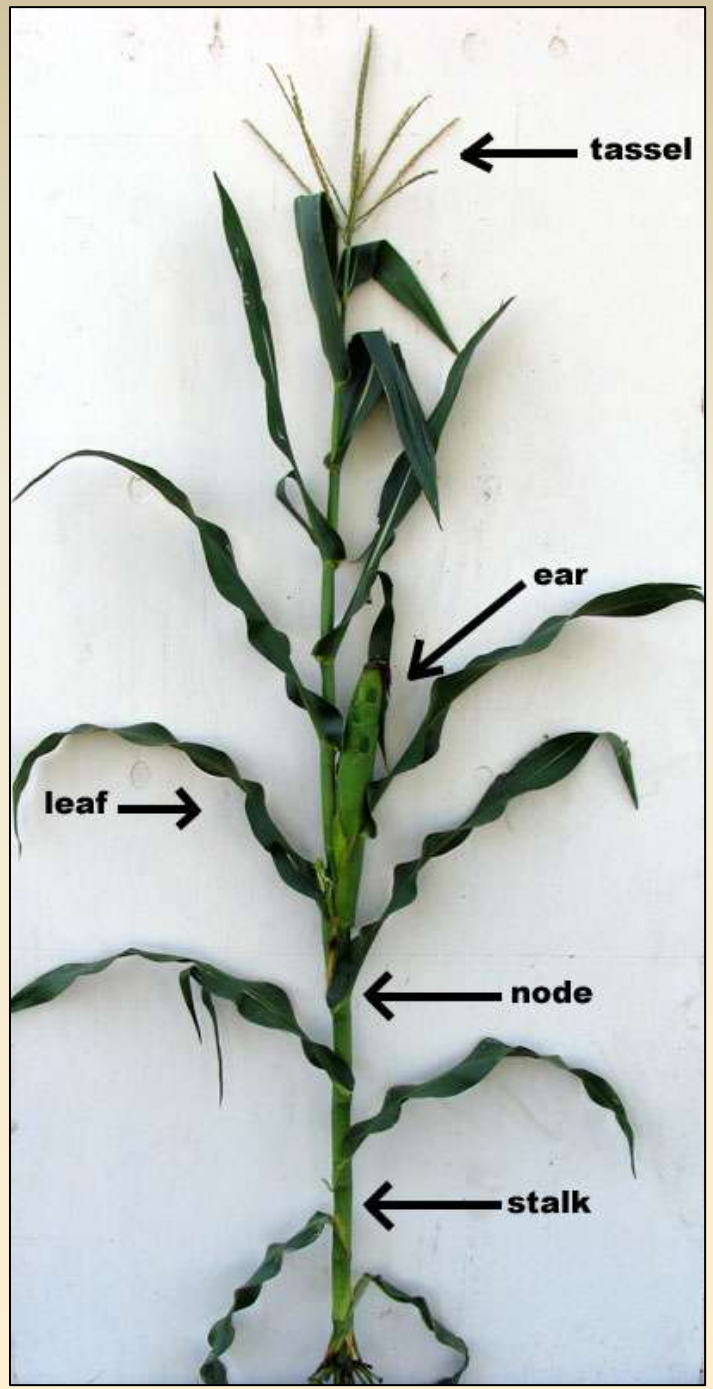
Corn facts

- United States is the largest producer of corn in the world. In 2014, U.S. planted 83.8 million acres.
- About 65% of the maize produced in the world is used as animal feed.
- 5 major categories, mainly the dents (most of the modern corns; for feed, starch, meal), flints (“Indian” corn), flour (also “Indian” corn), pop, and sweet corn (higher sugar content).
- Almost all is hybrid corn.
- High in fiber, 7-10% protein, low in trp & lys and niacin.

Maize Morphology

- Large plants
- Separate staminate and pistillate inflorescence
- Tassel
- Ears
- Silks





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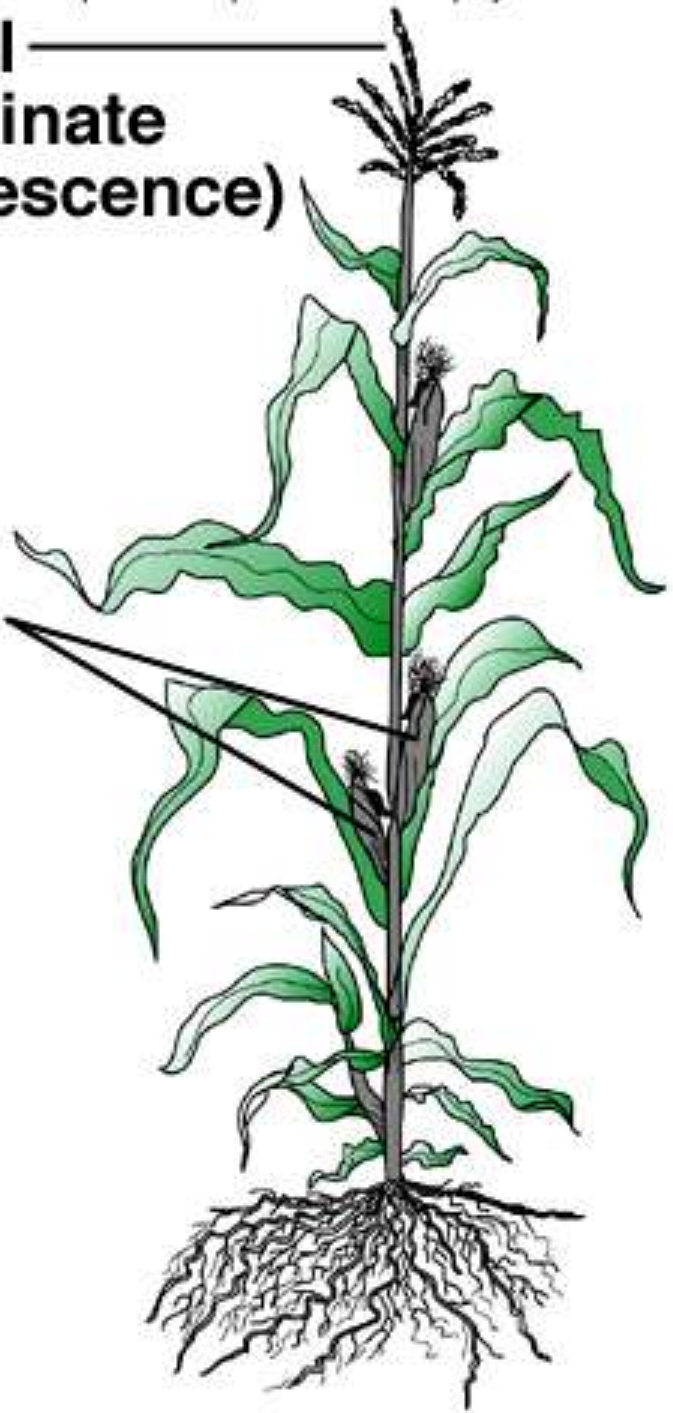
Corn Plant



