

Why study plants?



Plants, like most animals, are multicellular eukaryotes

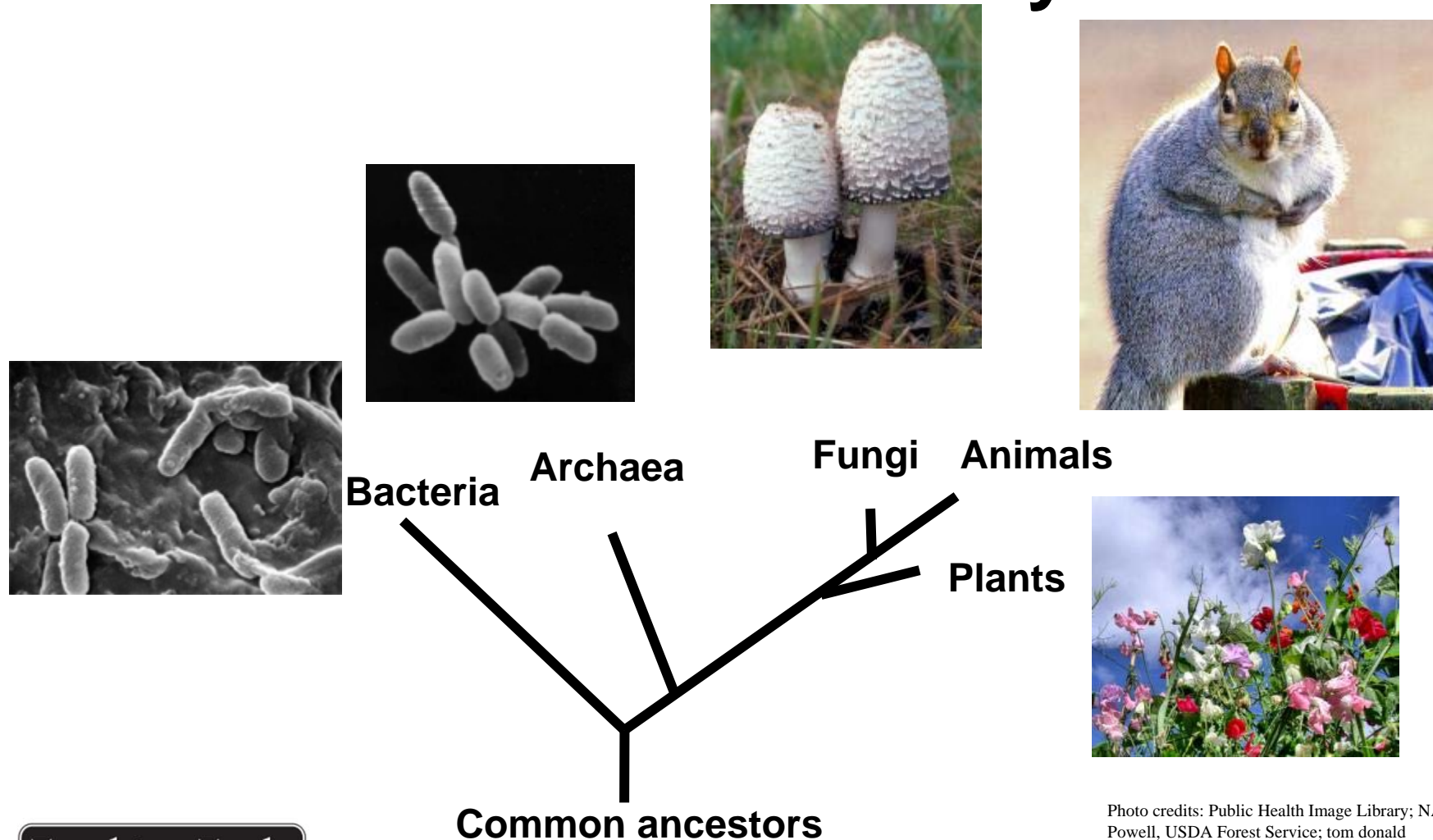
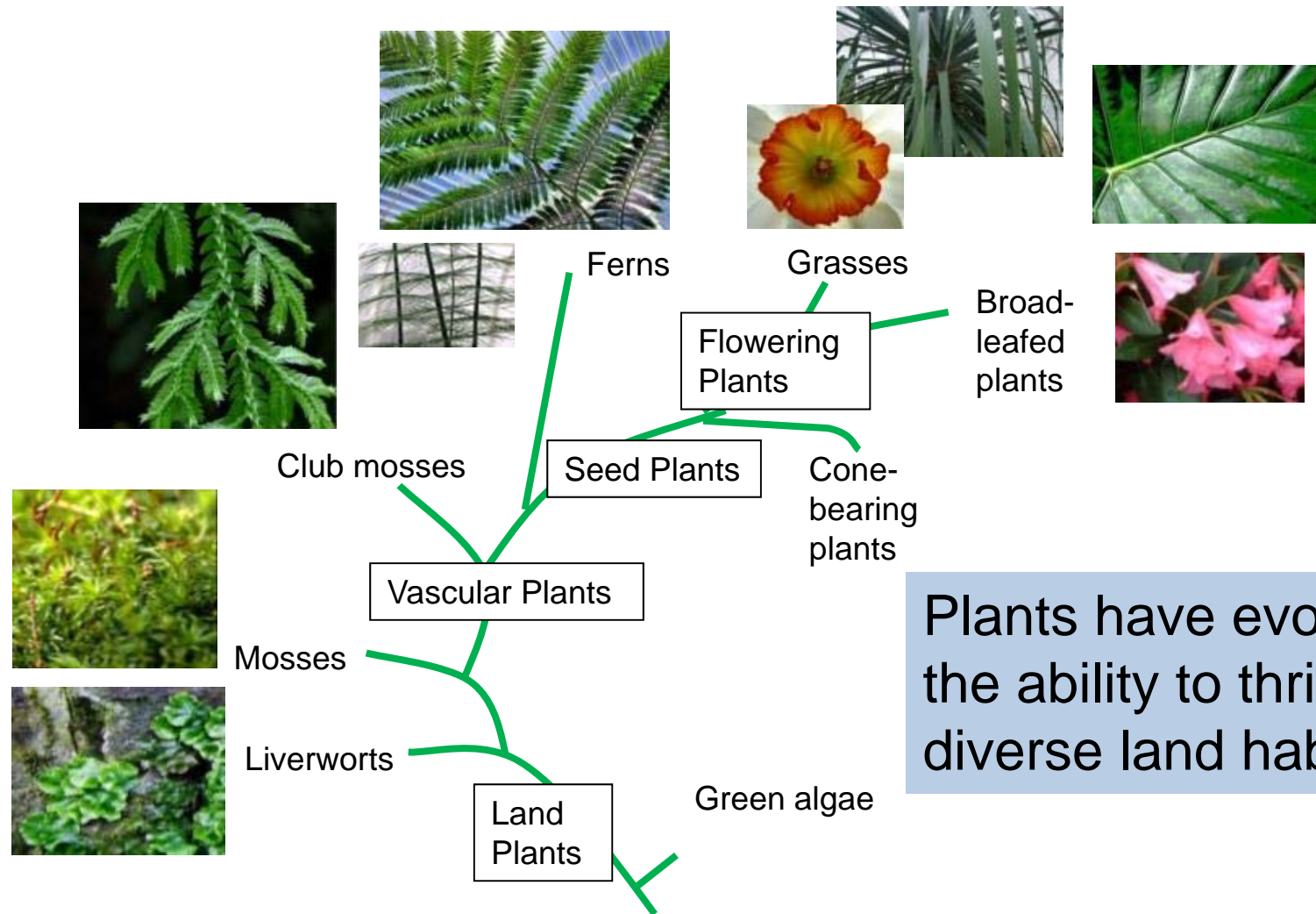


Photo credits: Public Health Image Library; NASA; © Dave Powell, USDA Forest Service; tom donald

Plants are diverse



Plants have evolved the ability to thrive in diverse land habitats.

Plants make us happy



People at work who can see plants report significantly greater job satisfaction than those who can't.

Plants are amazing living organisms

Largest flower (~ 1m)



Longest living (~ 5000 years)

Largest organism (> 100m)

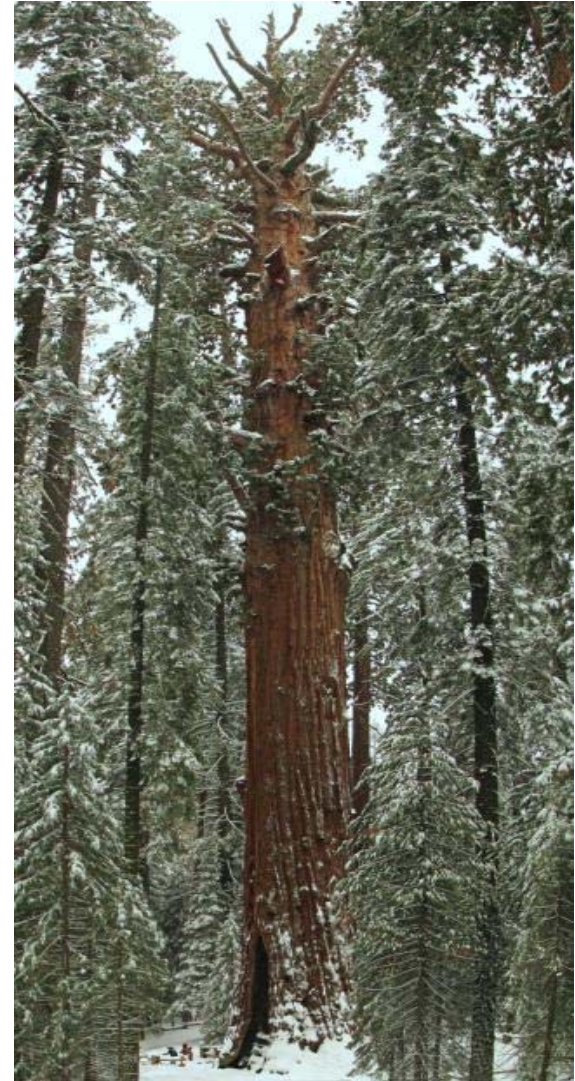


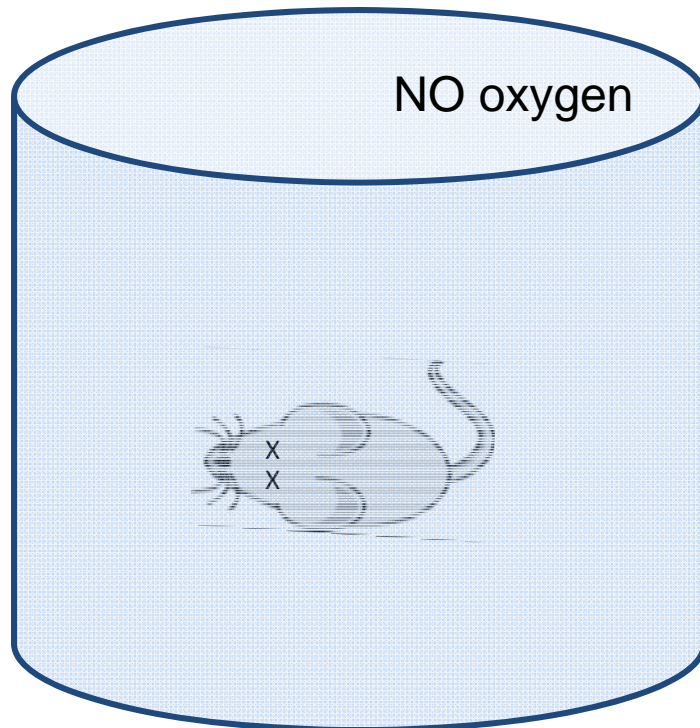
Photo credits: [ma_suska](#); [Bradluke22](#); [Stan Shebs](#)

We could not live without plants

- Plants produce most of the oxygen we breathe.
- Plants produce most of the chemically stored energy we consume as food and burn for fuel.
- Plants produce an amazing assortment of useful chemicals.



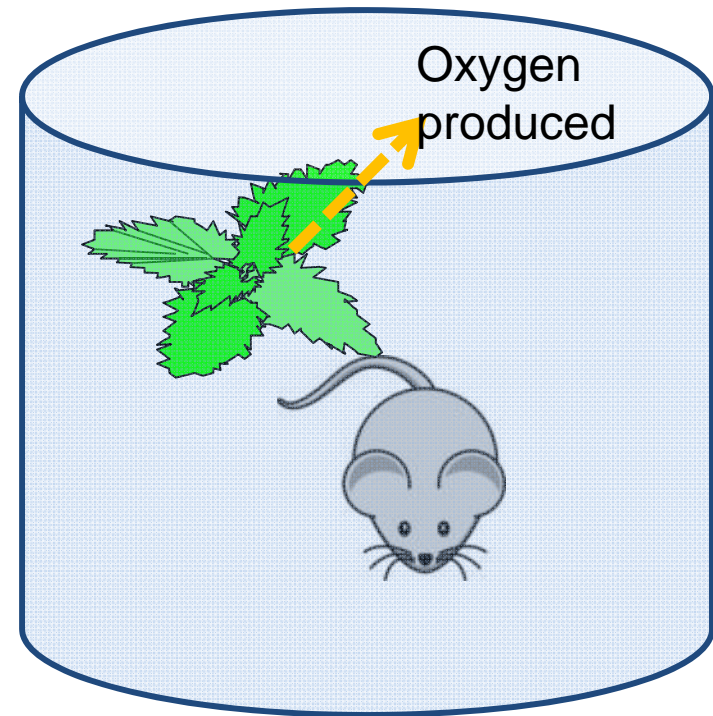
We can't live without oxygen!



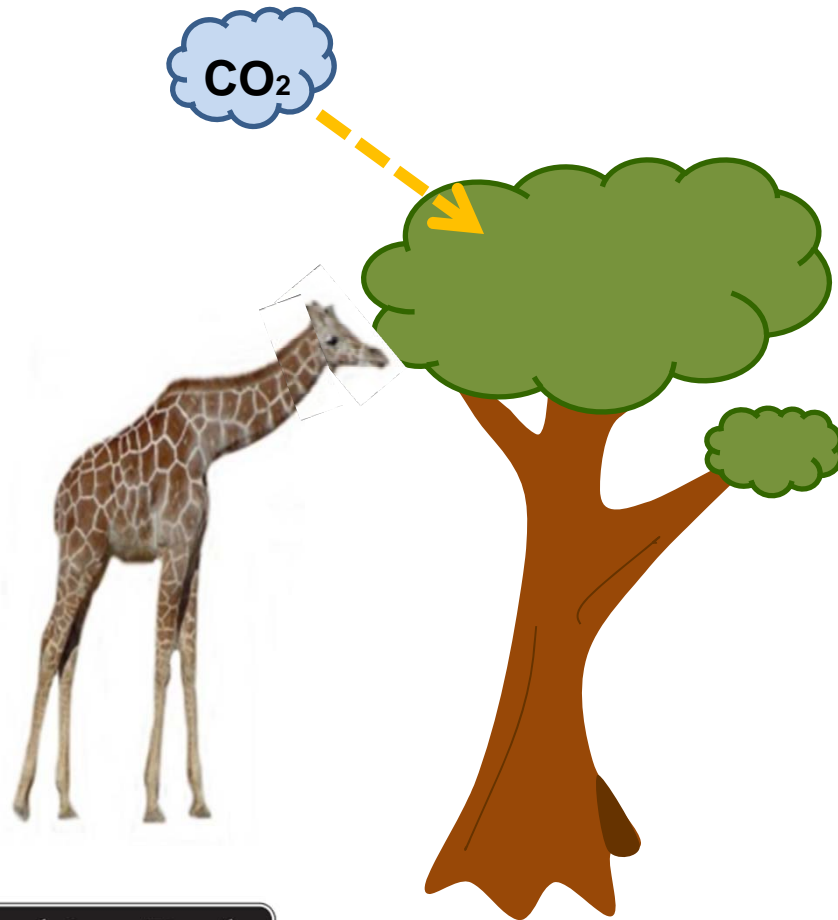
Joseph Priestley recognized that an animal's breathing "injured" air. An animal kept in a sealed container would eventually pass out.

