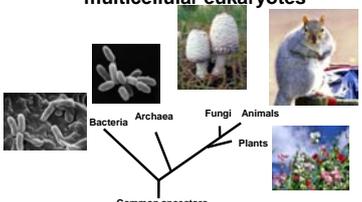


Why study plants?



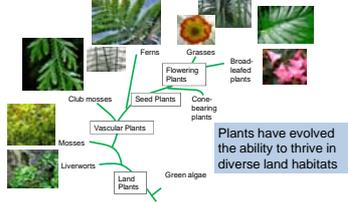
Teaching Tools
 WE CAN BIOTECHNOLOGY
 AN INNOVATION OF THE PLANT CELL

Plants, like most animals, are multicellular eukaryotes



Teaching Tools
 WE CAN BIOTECHNOLOGY
 AN INNOVATION OF THE PLANT CELL

Plants are diverse



Plants have evolved the ability to thrive in diverse land habitats

Teaching Tools
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Plants make us happy



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

Teaching Tools
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 AN INNOVATION OF THE PLANT CELL

Plants are amazing living organisms



Largest flower (~ 1m)
 Longest living (~ 5000 years)
 Largest organism (> 100m)

Teaching Tools
 WE CAN BIOTECHNOLOGY
 AN INNOVATION OF THE PLANT CELL

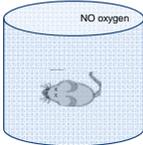
We could not live without plants



- 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.

Teaching Tools
 WE CAN BIOTECHNOLOGY
 AN INNOVATION OF THE PLANT CELL

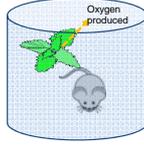
We can't live without oxygen!



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

Teaching Tools
 WE CAN BIOTECHNOLOGY
 AN INNOVATION OF THE PLANT CELL

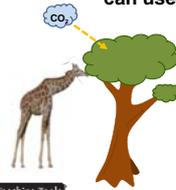
We can't live without oxygen!



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.

Teaching Tools
 WE CAN BIOTECHNOLOGY
 AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
 WE CAN BIOTECHNOLOGY
 AN INNOVATION OF THE PLANT CELL

Plants can produce an amazing assortment of chemicals

CO₂

vitamin A

vanillin

vitamin C

caffeine

morphine

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

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

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

Studying about plants informs us about our world

Cells were first observed in plants.