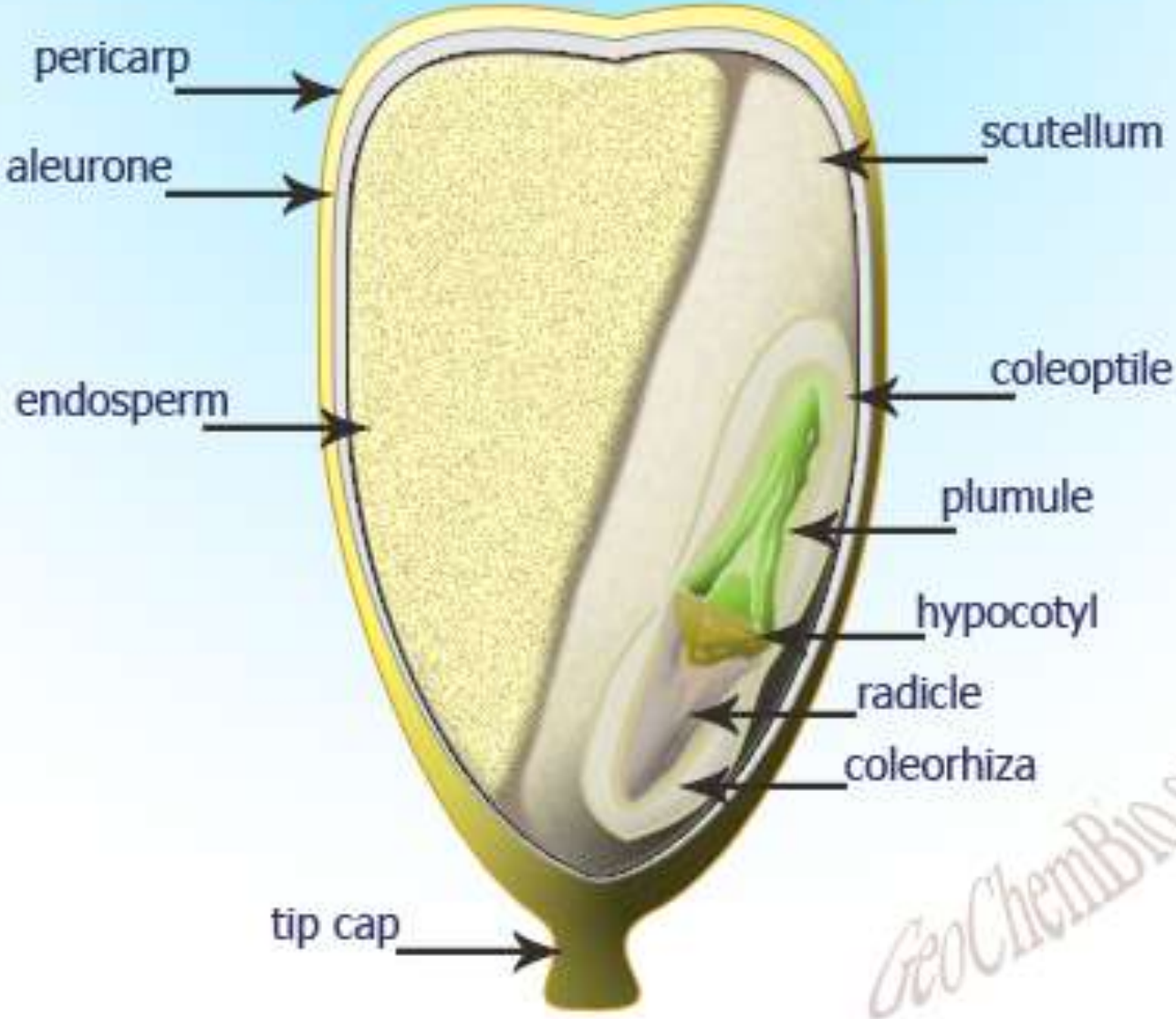
Unlike all other major grain crops, the corn plant has separate male and female flowering parts

Silk is the style and stigma of each flower.

