Why study plants?
Plants, like most animals, are multicellular eukaryotes.
Plants are diverse

Green algae
Liverworts
Mosses
Vascular Plants
Club mosses
Ferns
Flowering Plants
Grasses
Seed Plants
Cone-bearing plants
Broad-leafed plants
Grasses
Land Plants
Green algae

Plants have evolved the ability to thrive in diverse land habitats

Images courtesy tom donald
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 CO$_2$ gas into sugars through the process of **photosynthesis**.
Plants can produce an amazing assortment of chemicals

- Vitamin A
- Vanillin
- Vitamin C
- Caffeine
- Morphine

Plants can transform CO₂ into various chemical compounds.
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, discoverer of “cells”

Photograph of cork cells

Photo credit: ©David B. Fankhauser, Ph.D
Viruses were first purified from plants

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

Tobacco Mosaic Virus

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,
Nobel Laureate 1970
WHY STUDY PLANTS?
The world population grows and grows ...

The world population is expected to triple between 1950 (2.5 billion) and 2020 (7.5 billion)
The world population grows and grows ...

A major objective of plant science is to increase food production; current estimates indicate that we need to increase production by 70% in the next 40 years.
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 million of them were children under 5 years of age, of which 99% lived in low- or middle-income countries

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

Source: IWMI report, Insights from the Comprehensive Assessment of Water Management in Agriculture, 2008, p8

Image source: IWMI
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.

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.

Heat and drought reduce plant yields.
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
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.
- Removing trees to make way for crops puts more CO₂ into the atmosphere.
Altering a single gene can increase plants’ drought tolerance

A larger root system contributes to drought tolerance

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

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

Photo credits: Mining Top News; Library of Congress, Prints & Photographs Division, FSA-OWI Collection, LC-USW361-374
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.
Plant nutrient uptake can be improved

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

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](http://www.news.cornell.edu); [www.fao.org](http://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.
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.

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.
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.

Photo credit: www.wheatrust.cornell.edu
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...
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.

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

Aspergillus mold growing on corn kernels.

Photo credits: Dr. C.M. Christensen, Univ. of Minnesota; WSU; Pavalista, A.D. 2001
Vitamin A deficiency

Hunger

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

Anemia (young children)

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
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 that the standard variety.

Genetically biofortified foods

Iron-enriched rice

Wild-type (top) and antioxidant-enriched tomatoes

Vitamin A–enriched rice

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 quinine, which 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.”
*Artemisia annua* is a plant with novel antimalarial activities.

*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/
Plants can make safe and inexpensive edible vaccines and antibodies

OR

?
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.

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 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.

Photo credits: Chen Lab; IFPC
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.
Plants can replace petroleum for many products and purposes

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

Petroleum is NOT a renewable resource
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 be a source of biofuels

Energy from sunlight

Sugars, starches and cellulose can be fermented into ethanol

Microbes ferment sugars to ethanol, which is then separated from the mix of ethanol, water, microbes, and residue and purified through distillation.

Image source: Genome Management Information System, Oak Ridge National Laboratory
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.
Ethanol isolated from cell wall cellulose is an important energy source.
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

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