We can't live without oxygen!

Priestley also recognized that plants have the ability to “restore” the air. We now know that they produce oxygen as a by-product of photosynthesis.

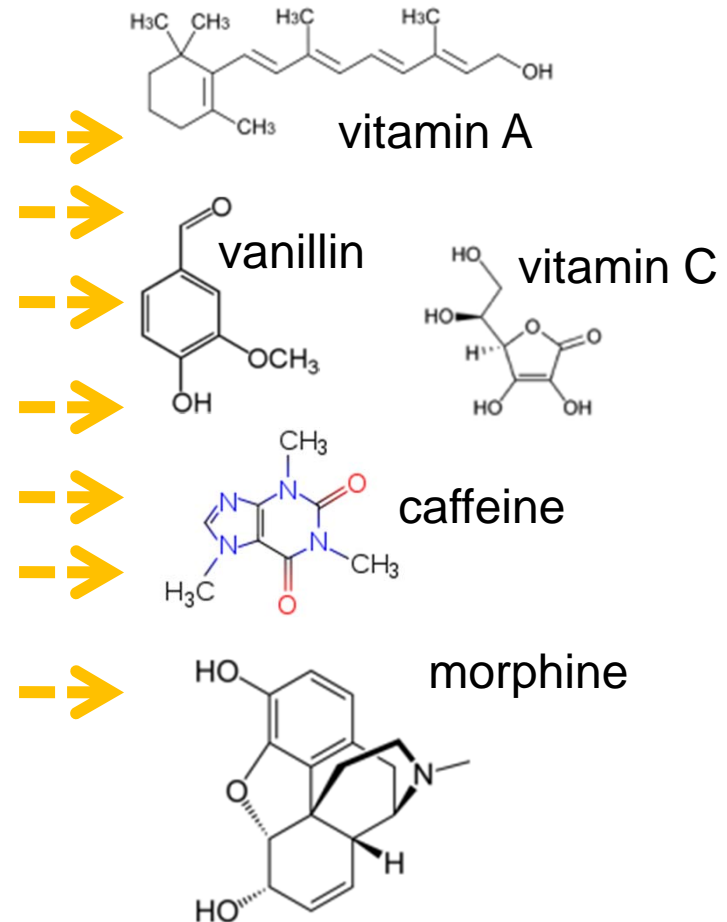
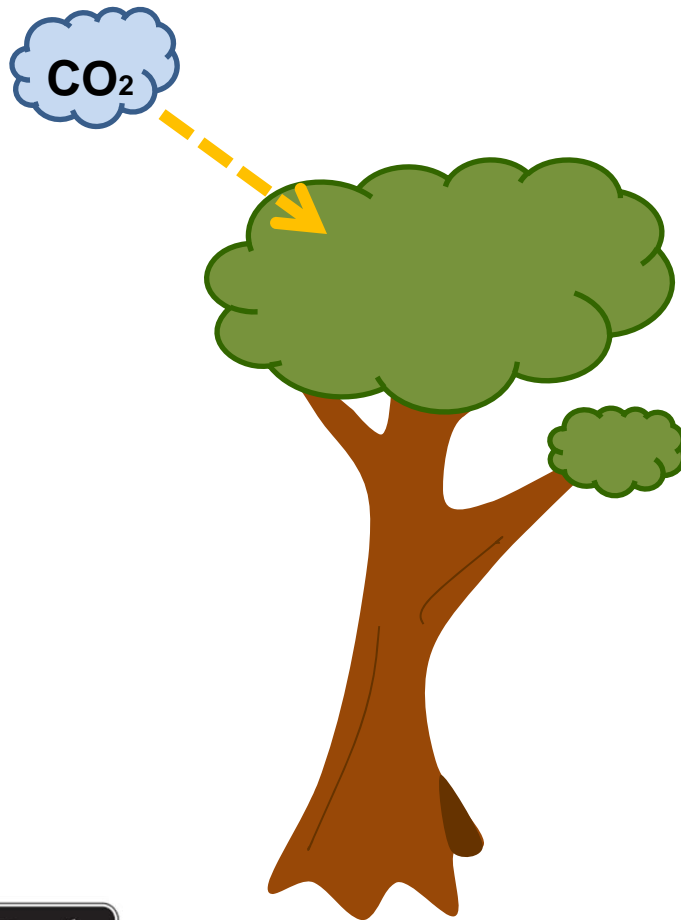


Plants fix carbon dioxide into energy- rich molecules we animals can use as food



Plants convert CO₂ gas into sugars through the process of **photosynthesis**.

Plants can produce an amazing assortment of chemicals



Why study plants?



To help conserve endangered plants and threatened environments

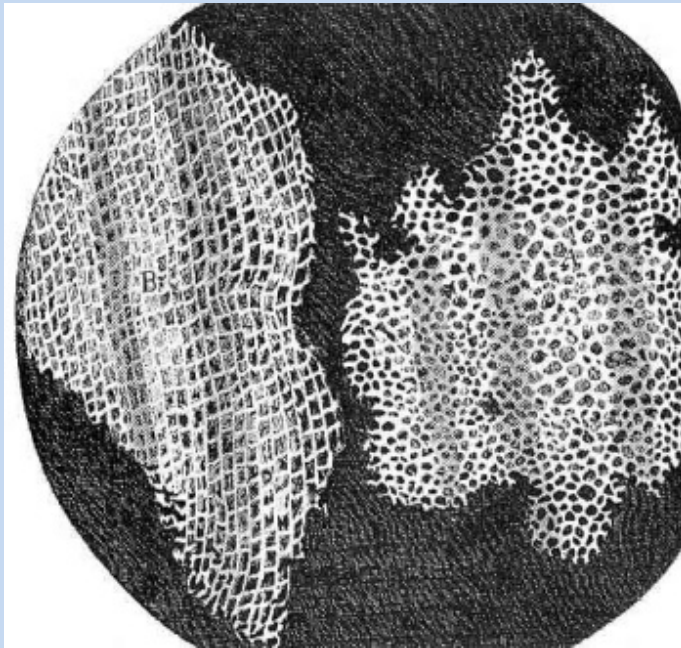
To learn more about the natural world

To better harness the abilities of plants to provide us with food, medicines, and energy

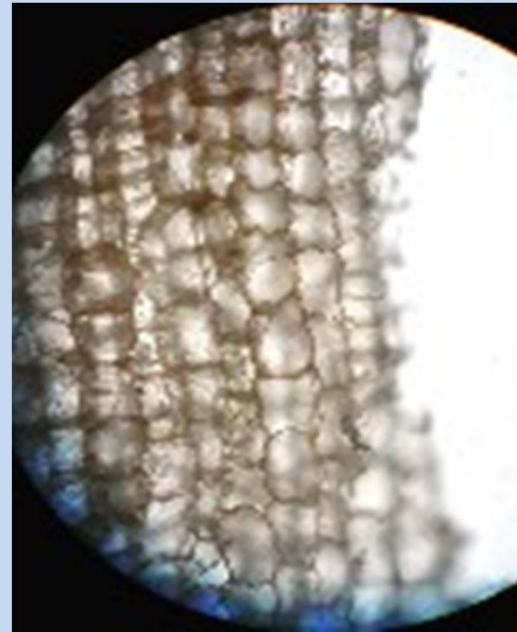
Photo credit: [tom donald](#)

Studying about plants informs us about our world

Cells were first observed in plants.



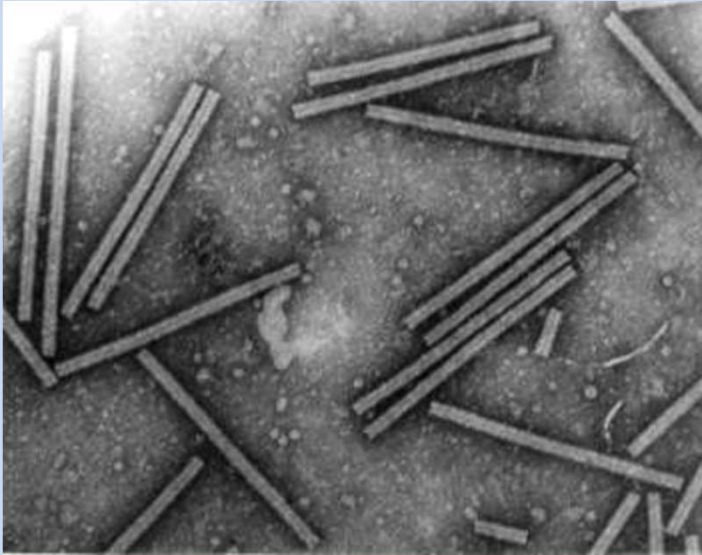
Drawing of cork by Robert Hooke, discover of "cells"



Photograph of cork cells

Photo credit: [©David B. Fankhauser, Ph.D](#)

Viruses were first purified from plants



Tobacco Mosaic Virus

Viruses infect humans as well as plants, causing many diseases including AIDS, hepatitis, SARS, swine flu, cervical cancer, chicken pox, and polio.



Image Copyright 1994 Rothamsted Research.

Mendel's studies of peas revealed the laws of inheritance



Mendel's studies of peas revealed the laws of inheritance

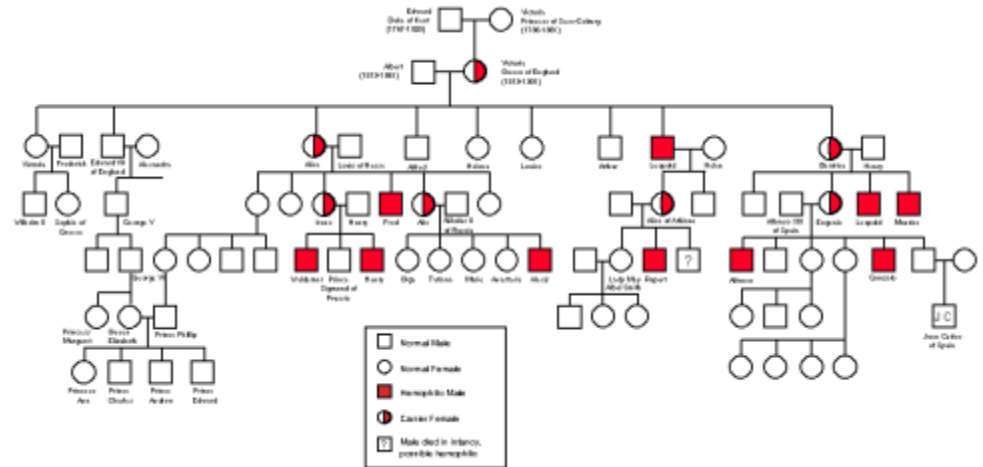


...which help us understand human diseases such as sickle cell anemia...

Mendel's studies of peas revealed the laws of inheritance



...and hemophilia, as well as countless other human diseases that have a genetic contribution.



Pedigree of family carrying hemophilia allele

Mendel's studies of peas revealed the laws of inheritance



Mendel's work laid the foundation for the sciences of plant genetics and plant breeding.



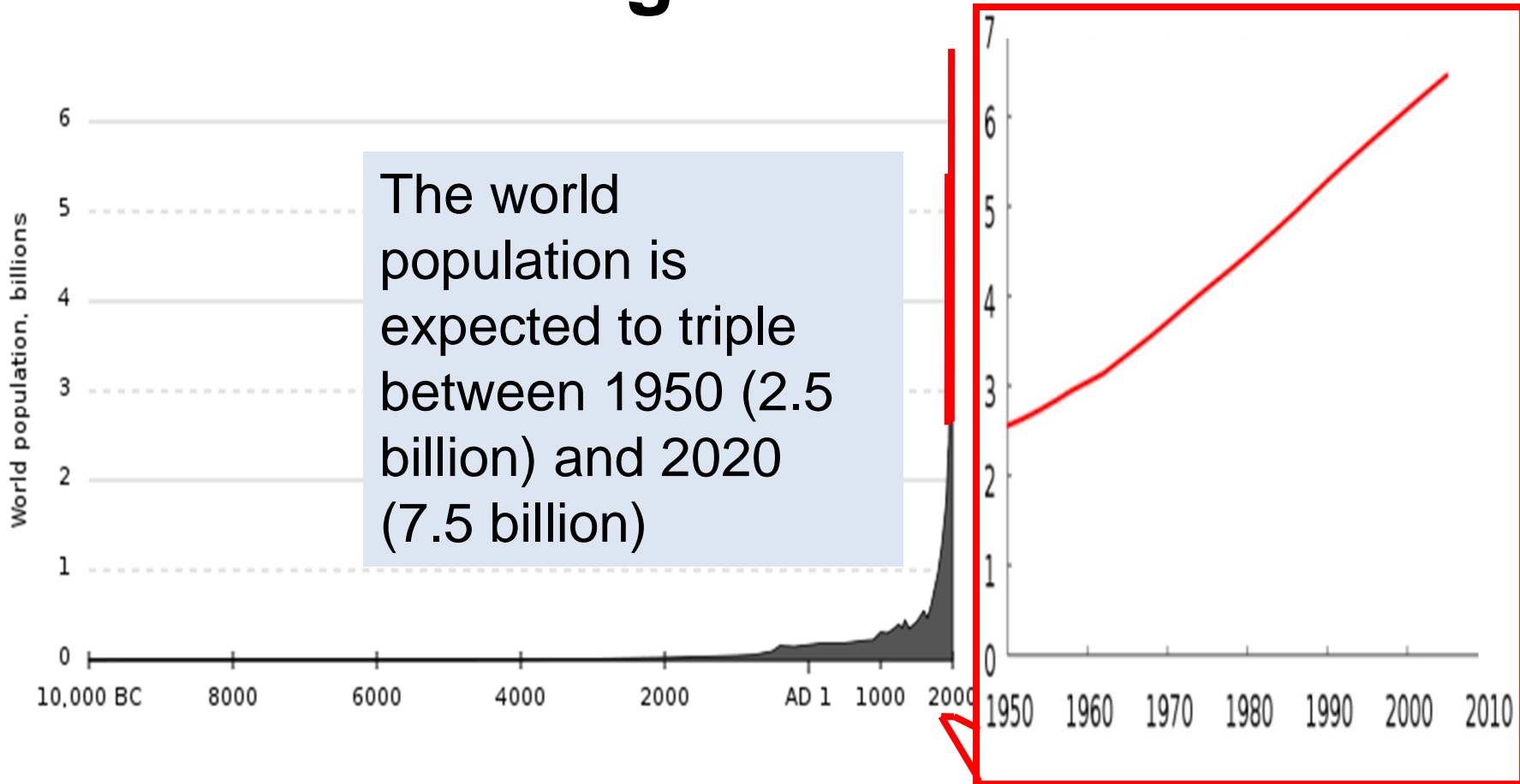
Distinguished
plant breeder

[Norman
Borlaug](#)