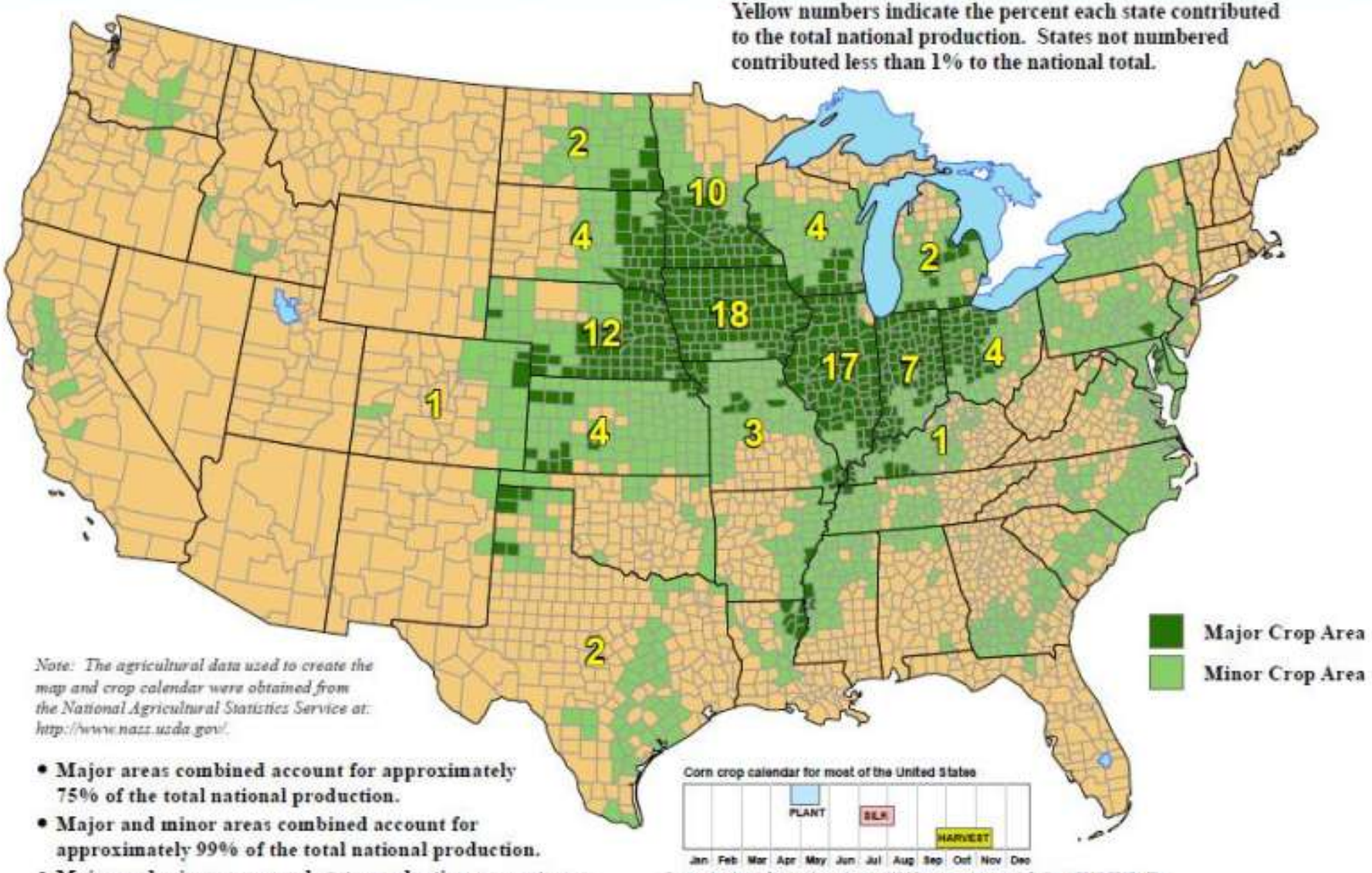
Tassel – staminate flowers

The female floral organ is called an ear. The ear develops at the tip of a shank, which is a small, stalk-like structure that grows out from a leaf node located approximately midway between the ground and the tassel

Corn seed


pericarp
aleurone
endosperm
tip cap
scutellum
coleoptile
plumule
hypocotyl
radicle
coleorhiza
GeoChemBio.com

United States: Corn



Note: The agricultural data used to create the map and crop calendar were obtained from the National Agricultural Statistics Service at: http://www.nass.usda.gov/.

- **Major areas combined account for approximately 75% of the total national production.**
- **Major and minor areas combined account for approximately 99% of the total national production.**
- **Major and minor areas and state production percentages are derived from NASS county- and state-level production data from 2006-2010.**

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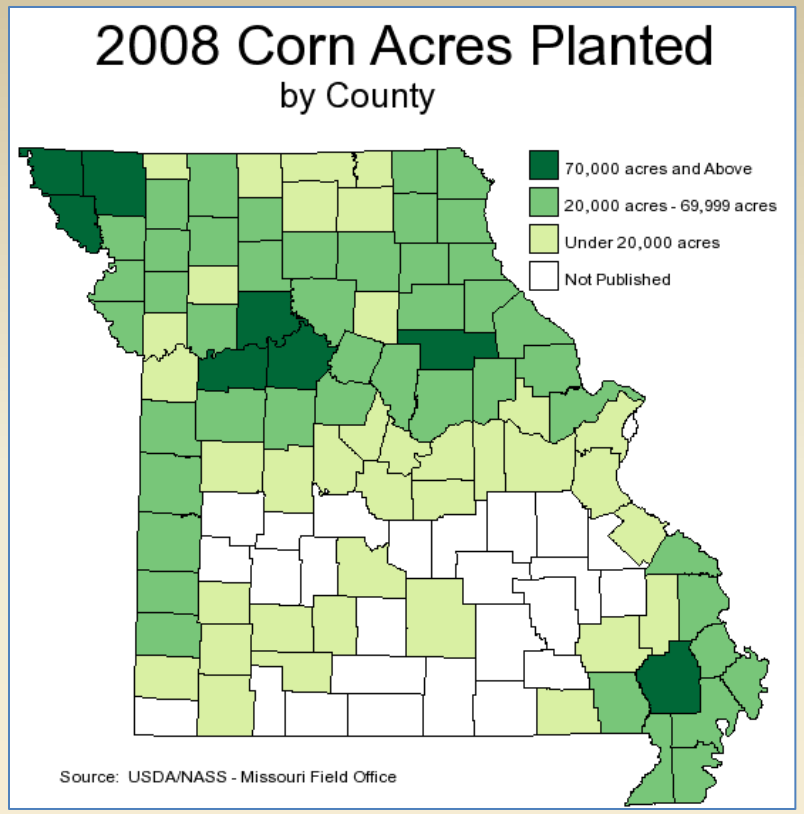
- The most productive grain crop in the world.
- Grain yields higher than 400 bushels per acre (27 tons per hectare) have been reported.