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

Photograph of cork cells

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

Mendel's studies of peas revealed the laws of inheritance

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

Mendel's studies of peas revealed the laws of inheritance

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

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

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

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

Mendel's studies of peas revealed the laws of inheritance

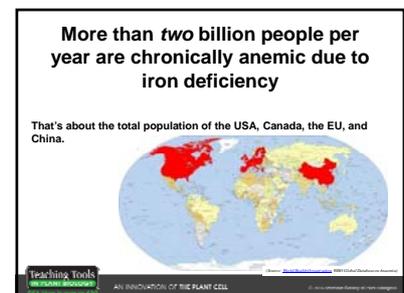
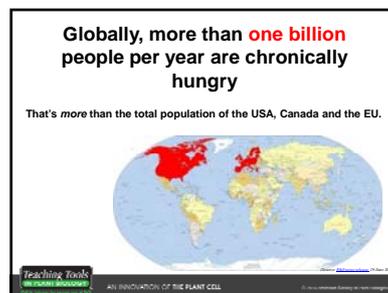
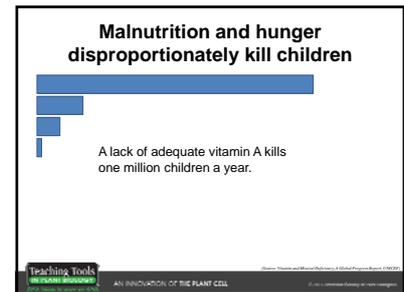
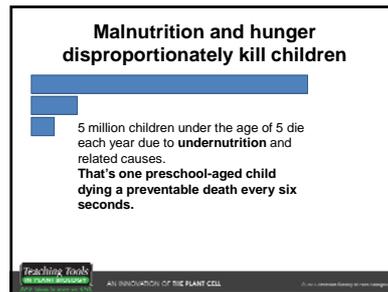
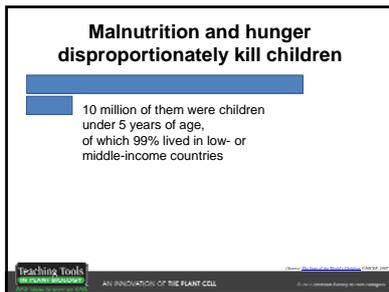
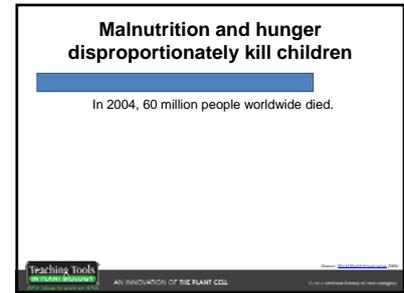
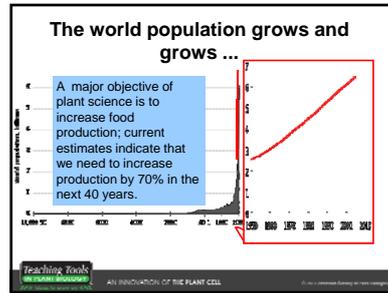
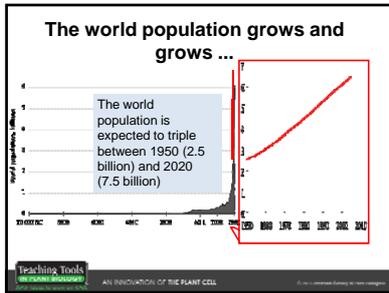
Mendel's work laid the foundation for the sciences of plant genetics and plant breeding.

Distinguished plant breeder [Norman Borlaug](#) 1914-2009, Nobel Laureate 1970

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL

WHY STUDY PLANTS?

Teaching Tools
 (WELSH/BLOOMSBURG) AN INNOVATION OF THE PLANT CELL



WHAT CAN SCIENTISTS DO ABOUT THIS?

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Plant scientists can contribute to the alleviation of hunger

By developing plants that

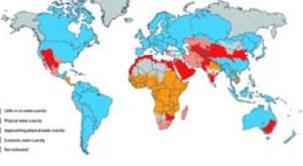
- are drought or stress tolerant
- require less fertilizer or water
- are resistant to pathogens
- are more nutritious



Teaching Tools
AN INNOVATION OF THE PLANT CELL

Plant growth is often limited by drought stress

Areas of physical and economic water scarcity

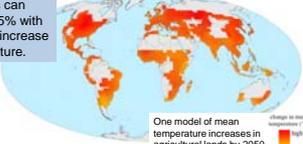


Legend:
Blue: High water scarcity
Red: Moderate water scarcity
Orange: Low water scarcity
Grey: Unpopulated

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Drought stress is compounded by increasing global temperatures

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



One model of mean temperature increases in agricultural lands by 2050.

Legend:
High
Low

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Even mild drought stress reduces yields

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



Teaching Tools
AN INNOVATION OF THE PLANT CELL

We need plants that grow well even under stressful conditions

Heat and drought reduce plant yields

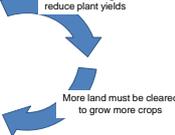


Teaching Tools
AN INNOVATION OF THE PLANT CELL

We need plants that grow well even under stressful conditions

Heat and drought reduce plant yields

More land must be cleared to grow more crops



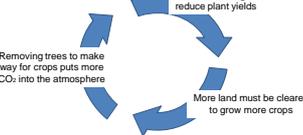
Teaching Tools
AN INNOVATION OF THE PLANT CELL