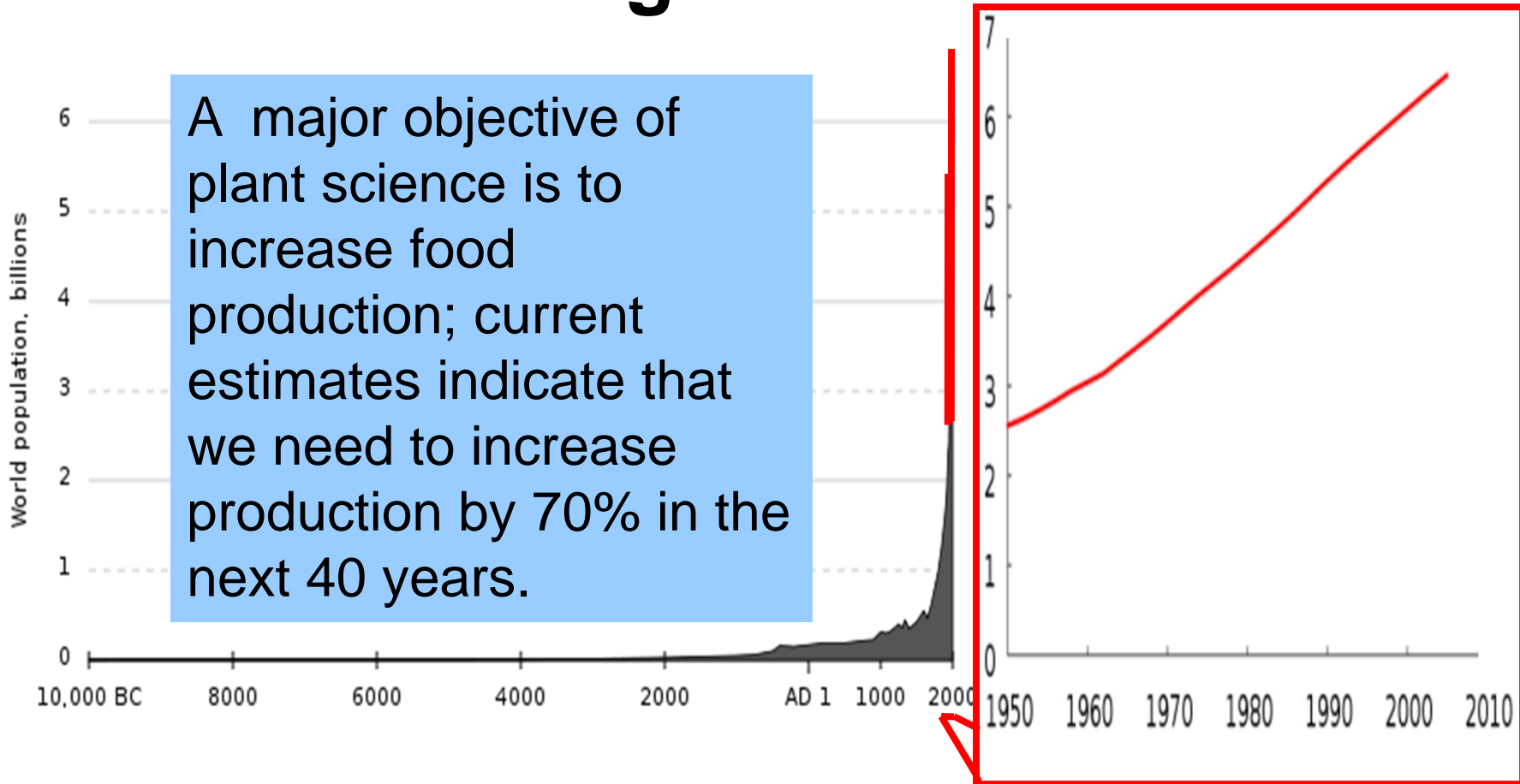
1914-2009

WHY STUDY PLANTS?

The world population grows and grows ...



The world population grows and grows ...




Malnutrition and hunger disproportionately kill children



In 2004, 60 million people worldwide died.

(Source: [World Health Organization](#), 2008)

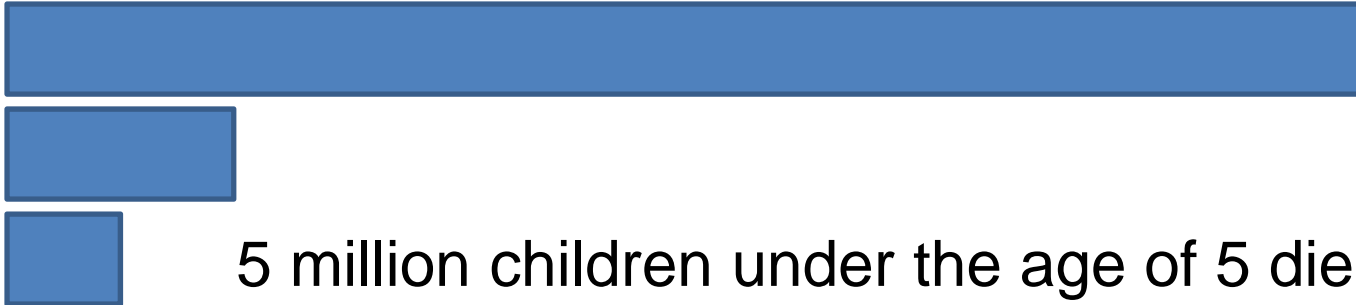
Malnutrition and hunger disproportionately kill children



10,000,000 of them were children under 5 years of age, of which 99% lived in low- or middle-income countries

(Source: [The State of the World's Children](#), UNICEF, 2007)

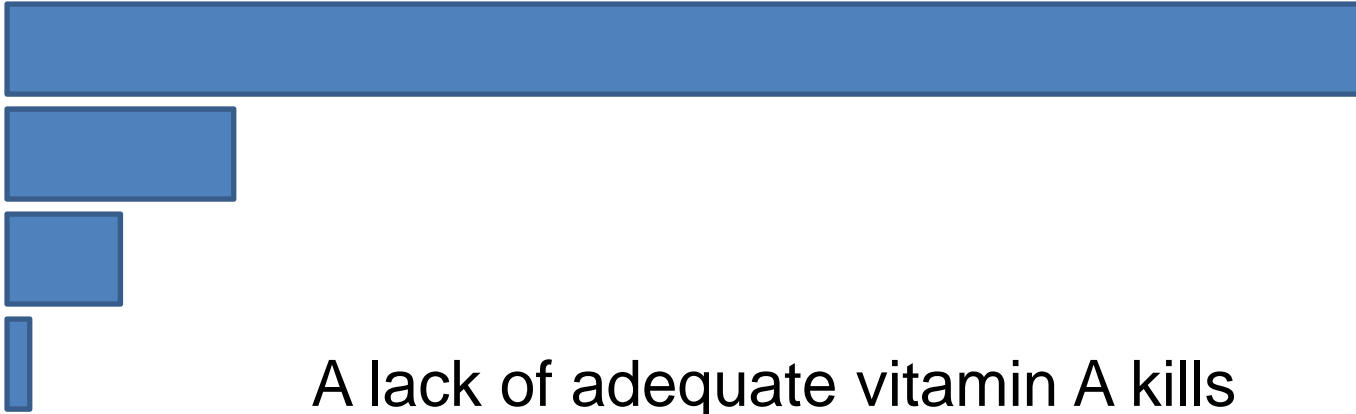
Malnutrition and hunger disproportionately kill children



5 million children under the age of 5 die each year due to **undernutrition** and related causes.

That's one preschool-aged child dying a preventable death every six seconds.

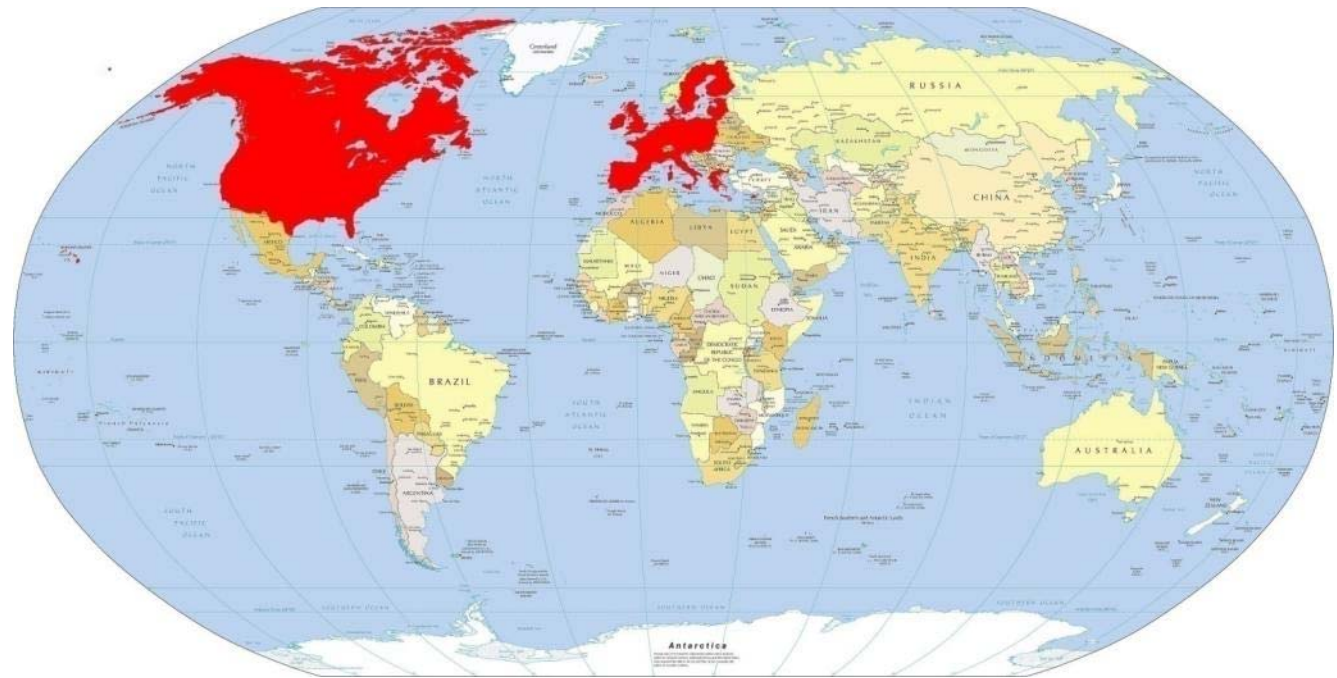
Malnutrition and hunger disproportionately kill children



A lack of adequate vitamin A kills one million children a year.

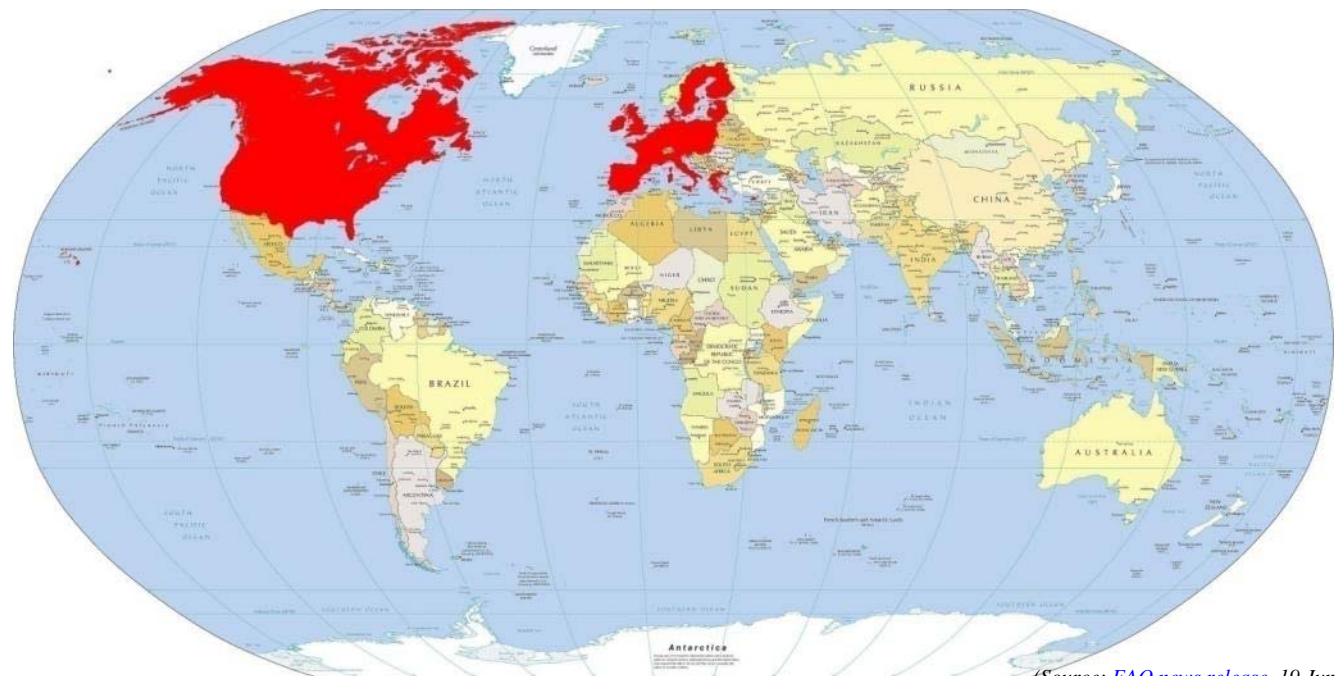
(Source: Vitamin and Mineral Deficiency, A Global Progress Report, UNICEF)

How would the world respond to a disease that affected the population of the USA, Canada, and the European Union?



Globally, more than **one billion** people per year are chronically hungry

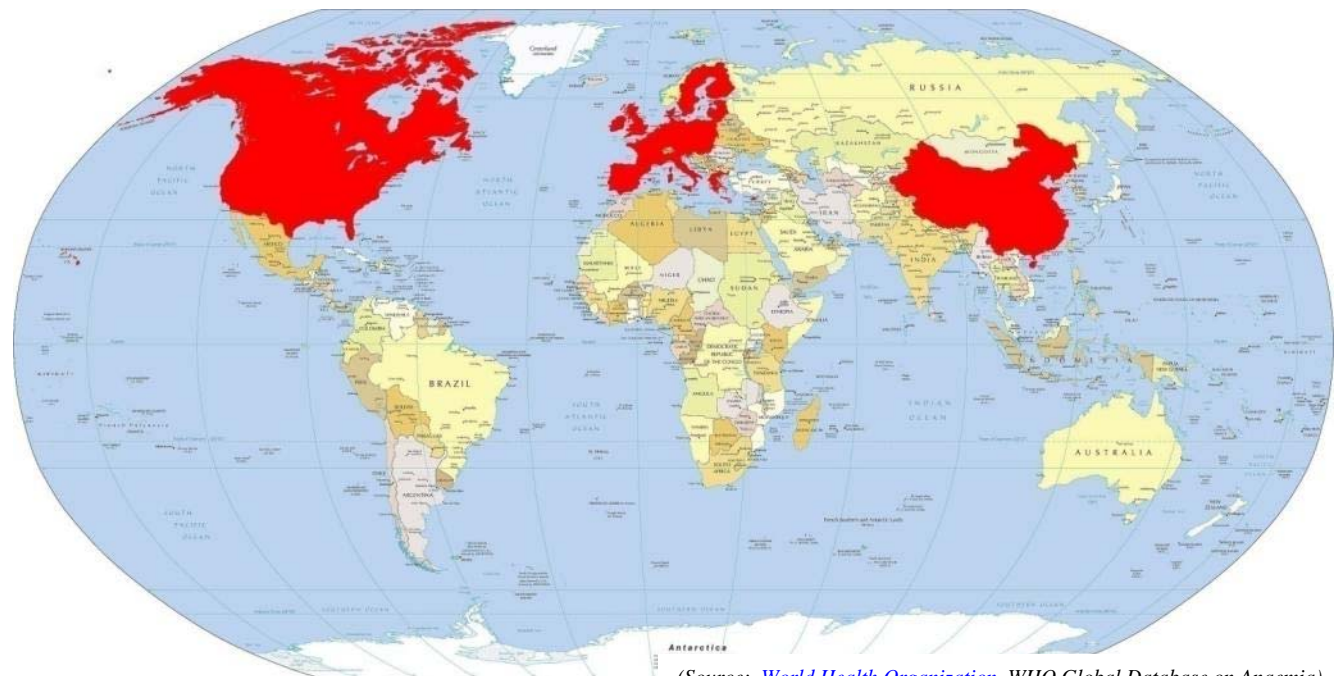
That's *more* than the total population of the USA, Canada and the EU.