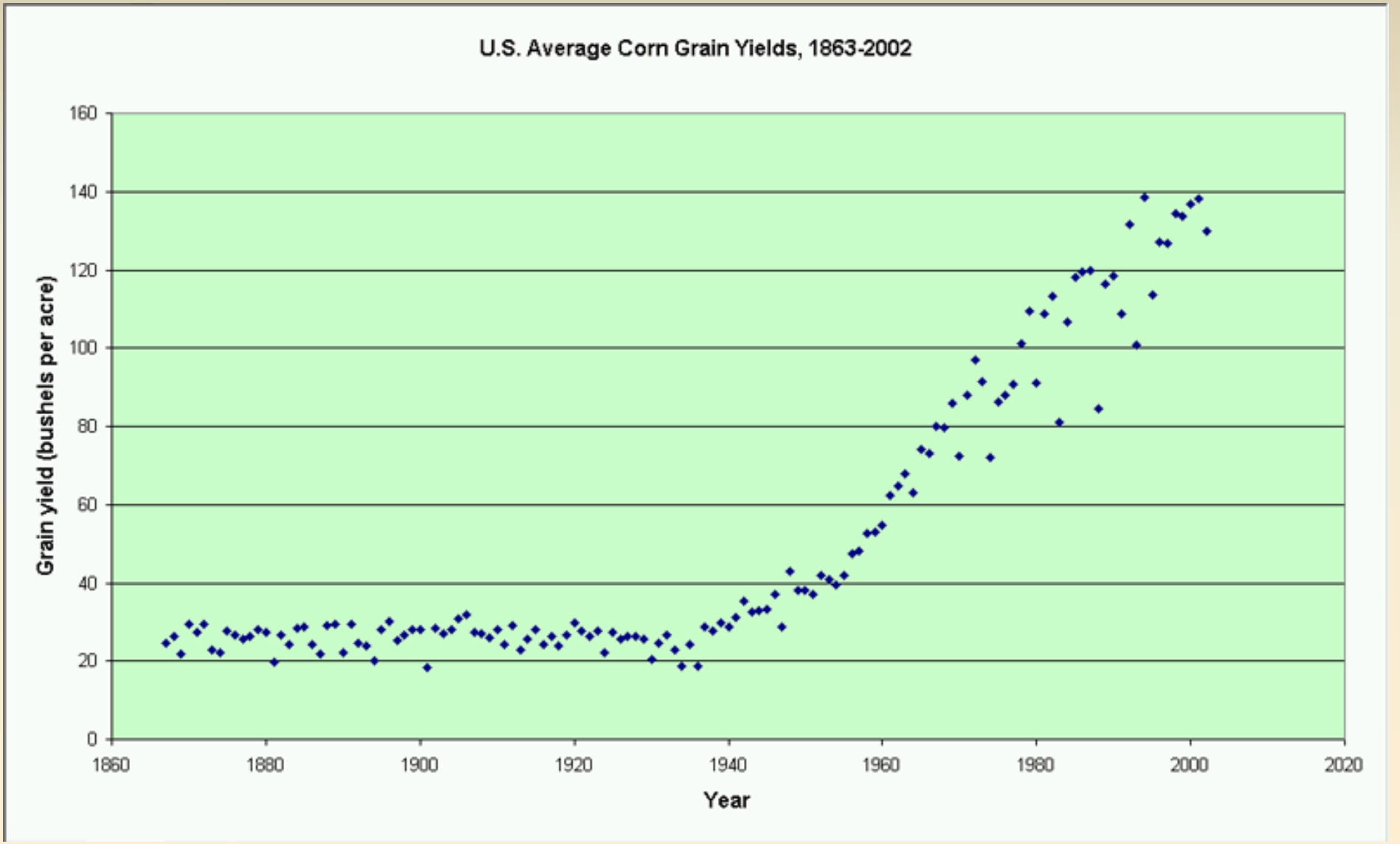
Corn for grain production set a new record in 2014 at 14.5 billion bushels on fewer acres planted compared to 2013.
World corn production is also setting new records.

Where is all the corn going?



- Missouri's corn production in 2014 will total 533 million bushels — the highest on record for the state and a 22 percent increase from last year.
- Yields are now forecast at 160 bushels of corn per acre. The USDA said that would be the highest since 2004, when Missouri producers averaged 162 bushels per acre.

