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Global Knowledge Center on Crop Biotechnology

ISAAA
INTERNATIONAL SERVICE
FOR THE ACQUISITION
OF AGRI-BIOTECH
APPLICATIONS

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Did You Know?

A booklet of facts on food, agriculture and biotechnology

ISAAA

Cotton

For as long as 7,000 years, cotton has been grown, picked, woven, and fashioned into materials as diverse as jeans, underwear, shirts, and even animal feed! Almost 757.1 million liters (200 million gallons) of cottonseed oil are used in food products such as margarine and salad dressing. Even products such as toothpaste, ice cream, and, of course, the paper money used to buy them, contain by-products of the cotton seed.

This productivity comes with a price. Conventionally grown cotton use a total of $2.6 billion worth of hazardous pesticides, some of them the most toxic in the market. These include carbamate pesticides, as well as broad spectrum organophosphates, which were originally developed as toxic nerve agents during World War II.

Did you know...

Biotech cotton is now available on the market, and is planted over 9.8 million hectares (24.2 million acres) in the US, India, China, Argentina, Colombia, Australia, South Africa, and Mexico. GM cotton is engineered to be both insect-resistant and herbicide tolerant.

Sources:
http://en.wikipedia.org/wiki/Cotton
http://www.cottonsjourney.com/Storyofcotton/page2.asp
http://www.agday.org/tc/tc-funfacts.html
http://www.panna.org/resources/documents/conventionalCotton.dv.html

Of People & Populations

All the world's a stage – but how many people are there, really, in the world? And how many more will be coming in the next few years? This section takes a look at the people who fill up the world, where they are, and where we all might be in the next few decades.

Did you know that ...?

- **Our world population is growing fast...and we mean really, really FAST?**

There will be 8.3 billion people in the world by 2025, and around 10-11 billion toward the end of the 21st century. That means we have billions of stomachs to fill, and that means massive changes in the production, distribution, and stability of food products. (Source: Norman Borlaug, in a speech given at Tuskegee University, 2001)

- **We'll be nudging each other for elbow space soon?**

Experts estimate that Asia's population will increase dramatically to a mind-blowing 1.1 billion. Sub-Saharan Africa will be filled with 80% more people by the year 2020.

With everyone flocking to cities, close to 50% of the developing world's population is now living in urban areas - a far cry from the 30% of less than a decade ago. (Source: Mike Davis, "A Planet of Slums," 2004)

- **By 2025, India will be the most densely populated country in the world?**

The country is projected to house 1.5 billion people, with grossly swollen cities. That means almost 1/5 of the planet will be living in the Indian peninsula! (Source: http://www.gmi.org)

And that goes for the rest of the world as well?

Three (3) people are born every second, and 1.33 die at the same time. This results in a net 2.67 increase in population. In fact, the number of people alive on earth at this very moment is higher than the total number of all the people that have ever died.

Did you know that the number of cars on the planet is increasing three times faster than the people - and if you put all the world's ants together and weigh them, they would still be heavier than the total weight of the world's population? (Source: http://www.corsinet.com/trivia/g-triv.html)

- **Not only will we need more crops in the future, but we won't have more land for planting?**

Methods in traditional agriculture can still yield good results, but could feed the increased population predicted for the year 2050 only if we have a 3-fold increase in cropland - an impossible feat. (Source: Anthony Trevawas, "The Population/ Biodiversity Paradox. Agricultural Efficiency to Save Wilderness," Plant Physiology, 2001)

Banana

There are over 500 varieties of banana today. This means that if you ate a different kind of banana each day, you would take almost a year and a half to eat every last one! In fact, about 99.5% of banana-eaters in the world are eating varieties of banana that have been selected by farmers and haven't changed in centuries. But wait: not all bananas are edible!

In any case, bananas are loved and eaten the world over. East Africans, and Ugandans in particular, eat around 450 kg (992.1 lbs) per person per year. In East Africa, the word for bananas is "matooke," which also means "food."

Bananas may be valuable, but there are many problems involved in their cultivation. For instance, almost all cultivated bananas are seedless and sterile. This means that they can't be grown from seeds. Banana plants also take up to 18 months to fruit, which makes them even harder to breed.