(Source: [FAO news release](#), 19 June 2009)

More than *two billion* people per year are chronically anemic due to iron deficiency

That's about the total population of the USA, Canada, the EU, and China.



(Source: [World Health Organization](#), WHO Global Database on Anaemia)

WHAT CAN SCIENTISTS DO ABOUT THIS?

Plant scientists can contribute to the alleviation of hunger

By developing plants that

- are drought or stress tolerant
- require less fertilizer or water
- are resistant to pathogens
- are more nutritious



Plant growth is often limited by drought stress

Areas of physical and economic water scarcity

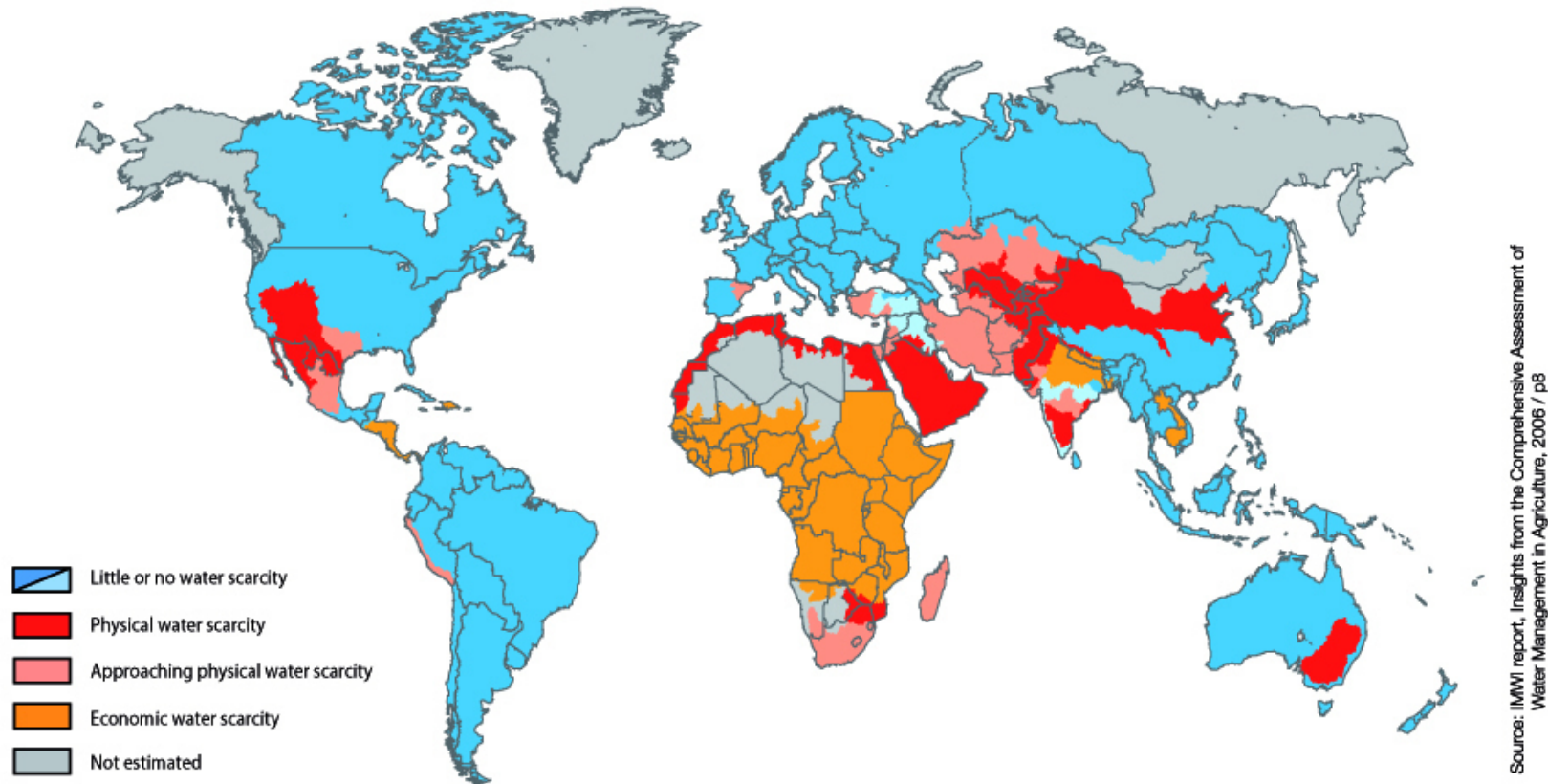
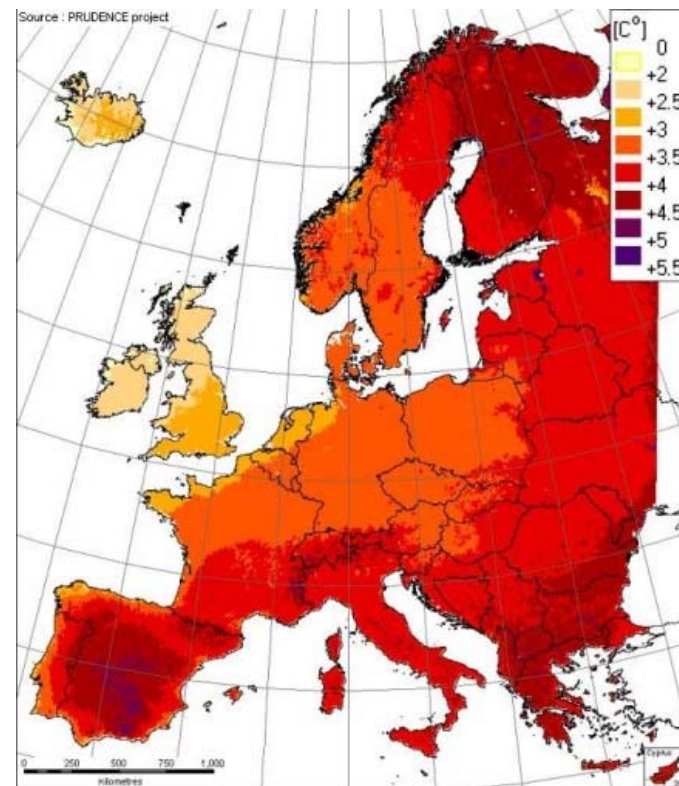


Image source: [IIMI](#)

Drought stress is compounded by increased global temperatures

Temperature change forecast 2071-2100 period, relative to the 1961-1990 period.

In warm regions, crop yields can drop ~3 – 5% with every 1°C increase in temperature.



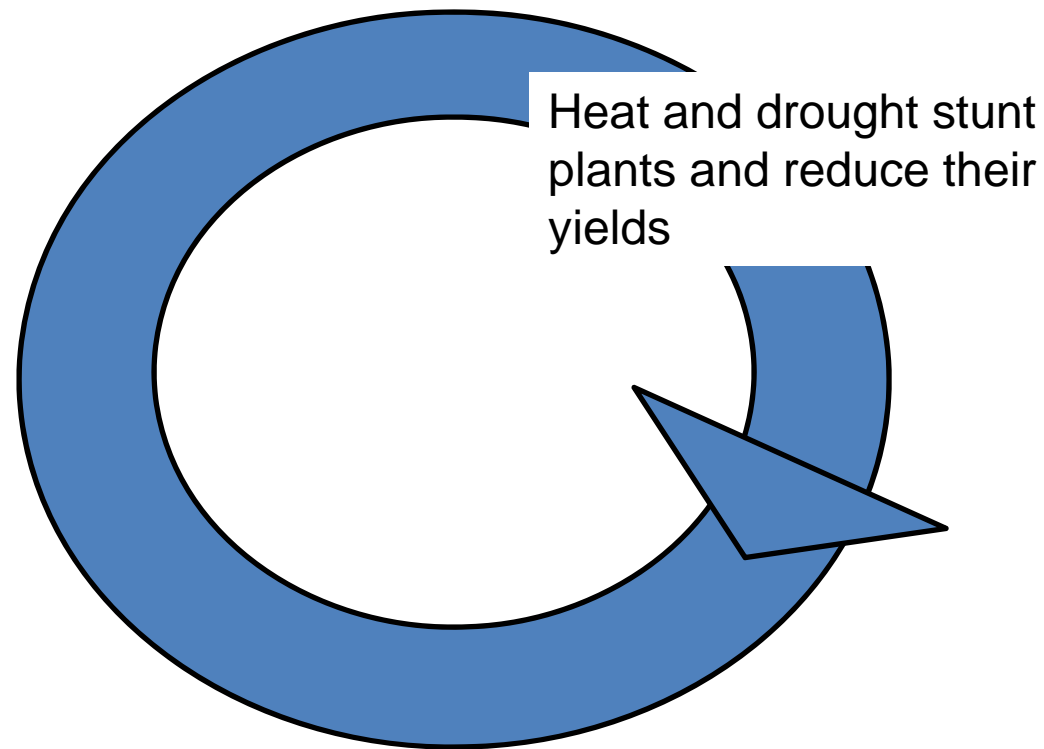
© European Communities, 1995-2009. Image Source: [The PESETA Project](#)

Even mild drought stress reduces yields

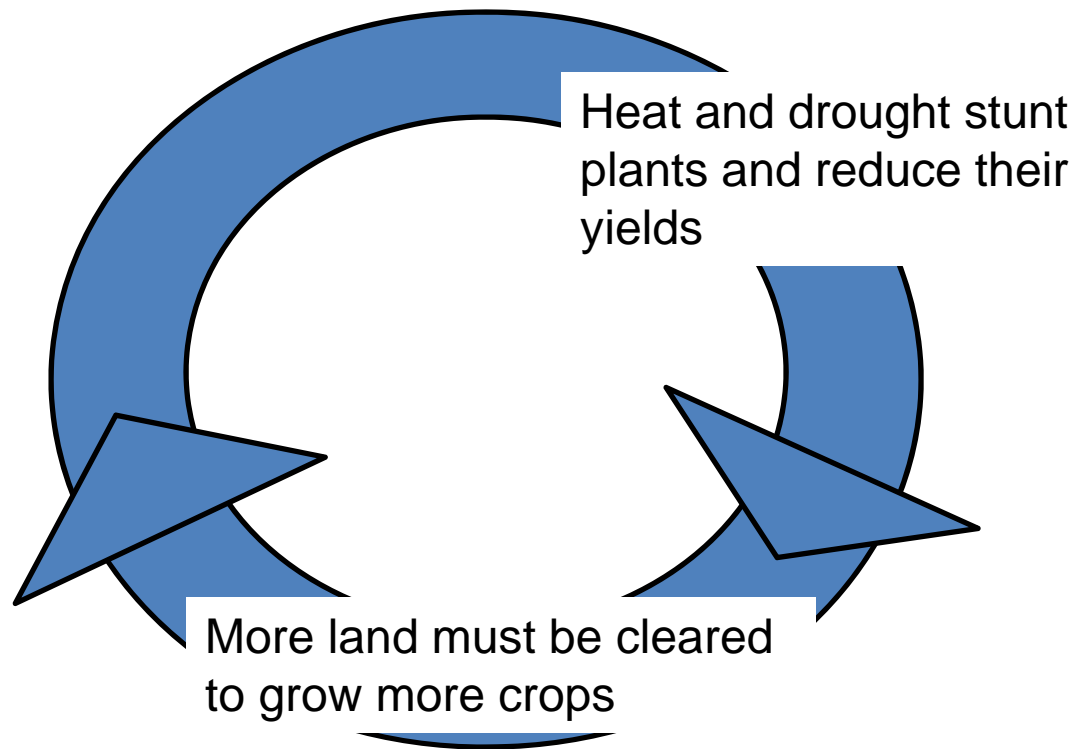
Mild drought stress reduces the rate of photosynthesis and growth, whereas extreme drought stress is lethal.



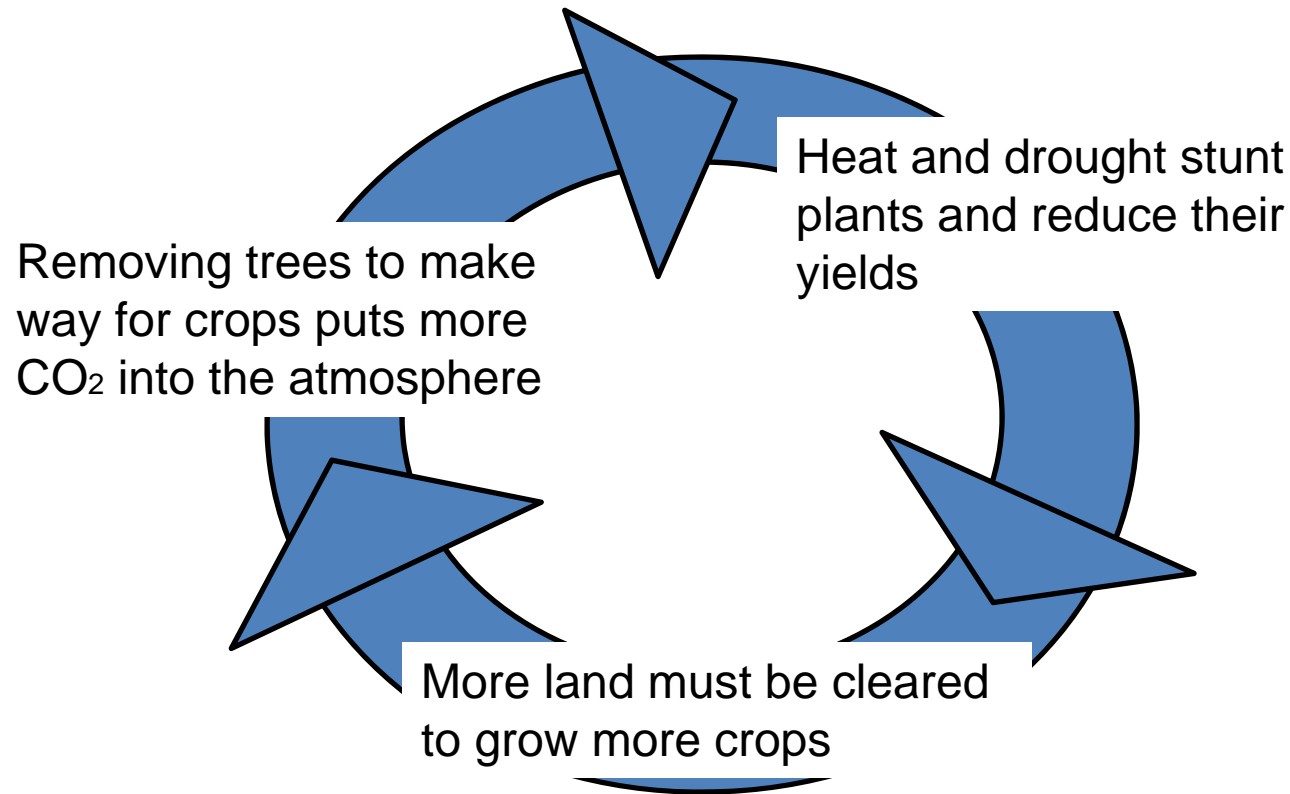
We need plants that grow well even under stressful conditions