Corn Yields – breeding efforts, hybrid corn, fertilizer, technology



Hybrid Corn – cross two inbred lines

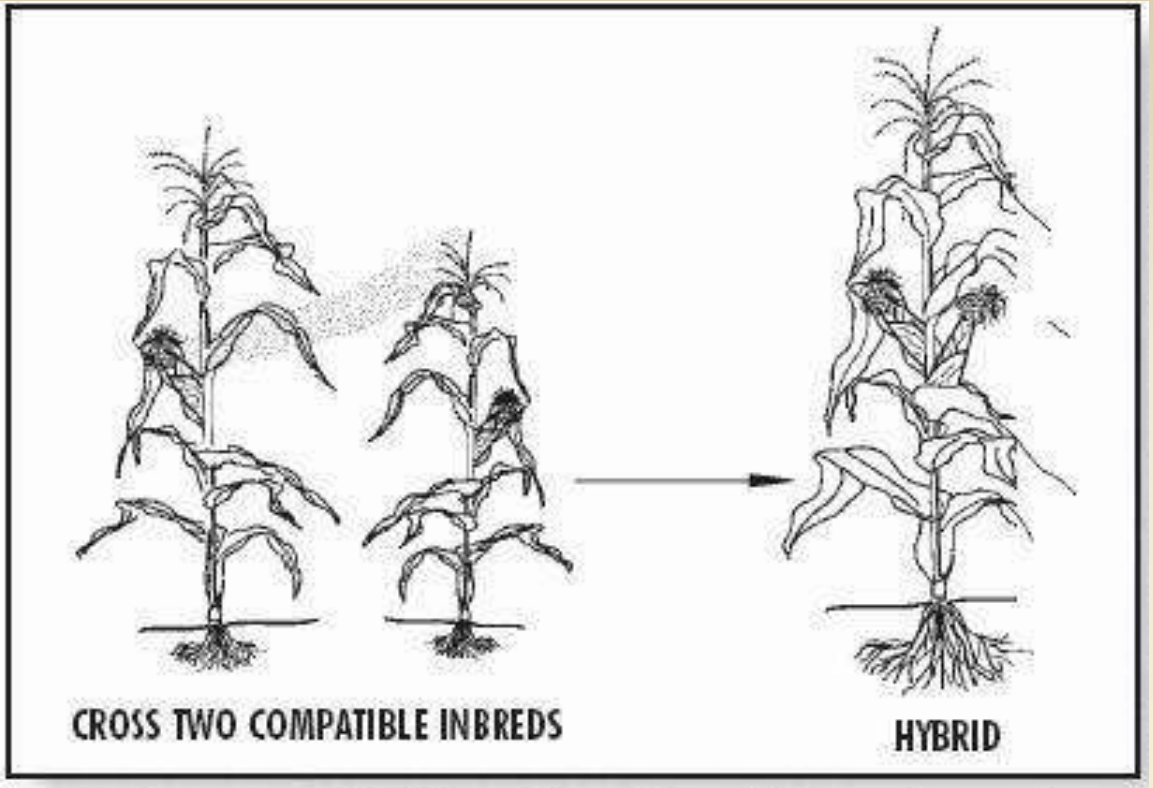


Figure 6. Cross pollination of two inbreds to produce a vigorous hybrid.

Ears of Corn – colors various

Color variants due to differences in pigmentation of endosperm, aleurone layer, and pericarp. Mendelian genetics and “jumping genes” involved.

Barbara McClintock – “Jumping Genes” - Transposons

Figure 8-17a
Biology of Plants, Seventh Edition
© 2005 W. H. Freeman and Company

Transposable Elements - Fragments of chromosomes that move at random from one position to another.

Corn Domestication

- Domesticated in southern Mexico 10,000 years ago
- Wild ancestor is Teosinte
- General growth form is similar to that of maize, but teosinte has much longer lateral branches.

Reduction in lateral branching

Zea teosinte – Teosinte - ancestor of corn?

Figure 12.9 Teosinte, *Zea diploperennis*. Immature ear on left; in center, ear is cut open; on right, mature fruit cases with grain visible on bottom.

Domestication of Corn

Maize cobs became larger over time, with more rows of kernels, eventually taking on the form of modern maize.

Popcorn

- Two types of popcorn,
- Pearl types have smooth and rounded kernels
- Rice types have more elongated kernels.
- Available in red, pink, blue, yellow, and multi-colored ears
- Look for varieties like Early Pink, Calico, and Dakota Black Popcorn

Dakota Black Popcorn

Strawberry Popcorn

Flint Corn

- Known as “Indian Corn”
- High in protein
- Hard seed coat with rounded, smooth, kernels
- Kernels consist of soft starch covered by horny starch.
- Type used for making hominy
- Not grown much anymore

Dent Corn

- Dominates the American agricultural landscape.
- Has hard and soft starch
- Characteristic dent on top
- Used for animal feed
- Milled food ingredients like grits, corn meals and flours
- Used for making fuel, and corn-based, biodegradable plastics

Sweet Corn

- Eaten fresh at the dinner table
- Gene which prevents some sugar from being converted into starch
- Many fine old varieties
- Pick in the MORNING and put in the fridge the day you intend on eating it (sugars get converted to starches in the afternoon)

Corn Cultivation

- Summer annual
- 3-5 month growing season
- Moderate temperature
- Evenly spread moisture
- Loves lots of nutrients, water
- Has shallow roots
- Thousands of cultivars

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Uses of Corn

Alcoholic beverages

Animal feed

Food products

Seed corn

Gasohol

Industrial and pharmaceutical products

Exported

Surplus

Corn YouTube Videos

Children of the Maize- From Kernel To Tortilla In Rural Oaxaca, Mexico
https://www.youtube.com/watch?v=5huPYMG7pB8

Discovery How Stuff Works : Corn
https://www.youtube.com/watch?v=LGJ6D3KNJ9E

Corn Cultivation
https://www.youtube.com/watch?v=TksBsAYyh5c

Popped Secret: The Mysterious Origin of Corn — HHMI BioInteractive Video
https://www.youtube.com/watch?v=mBuYUb_mFXA

Georgia Farmer Sets New State Corn Yield Record
https://www.youtube.com/watch?v=DOD5CsiMey8

Seed Corn Harvest
https://www.youtube.com/watch?v=KC2R9y1rH2U

Mexico's Timeless Maize
https://www.youtube.com/watch?v=8IPClfgXR-g

Rice - *Oryza*

Rice – *Oryza sativa*

- Feeds more people than any other crop.
- Most eaten directly by humans
- Origins in Far East (China & India).
- Domesticated *ca*. 11,500 years ago.
- 11% of arable land
- U.S. produces only 2% of world rice, but is a big exporter.