We need plants that grow well even under stressful conditions

Heat and drought reduce plant yields

Removing trees to make way for crops puts more CO₂ into the atmosphere

More land must be cleared to grow more crops



Teaching Tools
AN INNOVATION OF THE PLANT CELL

Altering a single gene can increase plants' drought tolerance

Drought-resistant

Wild-type



Well-watered 10 days drought 20 days drought After re-watering

Teaching Tools
AN INNOVATION OF THE PLANT CELL

A larger root system contributes to drought tolerance

Wild-type Drought tolerant Wild-type Drought tolerant

Seedlings Mature plants

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

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Fertilizer is an energy-demanding limiting resource

- Crops need fertilizer – potassium, phosphate, nitrogen, and other nutrients
- Potassium and phosphate are non-renewable, mined resources
- Synthesis of nitrogen fertilizers requires huge amounts of energy

Teaching Tools
AN INNOVATION OF THE PLANT CELL

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

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Plant nutrient uptake can be improved

More efficient transport systems in the root can reduce fertilizer needs.

Teaching Tools
AN INNOVATION OF THE PLANT CELL

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*

Teaching Tools
AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
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Late blight destroys potato plants

Infected Treated

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.

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Identification of resistance genes

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

Inoculated with fungus Not inoculated

Resistant Susceptible

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

Teaching Tools
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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

Teaching Tools
AN INNOVATION OF THE PLANT CELL

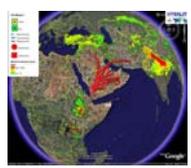
Ug99 threatens wheat everywhere



This is a global problem that needs global attention. Ug99 spores do not stop at national borders...
— United Nations Food and Agriculture Organization (FAO)

Teaching Tools
WE CAN SAVE BIODIVERSITY
AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
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AN INNOVATION OF THE PLANT CELL

The fungus is carried by wind



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

Probable Ug99 trajectories

Teaching Tools
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AN INNOVATION OF THE PLANT CELL



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...

Teaching Tools
WE CAN SAVE BIODIVERSITY
AN INNOVATION OF THE PLANT CELL

Plant biologists study ways to keep plants fresh after harvesting



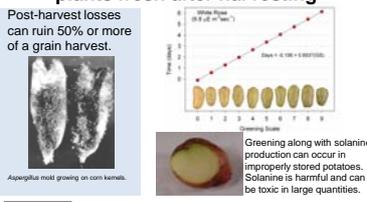
After harvesting, fruits soften, ripen, and eventually rot.

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

Teaching Tools
WE CAN SAVE BIODIVERSITY
AN INNOVATION OF THE PLANT CELL

Plant biologists study ways to keep plants fresh after harvesting

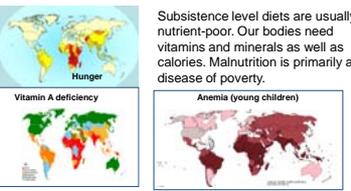
Post-harvest losses can ruin 50% or more of a grain harvest.



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

Teaching Tools
WE CAN SAVE BIODIVERSITY
AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
WE CAN SAVE BIODIVERSITY
AN INNOVATION OF THE PLANT CELL



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.

Teaching Tools
WE CAN SAVE BIODIVERSITY
AN INNOVATION OF THE PLANT CELL

Cassava is a staple food crop in much of Africa but low in nutrients



Scientists have recently identified a variant that produces much more vitamin A than the standard variety.

Newly discovered yellow variety

Teaching Tools
WE CAN SAVE BIODIVERSITY
AN INNOVATION OF THE PLANT CELL

Genetically biofortified foods

Iron-enriched rice

Vitamin A-enriched rice

Wild-type (top) and antioxidant-enriched tomatoes

Teaching Tools
MELISSA BLOOMBERG
AN INNOVATION OF THE PLANT CELL

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

Teaching Tools
MELISSA BLOOMBERG
AN INNOVATION OF THE PLANT CELL

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)

Teaching Tools
MELISSA BLOOMBERG
AN INNOVATION OF THE PLANT CELL

Malaria kills millions of people

The regions of the world with highest risk for malaria.