We need plants that grow well even under stressful conditions



We need plants that grow well even under stressful conditions

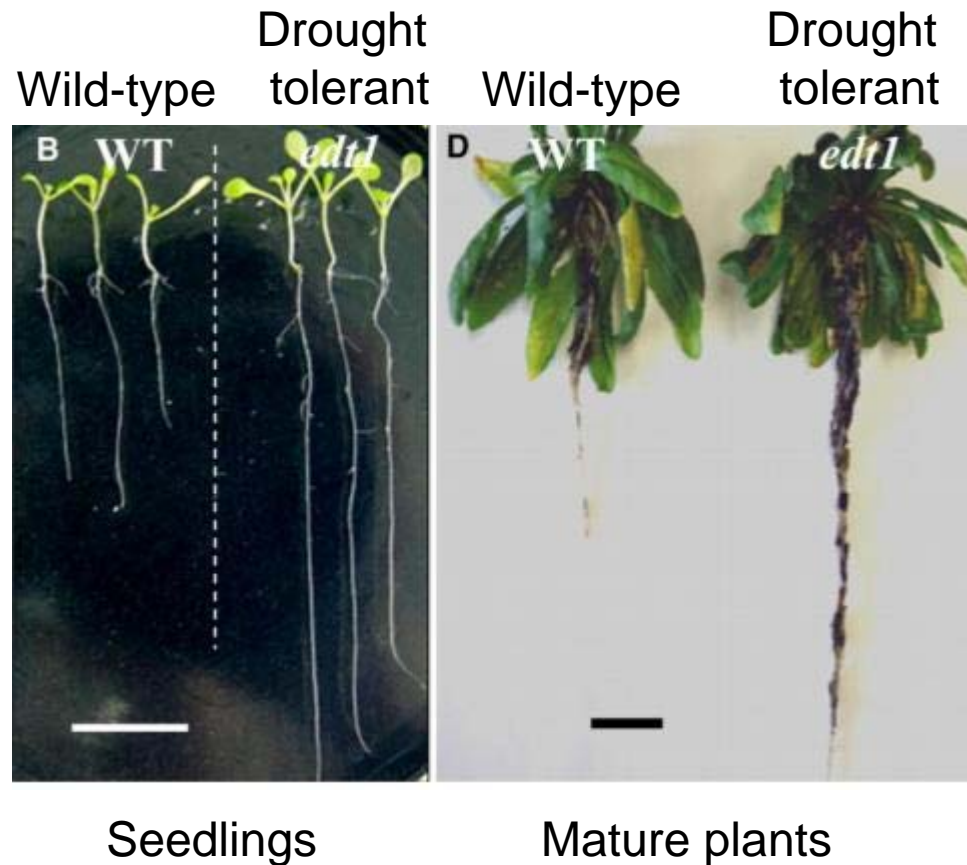


Altering a single gene can increase plants' drought tolerance



Yu, H., et al. Plant Cell 2008;20:1134-1151

A larger root system contributes to drought tolerance



Breeding plants for larger root systems can help them grow in drought-prone regions.

Yu, H., et al. Plant Cell 2008;20:1134-1151

Agricultural fertilizer use is a considerable source of environmental pollution

Fertilizer run-off causes dead zones, algal blooms that then decay, reducing oxygen levels in the water and making animal life impossible

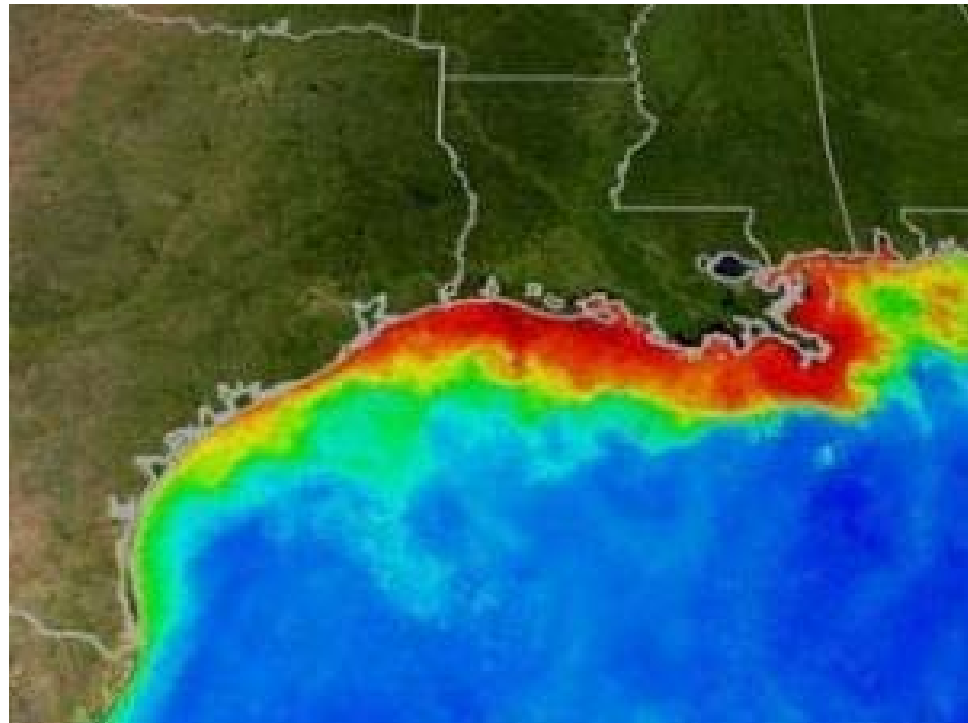
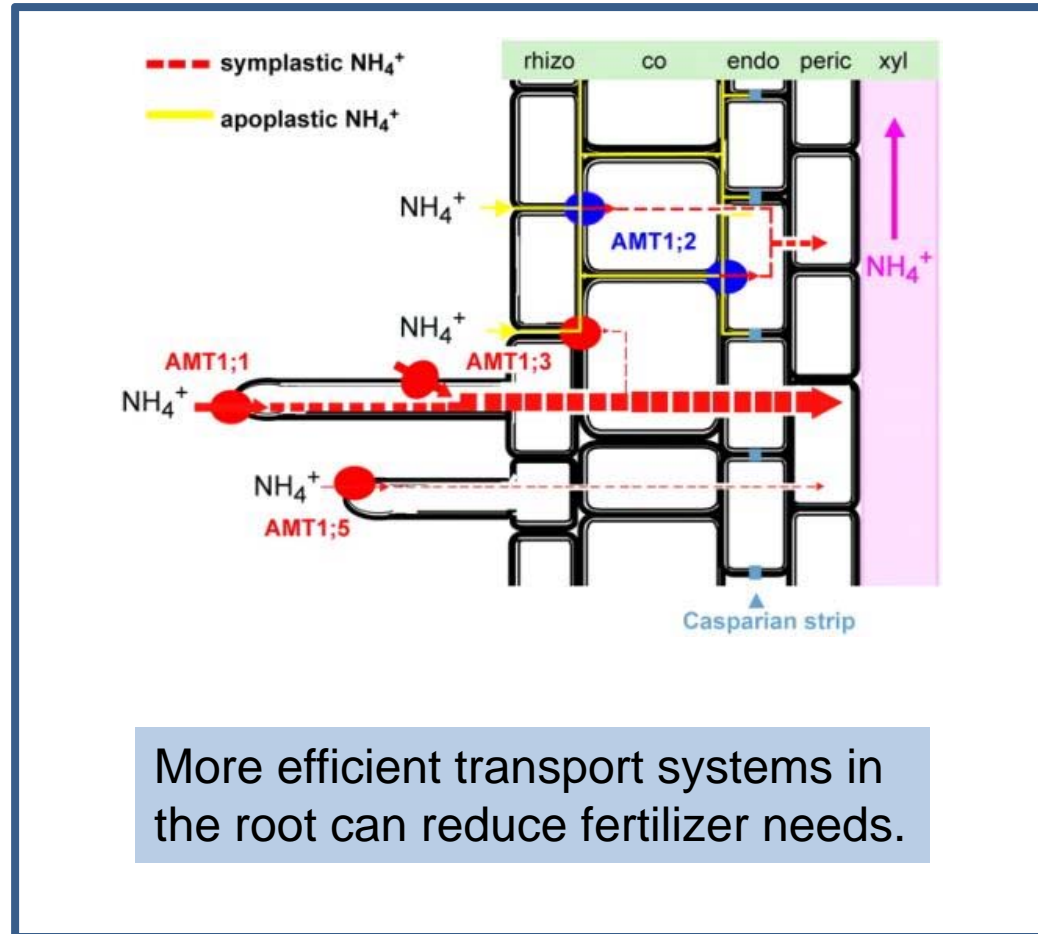


Photo courtesy of NASA/Goddard Space Flight Center Scientific Visualization Studio)

Plant nutrient uptake can be improved



Yuan, L., et al. (2007) Plant Cell;19:2636-2652

Perennial plants uptake water and nutrients better than most crop plants



Scientists are crossing crop plants with perennial plants to reduce crop plants' dependency on fertilizers and water

Wes Jackson of the Land Institute holding a perennial wheat relative *Thinopyrum intermedium*

Photo credit: Jodi Torpey, westerngardeners.com

Right now, two serious diseases threaten the world's food supply

Phytophthora infestans, cause of potato late blight, has re-emerged as a threat.



Puccinia graminis tritici, the wheat stem rust fungus, has developed into a highly aggressive form.

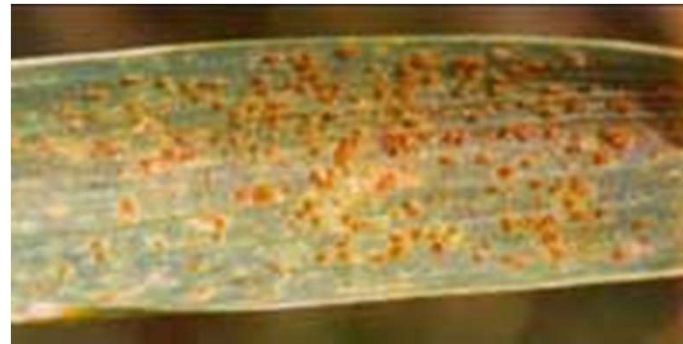


Photo credits: www.news.cornell.edu; www.fao.org

Late blight destroys potato plants



Potato late blight disease is caused by *Phytophthora infestans*. Outbreaks in the 1840s ruined crops and contributed to more than a million deaths in Europe.



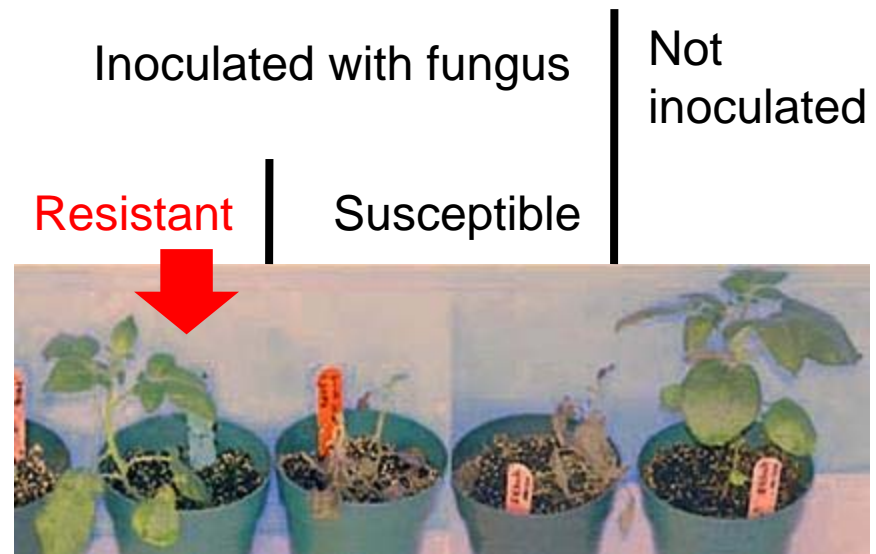
Infected

Treated

. (Photo credits: USDA; Scott Bauer)

Identification of resistance genes

Geneticists have identified the gene conferring resistance and are introducing it into edible varieties.



The plant on the left carries the resistance gene and is free from disease symptoms.

Song, J. et al.,(2003) PNAS 100: 9128-9133; Copyright (2003) National Academy of Sciences, U.S.A.

Wheat stem rust is an emerging threat

- A new, highly pathogenic strain emerged in Uganda in 1999 – it is called Ug99.
- Most wheat has no resistance to this strain.



Infected wheat plant

Photo credit: [ARS USDA](#)

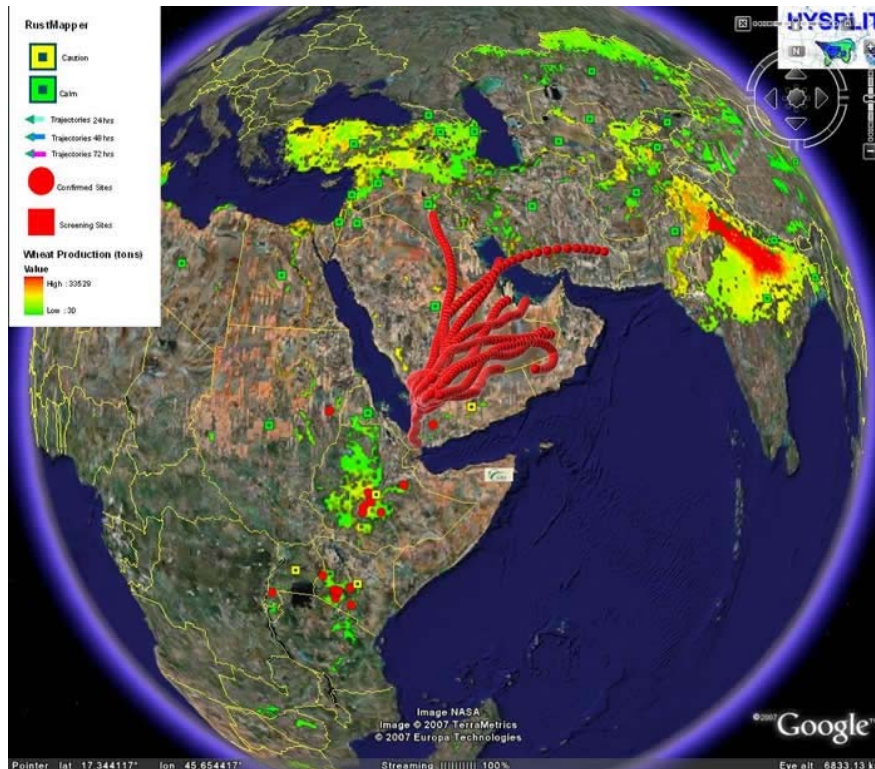
Ug99 threatens wheat everywhere



This is a global problem that needs global attention. Ug99 spores do not stop at national borders...