Rice is the staple food of nearly half the world's 7.2 billion inhabitants.

Rice

-Most modern rice is *Oryza sativa*
  - Japonica and Indica sub-types
  - African rice is another species

-Both lowland & upland varieties.

-Wild rice is another genus (*Zizania*).

-Origins from tropical periodically-flooded lowlands, so needs lots of water (during seedling establishment).

-Very flood & heat tolerant, but can “drown”.

Rice (cont.)

- White rice: husk, bran, and germ removed.
  - Long-grain rice is four to five times longer than it is wide
    - aromatic rice, i.e., basmati and jasmine varieties
  - Medium-grain rice has shorter, fatter grains and a medium starch content
  - Short-grain rice is plump, almost round, with high starch
    - easy to handle with chopsticks
- Brown rice
  - Only the inedible outer husk has been removed
  - More protein (*e.g.*, 9 *vs*. 6%)

Rice - Morphology

(a)

(b)

Figure 12.11 Rice, *Oryza sativa*, is the dietary staple for over 2 billion people. (a) Close-up of fruiting stalks. (b) Rice paddy in Indonesia.

Wet Rice Cultivation in Vietnam

Azolla – aquatic fern with nitrogen-fixing cyanobacteria inside, used as fertilizer in rice paddies.

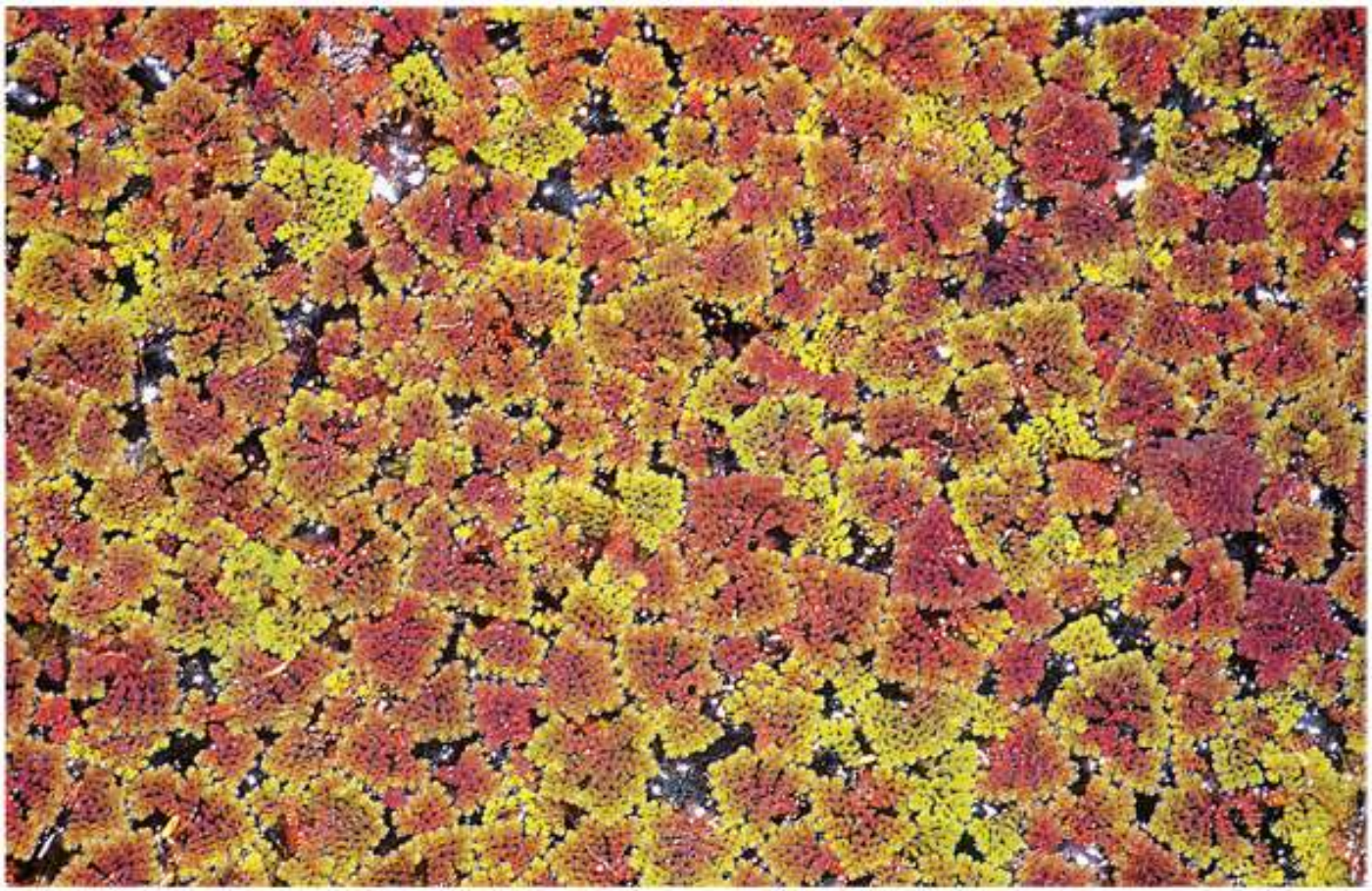
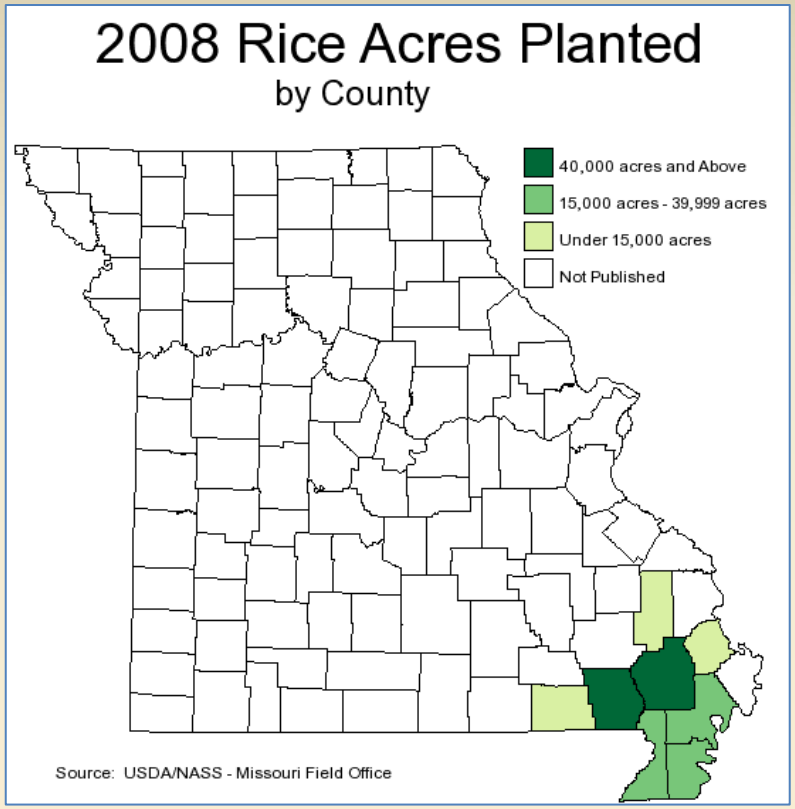