Teaching Tools
MELISSA BLOOMBERG
AN INNOVATION OF THE PLANT CELL

The protozoan *Plasmodium* causes malaria

Plasmodium inside a mouse cell

Teaching Tools
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AN INNOVATION OF THE PLANT CELL

Plasmodium is transferred into humans by infected mosquitoes

Teaching Tools
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AN INNOVATION OF THE PLANT CELL

Cinchona tree bark contains quinine, which kills *Plasmodium*

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

Teaching Tools
MELISSA BLOOMBERG
AN INNOVATION OF THE PLANT CELL

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."

Teaching Tools
MELISSA BLOOMBERG
AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
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AN INNOVATION OF THE PLANT CELL

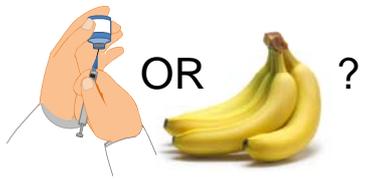
Plant scientists are developing higher-producing *Artemisia*



The Genetic Map of *Artemisia annua* L. Identifies Loci Affecting Yield of the Antimalarial Drug Artemisinin

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Plants can make safe and inexpensive edible vaccines and antibodies



Teaching Tools
AN INNOVATION OF THE PLANT CELL

Plant cell walls provide important durable materials

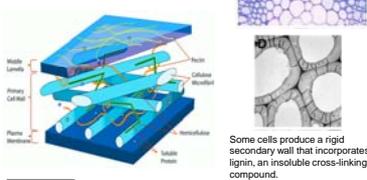


Wood is primarily composed of plant cell walls.

Teaching Tools
AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Wood and fibers are everywhere



Clothing made from plant fibers (cotton, linen)

Wood is used for buildings and furniture.

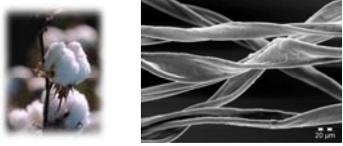
Plant fibers are used for making paper, and before that papyrus.

Painting canvases is made from flax or hemp fibers.

Rembrandt van Rijn (1631)

Teaching Tools
AN INNOVATION OF THE PLANT CELL

Plants provide fibers for paper and fabric



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

Teaching Tools
AN INNOVATION OF THE PLANT CELL

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



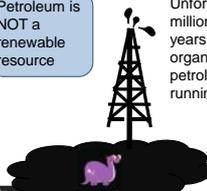
This information is being used to improve the efficiency of paper production.

Teaching Tools
AN INNOVATION OF THE PLANT CELL

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.

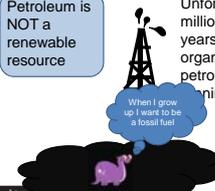


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AN INNOVATION OF THE PLANT CELL

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Teaching Tools
AN INNOVATION OF THE PLANT CELL

Plants can be a source of biofuels

Energy from sunlight

Sugars, starches and cellulose can be fermented into ethanol

Teaching Tools
WILSON BIOLOGIST
AN INNOVATION OF THE PLANT CELL

Plants can be a source of biodiesel

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

Teaching Tools
WILSON BIOLOGIST
AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
WILSON BIOLOGIST
AN INNOVATION OF THE PLANT CELL

Ethanol isolated from cell wall cellulose is an important energy source

Cellulose molecule
Cellulose is made up of double glucose molecules (polysaccharide)

Cell walls from corn stalks and other agricultural residue

Ethanol

Teaching Tools
WILSON BIOLOGIST
AN INNOVATION OF THE PLANT CELL

Plants can be sources of biorenewable and biodegradable resources

Energy from sunlight

Produce plastics from renewable plant material

Teaching Tools
WILSON BIOLOGIST
AN INNOVATION OF THE PLANT CELL

Plants can be sources of biorenewable and biodegradable resources

Energy from sunlight

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

Biodegradation

Teaching Tools
WILSON BIOLOGIST
AN INNOVATION OF THE PLANT CELL

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.

Teaching Tools
WILSON BIOLOGIST
AN INNOVATION OF THE PLANT CELL