– *United Nations Food and Agriculture Organization (FAO)*

The fungus is carried by wind

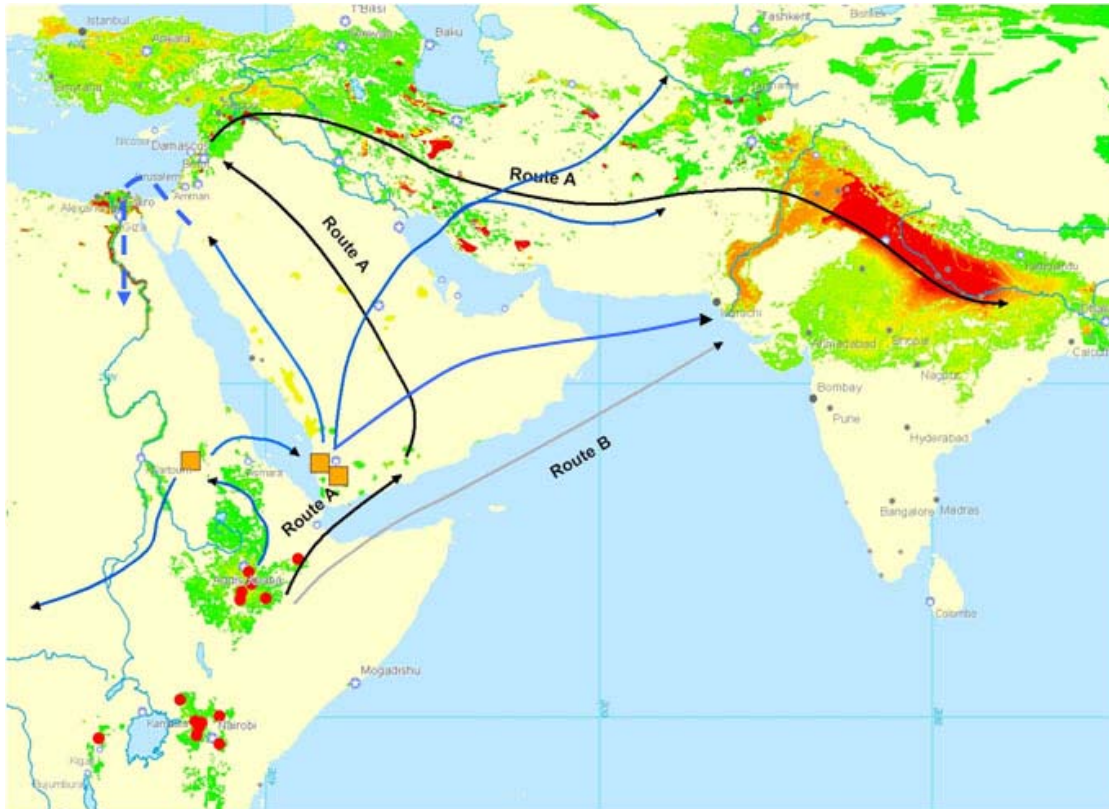


Ug99 is found in Uganda, Kenya, Ethiopia, Sudan, Yemen, and Iran, and threatens regions of the near east, eastern Africa, and central and southern Asia.

Wind currents carrying spores are shown in red.

Photo credit: www.wheatrust.cornell.edu

The fungus is carried by wind



Probable Ug99 trajectories

Wheat is the major food crop in many of these threatened regions, especially for the poorest inhabitants.



International teams of scientists are cooperating to monitor the spread of Ug99 and develop wheat strains that resist it.

At this time, no one knows if resistant strains will be developed in time to avoid a major famine...

Photo credits: [Bluemoose](#); [FAO](#)

Plant biologists study ways to keep plants fresh after harvesting



After harvesting, fruits soften, ripen, and eventually rot.

These processes make the fruit less appealing and affect the nutritional qualities.



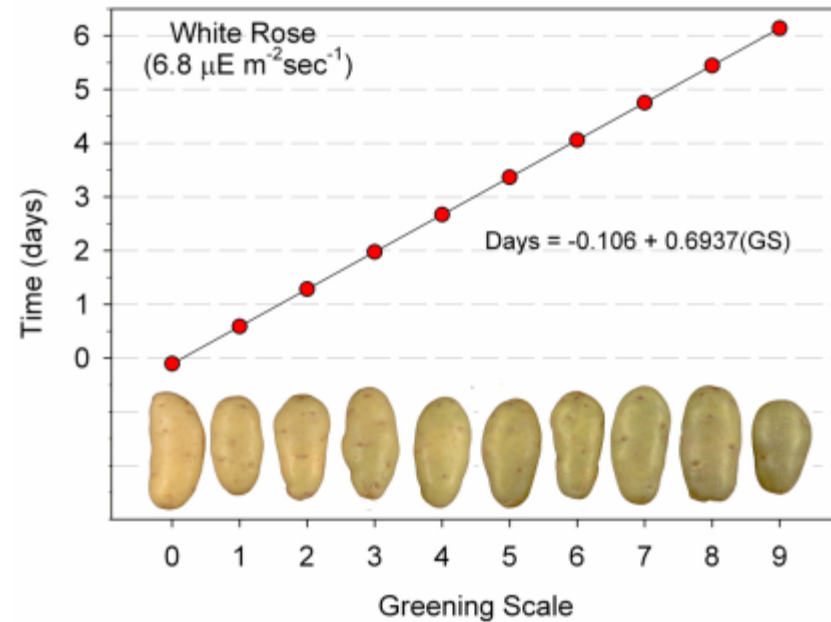
Photo credits: [Cornell University](#) ; [ARC](#)

Plant biologists study ways to keep plants fresh after harvesting

Post-harvest losses can ruin 50% or more of a grain harvest.

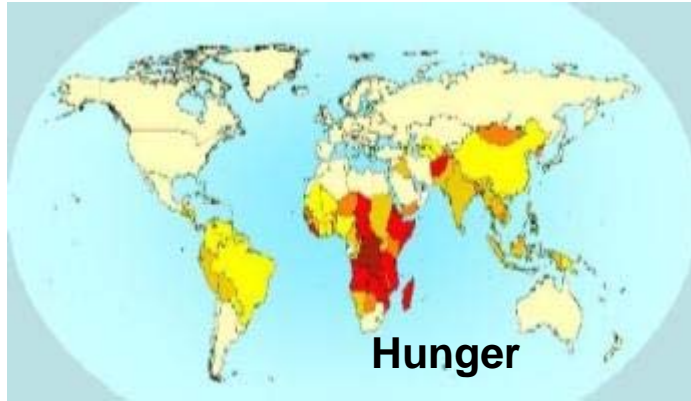


Aspergillus mold growing on corn kernels.



Greening along with solanine production can occur in improperly stored potatoes. Solanine is harmful and can be toxic in large quantities.

Improved nutrient content in plants can help alleviate malnutrition



Subsistence level diets are usually nutrient-poor. Our bodies need vitamins and minerals as well as calories. Malnutrition is primarily a disease of poverty.

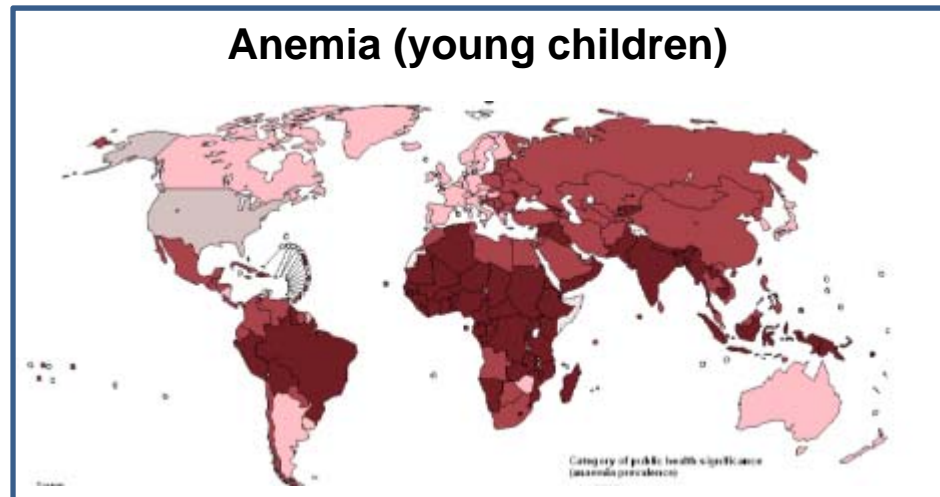
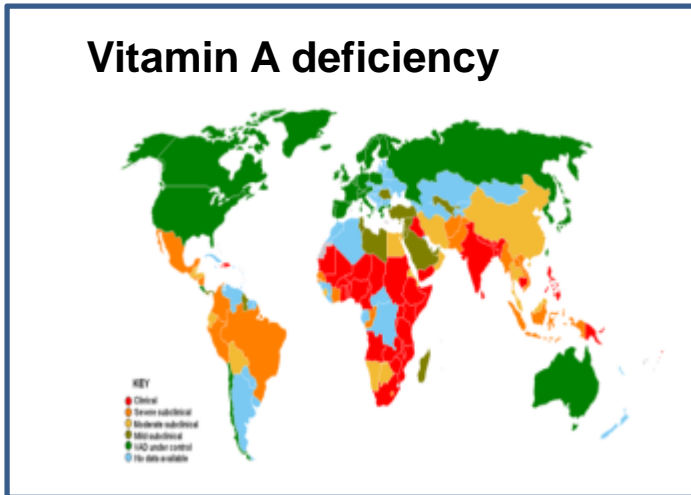


Image sources: [Petaholmes](#) based on [WHO data](#); [WHO](#)

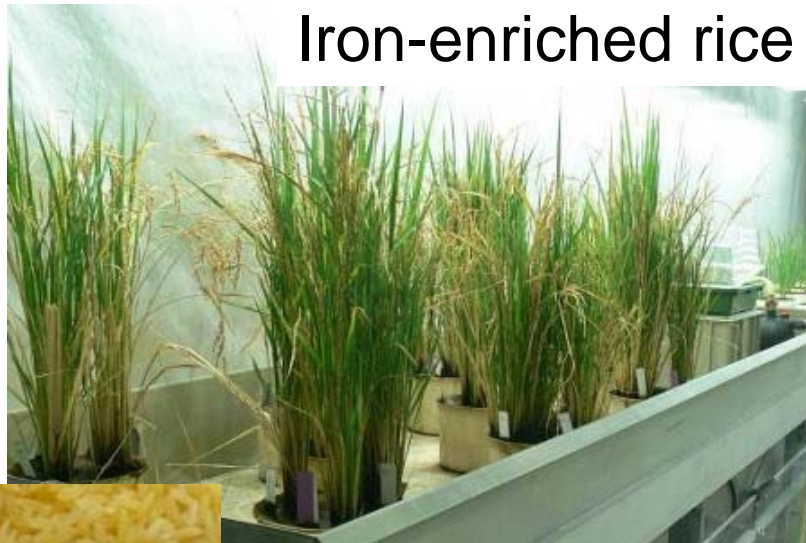


The practice of fortifying foods with vitamins (such as folate and vitamin A) and micronutrients (such as iron, zinc, and iodine) has dramatically reduced malnutrition in much of the world.

Photo credit: © UNICEF/NYHQ1998-0891/Giacomo Pirozzi

Genetically biofortified foods

Iron-enriched rice



0

Vitamin A–enriched rice



Wild-type (top) and antioxidant-enriched tomatoes

Photo credits: [Golden Rice Humanitarian Board © 2007](#); Credit: [ETH Zurich / Christof Sautter](#); Reprinted by permission from Macmillan Publishers, Ltd: Butelli, E., et al., Nature Biotechnology 26, 1301 - 1308 copyright (2008).

Plants provide us with more than food



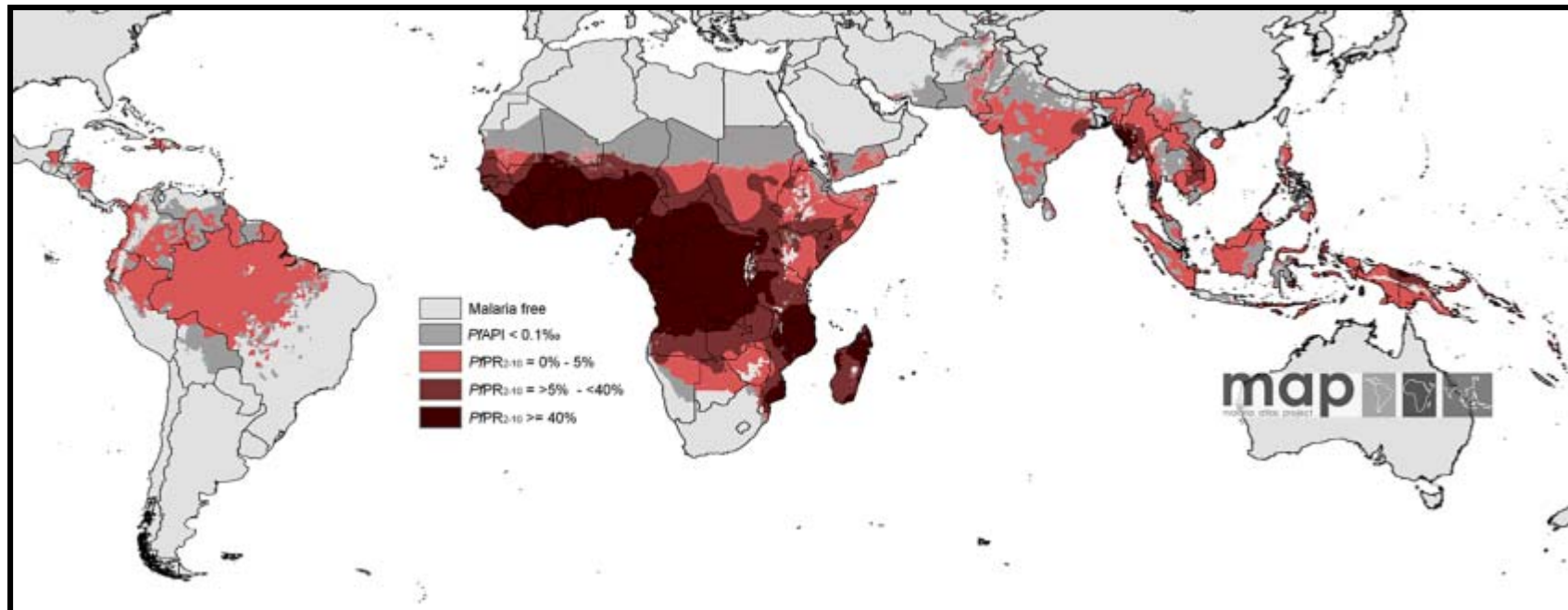
Plants:

- are sources of novel therapeutic drugs
- provide better fibers for paper or fabric
- are sources of biorenewable products
- provide renewable energy sources

Plants produce hundreds of compounds we use as medicines or drugs

- **Willow** (*Salix*) bark as a source of aspirin (acetylsalicylic acid)
- **Foxglove** (*Digitalis purpurea*) as a source of digitalis (treatment for cardiac problems)
- **Pacific yew** (*Taxus brevifolia*) as a source of taxol (treatment for cancer)
- **Coffee** (*Coffea arabica*) and **tea** (*Camellia sinensis*) as sources of caffeine (stimulant)

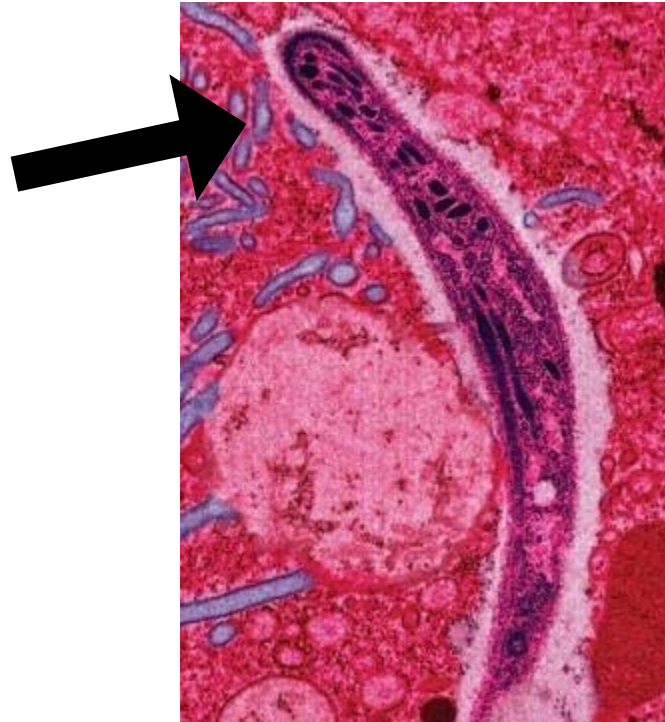
Malaria kills millions of people



The regions of the world with highest risk for malaria.