Figure 12.12 *Azolla* was originally noticed as a weed in rice paddies, but today it is deliberately introduced to cut down on the need for expensive fertilizer.

Rice Field, Madagascar

Rice in Missouri



- Missouri grows mostly long grain rice.
- Sodium-, cholesterol- and gluten free.
- Is predominantly used for human food
- Value of rice exports from Missouri in 2013 was $122,167,586

Golden Rice, which contains extra beta carotene, a source of vitamin A, has the potential to save millions of poor children from blindness, a symptom of vitamin A deficiency

GMO

Flood Tolerant Rice

Swarna-Sub1 is a flood-tolerant rice variety developed by the Philippines-based International Rice Research Institute (IRRI). It was bred from a popular Indian variety, Swarna, which has been upgraded with SUB1, the gene for flood tolerance millions of farmers who have found that there is a way out of losing their rice crop from regular flooding. They are no longer at the mercy of the seasons, which they have been for generations

Rice YouTubes

How rice is made
https://www.youtube.com/watch?v=dT6gjb48_N0

Rice planting
https://www.youtube.com/watch?v=keytHldOvYY

Cultivation of Rice in Nepal, Part-1
https://www.youtube.com/watch?v=3DJs_MoKsQg

Louisiana Rice Harvest
https://www.youtube.com/watch?v=V2SSKAf0yBU

How To Cook Perfect Rice On Stove(long grain, medium grain and short grain)
https://www.youtube.com/watch?v=6jnGTELP-TU

Some other major cereals

a. Rye
b. Triticale
c. Oats
d. Barley
e. Millet
f. Sorghum

Figure 12.13 Other commercially important grains include (a) rye, (b) triticale, (c) oats, (d) barley, (e) pearl millet, and (f) sorghum.

Some other major cereals

- Rye
  - Cold & drought tolerant
  - Makes leavened bread
  - Lower protein content than wheat, but w/ lys
- Tricale
  - Cross between wheat & rye
  - Not a good bread cereal
- Oats
  - High protein (15%), good overall nutrition
  - Best in moist cool climates
- Barley
  - One of oldest grains, from Near East
  - Cold and salt tolerant
- Sorghum & Millets
  - Sorghum used for food or feed, or for molasses
  - Millet used as food or birdseed