If those problems aren't big enough, consider the fact that bananas can get sick, too. An illness of bananas called Black Sigatoka can cut a harvest by as much as 50%. Farmers control the disease by spraying banana crops with fungicide up to 40 times in one growing season.

Did you know...

Tissue cultured bananas are currently helping farmers in Tanzania and Kenya in improving their banana crop. Scientists are also working on a variety resistant to Black Sigatoka, and this special biotech banana may be available soon.

Sources:
http://www.greenhousebusiness.com/banananinfo.html
http://www.agday.org/tc/tc-funfacts.html
http://ipgri-pa.grinfo.net/index.php?itemid=1066
http://www.futureharvest.org/pdf/Banana_final.pdf

Fruit Crops

Tomato

First known as the *tomatil*, tomatoes were grown as wild, cherry-sized berries in the South American Andes, before they were brought to Mexico, where they were destined to grow into the large fruit we know today. *Tomatil* found its way to Europe via the conquistadors, and into popular tomato legend. Tomatoes were thought to be poisonous, but when the myth was dispelled, the fruit grew to be so popular, it was used in everything from spaghetti sauces to juice.

Today, more than 60 million tons of tomatoes are produced annually, 16 million tons more than the second most popular fruit, the banana. And, no matter what they tell you: tomatoes really ARE fruits, since they are an edible part of the plant that contain the seeds (as opposed to a vegetable, which is an edible stem, leaf, or root). This despite the "Nix vs. Hedden" case of 1893, where the U.S. Supreme Court ruled that tomatoes were to be considered vegetables.

Did you know...

The very first GM crop was the FlavrSavr tomato, a variety that stayed longer on the shelf and ripened later, allowing it to be shipped without much damage to the fruit. Although FlavrSavr is already off the market, there are still biotech tomatoes available, engineered with delayed ripening, delayed softening, and insect resistance traits. Soon to come: tomatoes with higher amounts of the antioxidant lycopene.

Sources:
http://www.californiatomatoes.org/facts_trivia.html
http://www.whybiotech.com/index.asp?id=4176
http://www.nubella.com/content/blogsection/15/158/
http://whatscookingamerica.net/tomato.htm

Water, Water... Everywhere?

Did you know...?

- **The world has a whole lot of salty water?**

The earth is over 70% water, 97% of which is in the world's oceans. Of the total water in our oceans, 46% belongs to the Pacific, 23.9% to the Atlantic, 20.3% to the Indian, and 3.7% to the Arctic. (Source: http://bottledwaterstore.com/waterfacts2000.htm)

- **And what little is left is the only fresh water we've got?**

While 97% of the world's water is salty and sloshing about in the oceans, only about 2% is left as fresh and drinkable - and 70% of that 2% is locked in the icecaps of Antarctica. If this entire ice sheet were to melt, sea levels would rise by nearly 67 meters (220 feet), the height of a 20-story building.

The water we can drink is found underground, in the form of groundwater; or is readily accessible in lakes, steams, and rivers. (Source: http://www.lenntech.com/water-trivia-facts.htm)

And we've had the same water for ages?

The total amount of water on earth has been constant for the last two billion years. Every drop you drink has been witness to history - in fact, you might be drinking or bathing with the same water that our ancestors used! (Source: http://www.freshwater.org/water_facts.html)

➤ A lot of people can't get the water they need?

At least 400 million of the world's people live in regions that have severe water shortages, and most of these people must walk at least 3 hours to get some. And, even if they do have access to water, over 2 billion people on earth do not have a fresh, safe supply. (Source: http://www.populationmedia.org/issues/issues.html)

➤ But we need a lot down here?

Agriculture needs a whole lot of water to succeed. For instance, to produce one kilo (2.2 pounds) of rice, a farmer needs up to 5,000 liters (1,321 gallons) of water. To produce the same amount of soybeans, farmers water their soy fields with 2,200 liters (581 gallons) of water; while maize farmers produce a kilogram of maize with the help of 630 liters (166 gallons). (Sources: http://www.irri.org/about/faq2.asp and http://www.clw.csiro.au/issues/water/water_for_food.html)

Sweet Potato

Sweet potatoes have been cultivated for 20,000 years: the Aztecs and Incas cooked and served them, and today, they are the 6th most important food crop in the world.