The protozoan *Plasmodium* causes malaria

Plasmodium
inside a
mouse cell



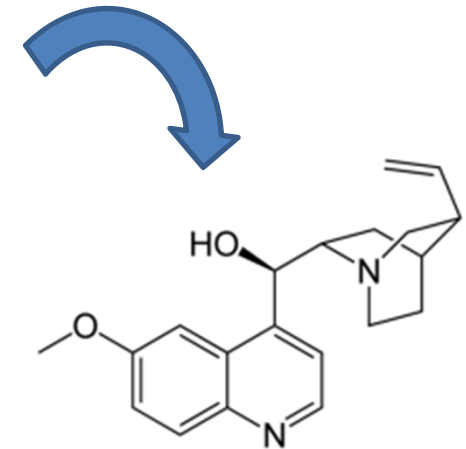
[Image by Ute Frevert; false color by Margaret Shear.](#)

Plasmodium is transferred into humans by infected mosquitoes



Photo credit: [CDC](#)

Cinchona tree bark contains a compound, quinine, that kills *Plasmodium*



But *Plasmodium* are developing resistances to quinine, so other sources of anti-malarial compounds must be found.

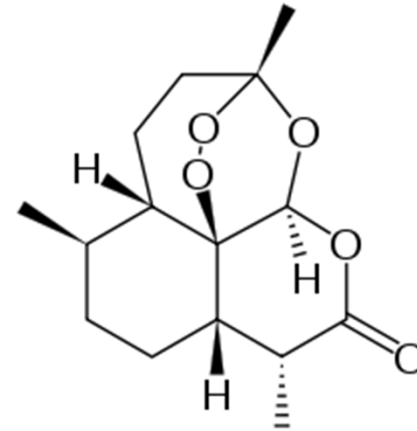
Gin and quinine?

British soldiers in tropical regions were given quinine pills to prevent malaria. To disguise its bitter flavor, quinine was mixed with sweet, carbonated water (“tonic”) and frequently also with gin – the origin of the “gin and tonic.”



(Crown copyright; Photograph courtesy of the Imperial War Museum, London - Q 32160)

Artemisia annua is a plant with novel antimalarial activities



Artemisinin

Artemisia has been used by Chinese herbalists for thousands of years. In 1972 the active ingredient, artemisinin, was purified.

Plant scientists are developing higher-producing *Artemisia*

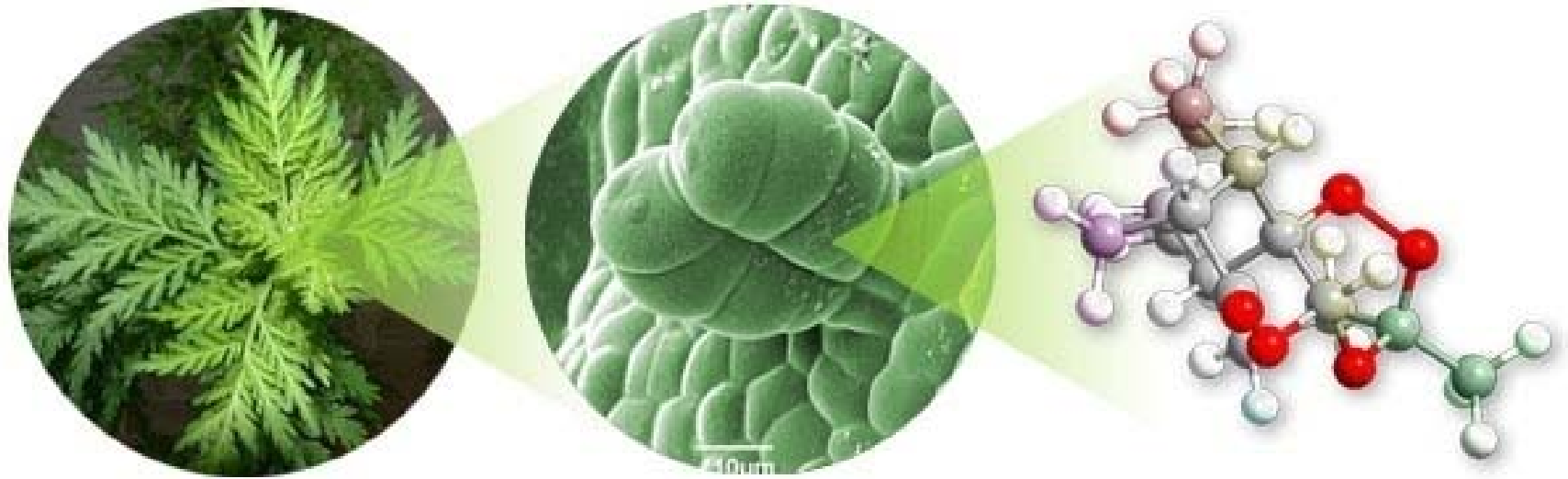


Photo credit: www.york.ac.uk/org/cnap/artemisiaproject/

Plant cell walls provide important durable materials

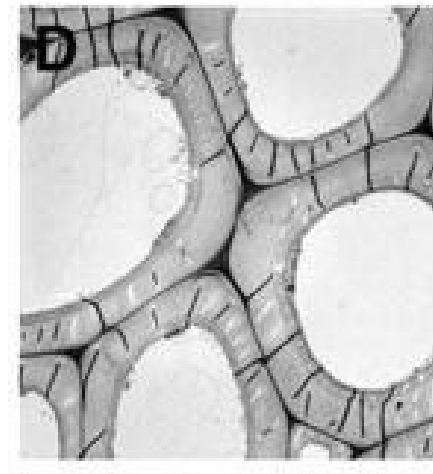
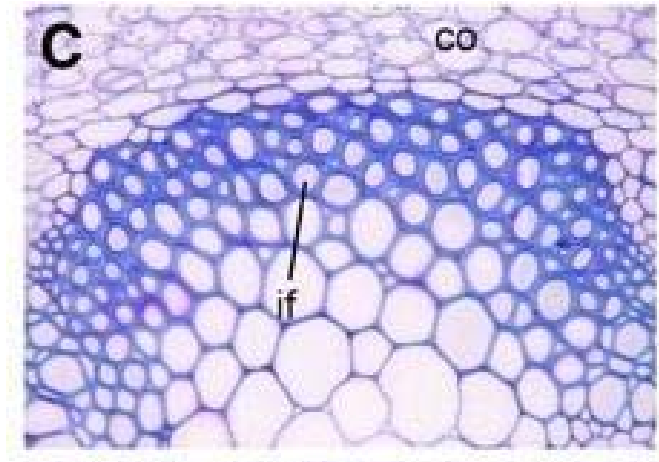
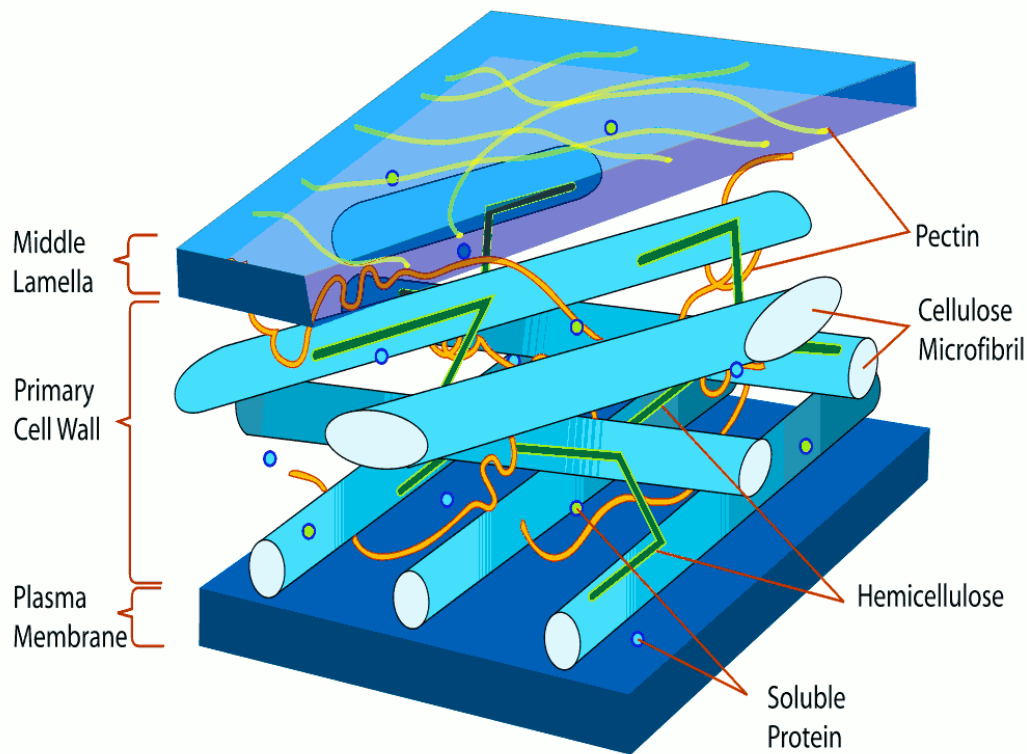


Wood is primarily composed of plant cell walls.

Photo credit: [tom donald](#)

Cell walls

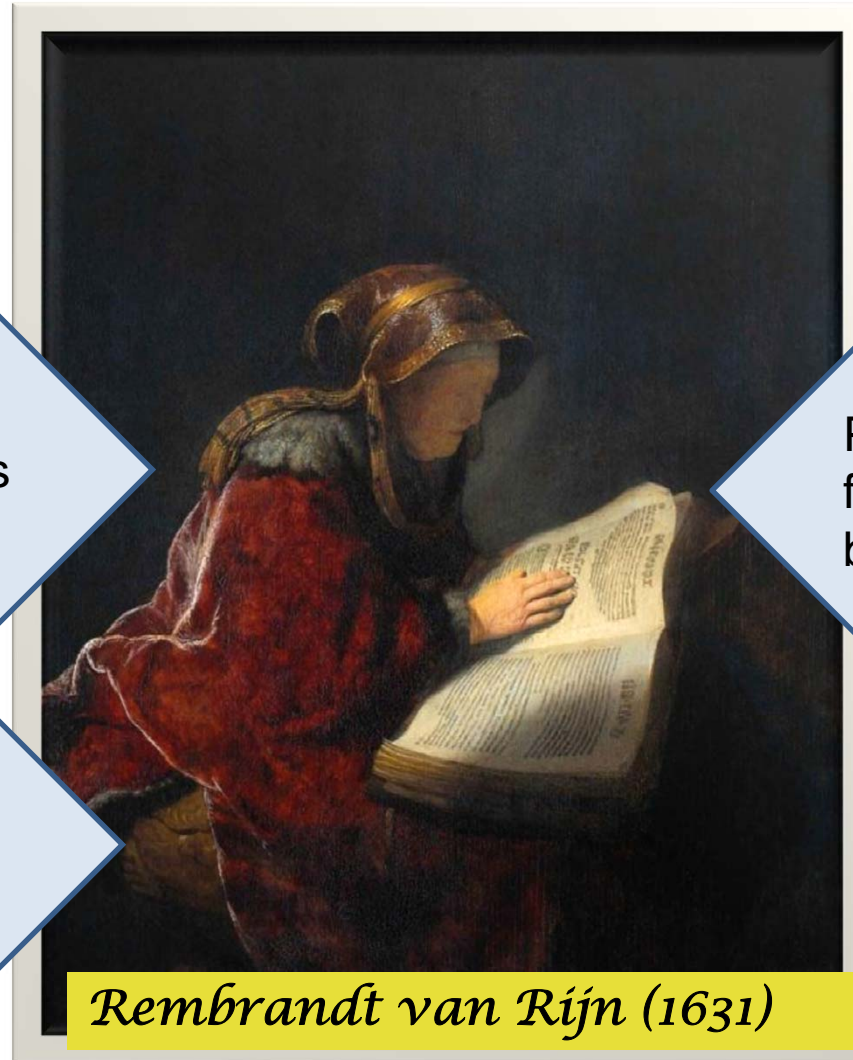
Primary plant cell walls are composed mainly of carbohydrates and proteins.



Some cells produce a rigid secondary wall that incorporates lignin, an insoluble cross-linking compound.

Photo credit: www.wpclipart.com/plants; Zhong, R., et al., (2008) Plant Cell 20:2763-2782 .

Wood and fibers are everywhere



Clothing made from plant fibers (cotton, linen)

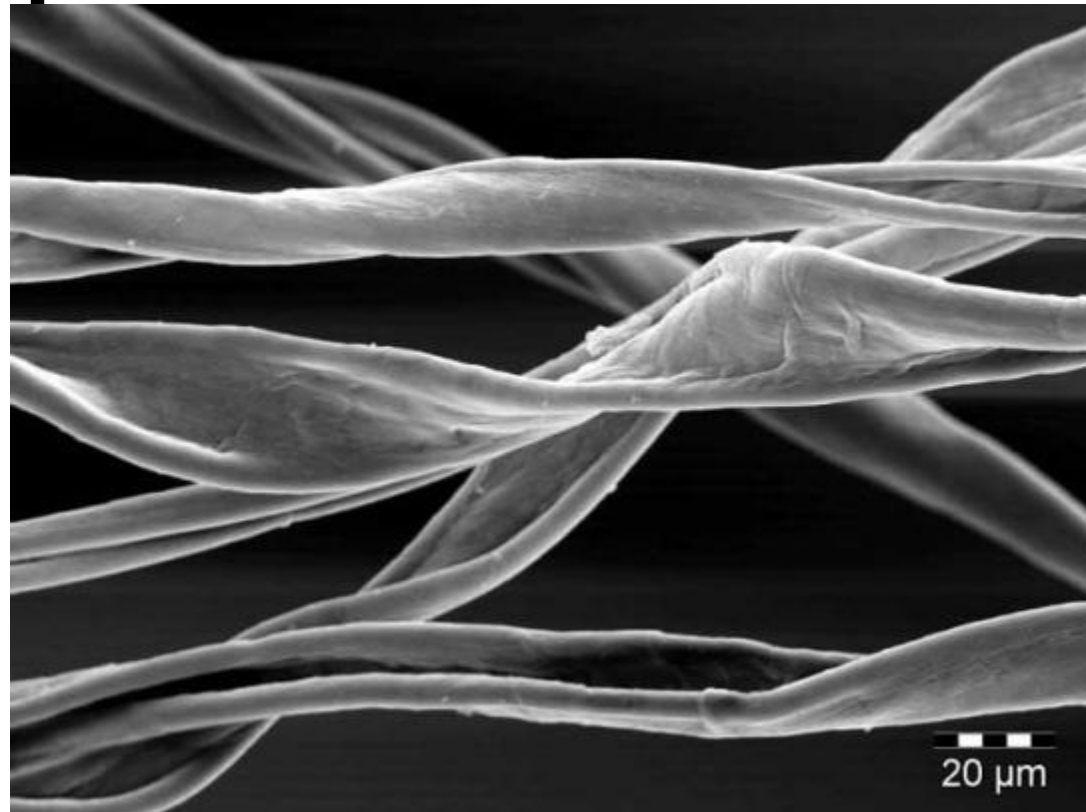
Plant fibers are used for making paper, and before that papyrus.