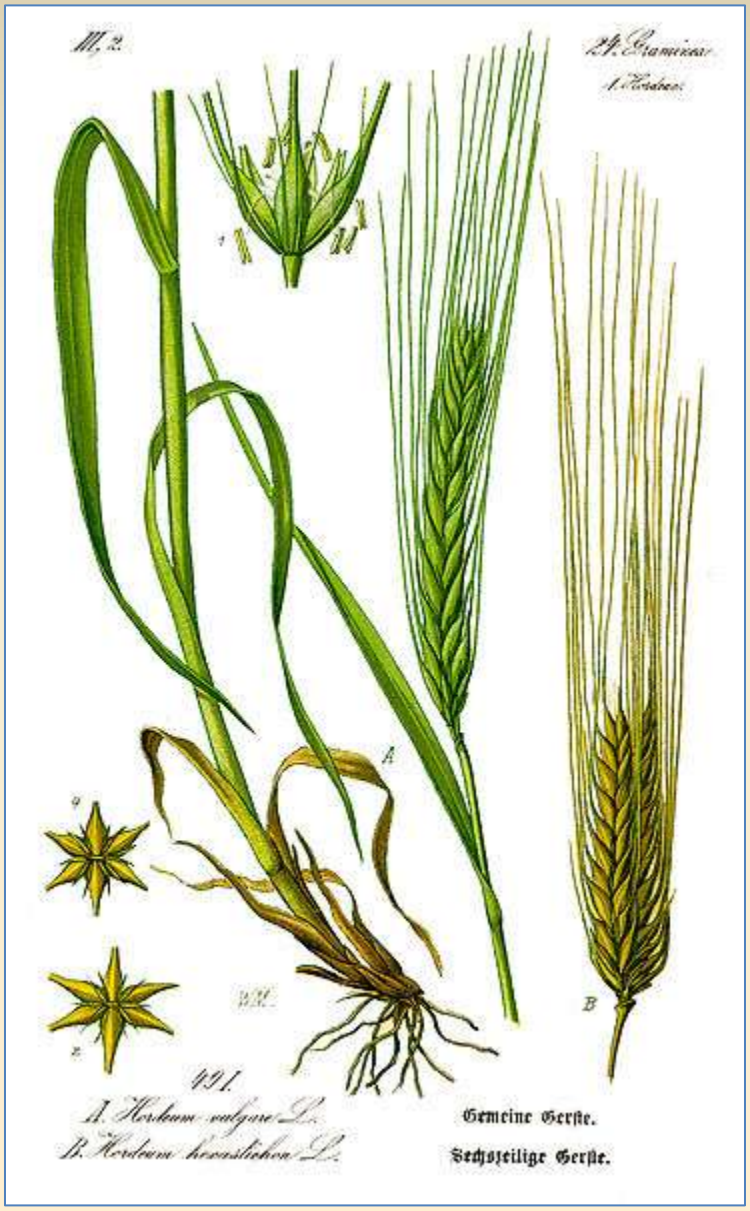
Rye (*Secale cereale*) and Triticale

<u>Rye</u>

- Cold & drought tolerant
- Related to wheat and barley
- Makes leavened bread
- Lower protein content than wheat, but w/ lysine

<u>Triticale</u> (*Tritisecale*)

- Cross between wheat (*Triticum*) & rye (*Secale*)
- Hardy, disease resistant
- High protein content
- Not a good bread cereal



Ergot of Rye

- Plant disease caused by the fungus *Claviceps purpurea*.
- Fungal fruiting body replaces the grain of the rye
- Flour containing ergot causes hallucinations, gangrene, and death
- Outbreaks occurred often in the past - “Holy Fire”, affected whole villages
- Livestock also susceptible

Oats – *Avena sativa*

- Inflorescence a branched panicle
- High protein (15%), good overall nutrition
- Best in moist cool climates
- Horse food
- Soluble fiber in oatmeal
- Oat bran lowers cholesterol levels

Barley - *Hordeum vulgare*

- One of oldest grains, from the Fertile Crescent
- Cold and salt tolerant
- Used for fodder, beer, bread
- Replaced by wheat and potatoes
- Tibet – tsampa
- Malted barley used for making beer

Sorghum

A farmer's sorghum field in Moshi, Tanzania
(Photo: ICRISAT HOPE/Christine Wangari)

Sorghum – *Sorghum bicolor*

- Perfect flowers, terminal inflorescence
- Sorghum used for food or feed, biofuel, molasses
- Seldom eaten by humans in U.S.
- More important as human food in Africa
- Broomcorn - brooms

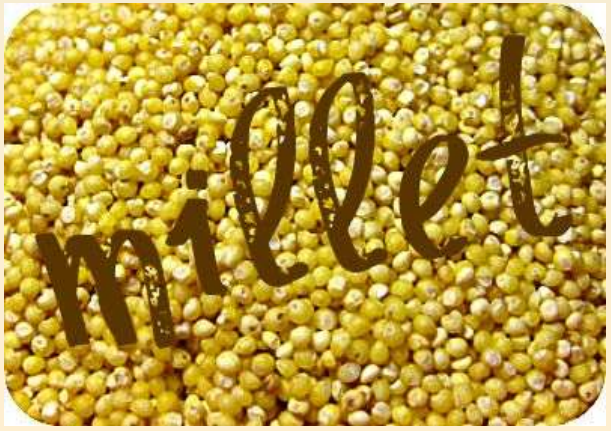
Sorghum Molasses

Making Sorghum Molasses

Industrial manufactured brooms from *Sorghum bicolor* in the street market in Sofia (Bulgaria).

Millets – *Pennisetum, Setaria*

- Several genera called millet – *Pennisetum, Setaria*
- Used as food or birdseed in U.S.
- Staple cereal in India, Africa, China
- Gluten-free



Hay and Silage

Sugar Cane - *Saccharum*

- More tonnage harvested than any other crop
- Sugar, biofuel

Miscanthus giganteus

Allopolyploid hybrid, sterile, C4 perennial, potential for biomass production for fuel

Lawn Grasses

Poa - Bluegrass

Festuca - Fescue

Table 12.3 Common Lawn Grasses and Their Characteristics

Grass	Desirable Characteristics	Region of United States Commonly Grown
Bahia grass	Heat- and drought-tolerant; coarse texture	South
Bermuda grass	Drought-tolerant; coarse texture	South
Kentucky bluegrass	Fine texture; beautiful color	North
Perennial ryegrass	Winter grass; fine texture	South
Red fescue	Drought- and shade-tolerant; fine texture	North
St. Augustine	Drought-tolerant; coarse texture	South
Tall fescue	Coarse texture; drought-tolerant	North
Zoysia	Dense growth; low water need	South

End