Wood is used for buildings and furniture.

Painting canvas is made from flax or hemp fibers.

Rembrandt van Rijn (1631)

Plants provide fibers for paper and fabric



Cotton is being bred for increased pest resistance and better fiber production.

The genome sequence of poplar, a source of fiber for paper, was recently completed

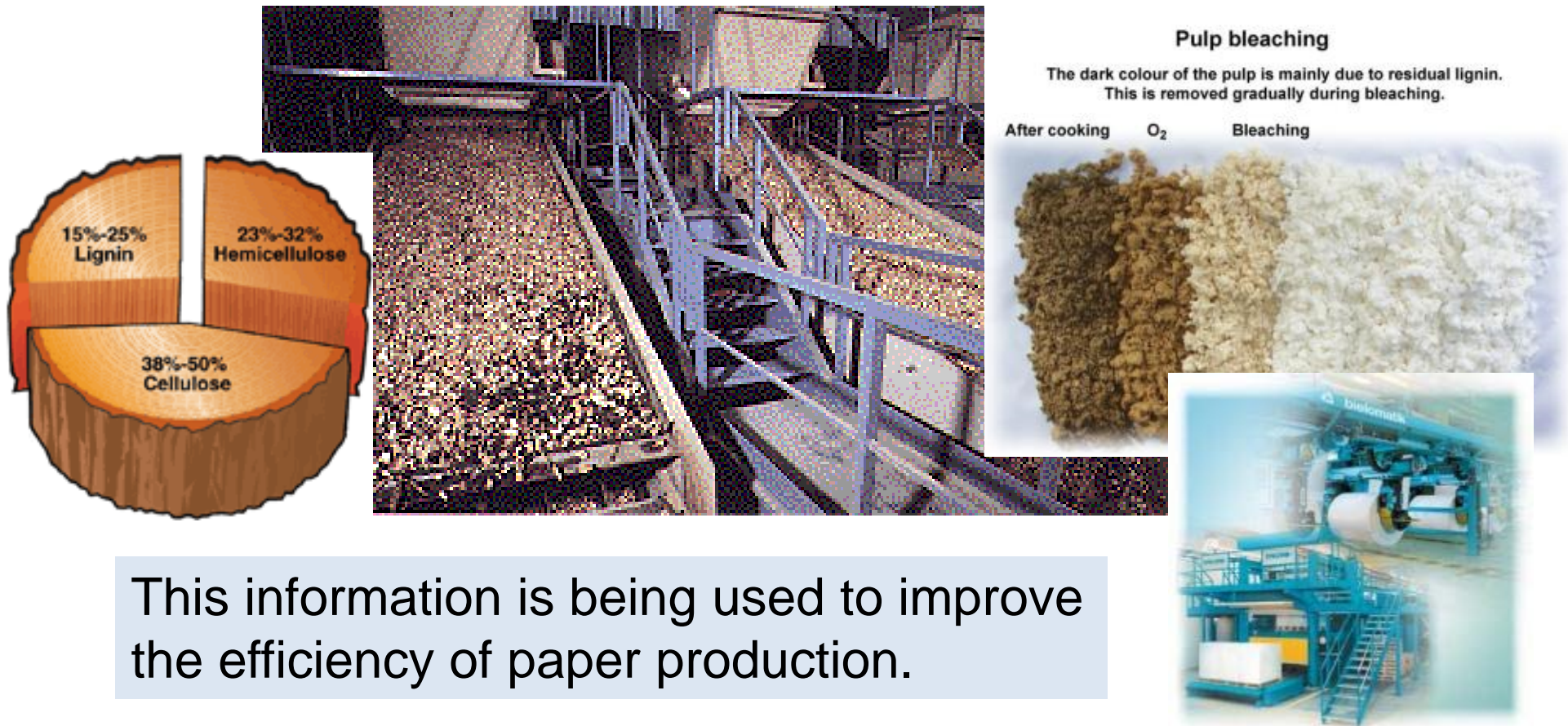
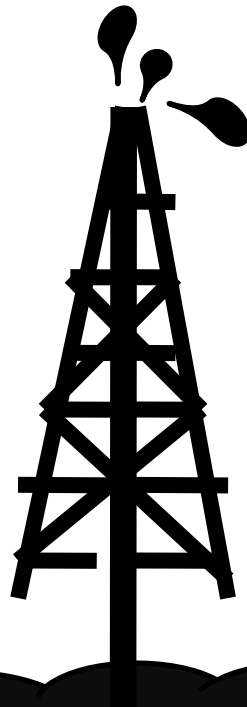


Photo credit: ChmlTech.com

Plants can replace petroleum for many products and purposes

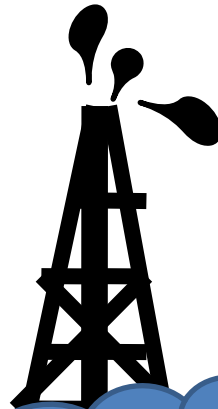
Petroleum is NOT a renewable resource



Unfortunately, it takes millions and millions of years to convert dead organic material into petroleum...and we are running out of it.

Plants can replace petroleum for many products and purposes

Petroleum is NOT a renewable resource

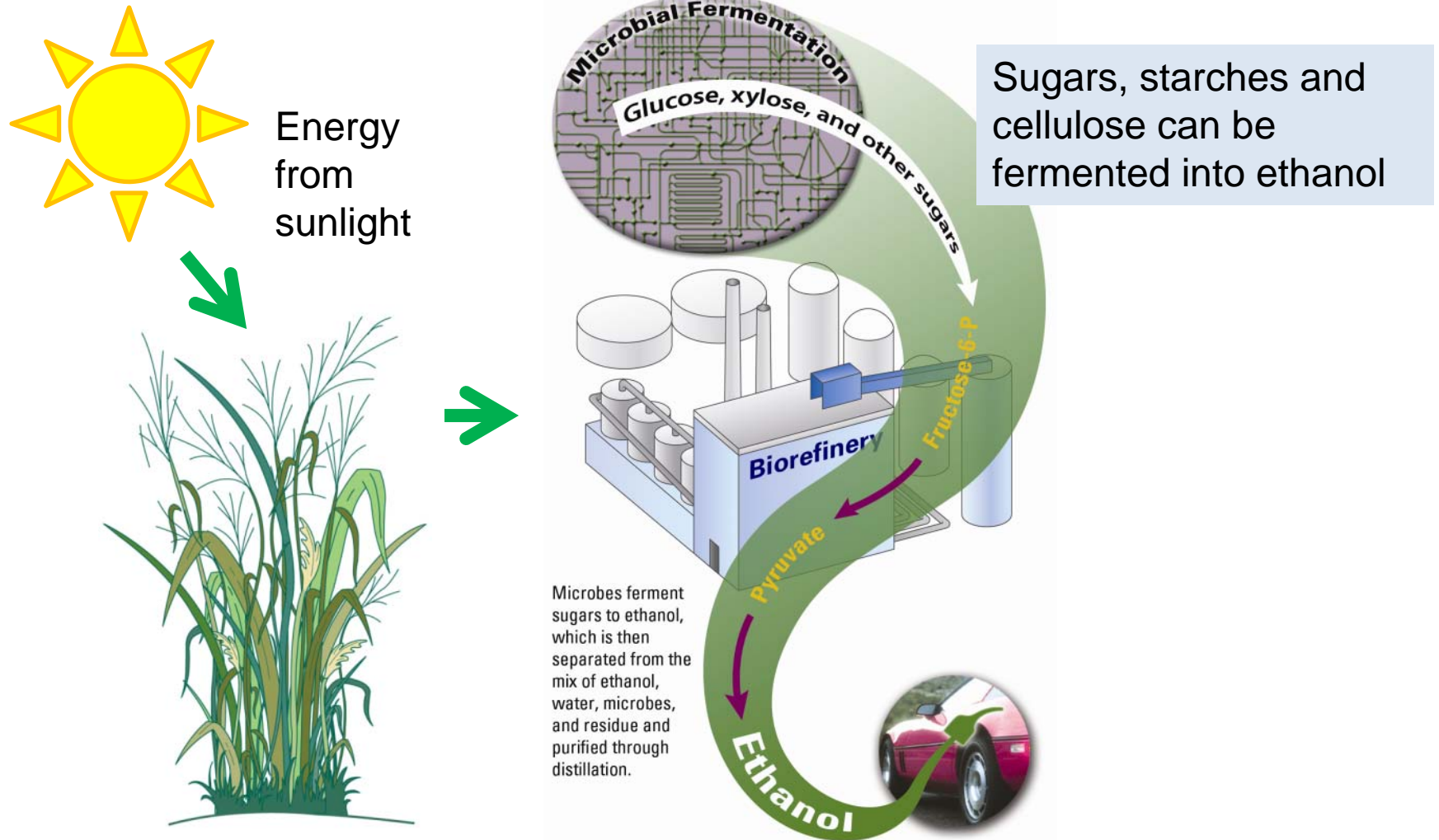


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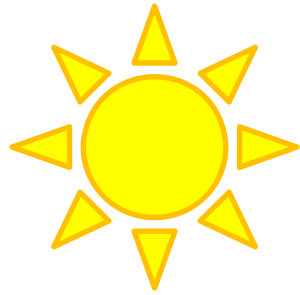
When I grow up I want to be a fossil fuel



Plants can be a source of biofuels



Plants can be a source of biodiesel



Biodiesel produced from rape, algae and soybeans are replacing petroleum-derived diesel.



Image sources: [Tilo Hauke](#), University of Minnesota, Iowa State University Extension.

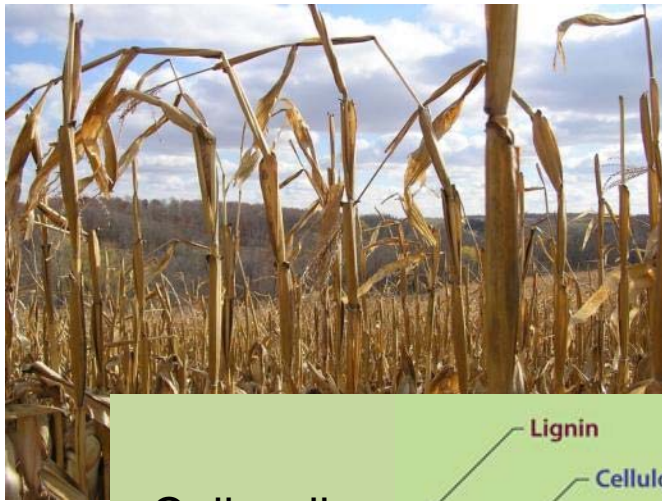
Bioenergy crops should not affect food production or prices



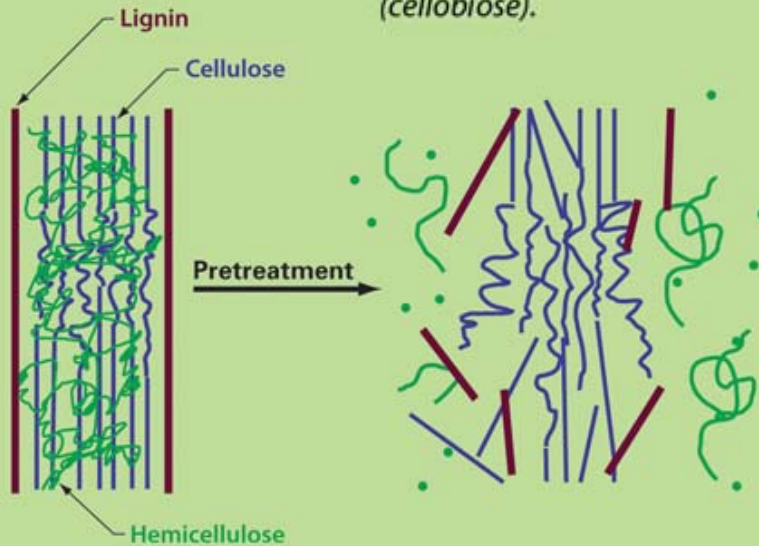
Miscanthus giganteus is a fast growing perennial bioenergy crop that grows on land unsuitable for food production.

Photo Illustration courtesy S. Long Lab, University of Illinois, 2006

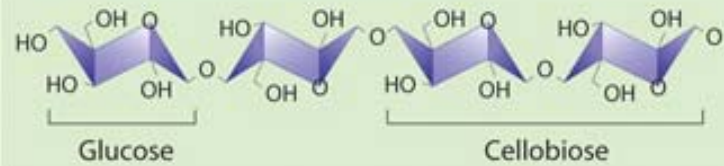
Ethanol isolated from cell wall cellulose is an important energy source



Cell walls from corn stalks and other agricultural residue



Cellulose molecule

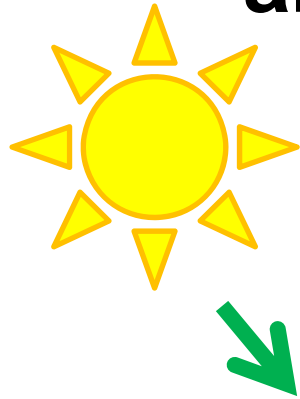


Cellulose is made up of double glucose molecules (cellobiose).

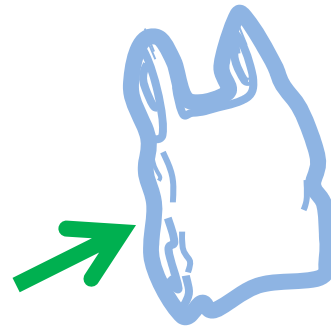
Ethanol



Plants can be sources of biorenewable and biodegradable resources



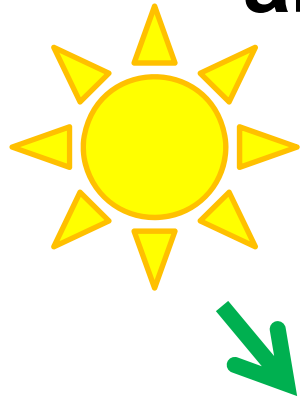
Energy from sunlight



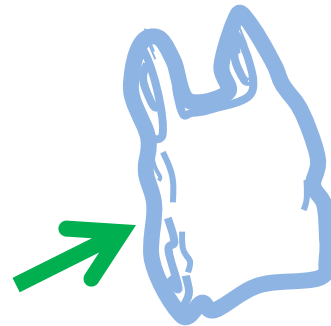
Produce plastics from renewable plant material

Photo Illustration courtesy S. Long Lab, University of Illinois, 2006

Plants can be sources of biorenewable and biodegradable resources



Energy from sunlight



Scientists are investigating cost-effective ways to convert plants into plastics.



Biodegradation

Why study plants?

Studying plants increases our knowledge about life in general and helps us to work with them to keep us fed, healthy, sheltered, clothed, and happy.