Sweet potatoes have an enzyme that can turn the starch in this vegetable into sugars. This happens as the sweet potato grows older, and it increases in speed when the vegetable is stored or cooked. Sweet potatoes were once called "vegetable indispensable," and rightly so, as they are packed with calcium, potassium, and vitamins A and C.

Did you know...

Scientists are currently working on sweet potatoes resistant to important viruses, such as the sweet potato chlorotic stunt and potato feathery mottle viruses; and insects, such as the sweet potato weevil.

Sources:
http://www.dole5aday.com/FoodService/Fun/Characters/F_Sweetpot.jsp
http://www.cookinglight.com/cooking/fd/features/package/0,14343,365129,00.html
http://www.foodreference.com/html/fsweetpotatoes.html

Cassava

Also known as *manihot*, cassava was first cultivated in Brazil and Paraguay, before it found its way to Europe via returning conquistadors. Cassava was used to make pancakes, as well as a ceremonial drink called cauim.

Cassava roots contain cyanogenic glucosides: compounds that are converted to cyanide in the presence of an enzyme also native to cassava. Raw, and especially drought-grown cassavas are high in such toxins. To remove them, cassavas must be cooked thoroughly: they are peeled, soaked in water, squeezed until dry, and then toasted.

Did you know...

The worldwide Cassava Biotech Network unites scientists and stakeholders in producing and cultivating better cassava. In line with all this, a group of scientists led by the Donald Danforth Plant Science Center is also working to complete the sequence of the cassava genome. In the offing are varieties with more or better quality starch. A cassava engineered to be 2.5 times larger than conventional varieties has also been developed, and is now being studied.

Sources:
http://www.floridata.com/ref/M/mani_esc.cfm
http://en.wikipedia.org/wiki/Cassava
http://www.danforthcenter.org/newsmedia/NewsDetail.asp?nid=122

Agriculture Today

Agriculture must keep up with growing humanity's ever greater needs. This section explores how agriculture has changed the way we live, and how it may need to evolve further in order to produce food for the next generation.

Did you know ...?

- **We've got only a few plants to live on?**

About 99% of our agricultural production depends on only 24 different domesticated crop species. The top ten domesticated crops in the world, in terms of production volume, are maize, wheat, rice, potato, sugar beet, soybean, cassava, barley, sweet potato, and tomato. (Sources: http://www.foodreference.com/html/fagriculture.html and http://faostat.fao.org)

- **Feeding Asia in the next quarter of a century will require both food and land, and in large amounts?**

Within the next 25 years, farmers in Asia must increase their cereal yields by 50-75%, simply to meet the demands of an increasing population. Cropland and population are not uniformly distributed, especially in China, which holds 20-25% of the world's population - but only 7% of the world's productive land. (Source: Martina McGloughlin, University of California, Davis)

We will soon need a large food supply . . . a VERY LARGE food supply?

To feed itself over the next forty years, mankind will have to produce a quantity of food larger than ALL the food produced SINCE THE BEGINNING OF TIME. (Source: Holman W. Jenkins, Jr., "Fun Facts to Know And Tell About Biotechnology," 1999)

- **Without pesticides, many more of our crops would have been destroyed?**

Without pesticides, 70% of the world food crop would be lost. At present, even with pesticide use, 42% of our planted crops are destroyed by insects and pathogenic fungi. (Source: E. C. Oerke and colleagues, "Conclusion and Perspectives. In Crop Production," and "Crop Protection: Estimated Losses in Food and Cash Crops," 1994)

- **Fertilizers really do make a difference in agriculture?**

Fertilizers can increase yields of food crops from 1.5- to 2-fold. Without fertilizers, farmers would need an extra 400-600 million hectares (988-1,482 million acres) of cropland to make up for their losses. Moreover, without fertilizer technology, current food production would only have been achieved by plowing up an extra 2,000 million hectares (4,942 acres)! (Source: Anthony Trevawas, "The Population/Biodiversity Paradox. Agricultural Efficiency to Save Wilderness," Plant Physiology, 2001)

Root Crops

Potato

The potato is credited with the rise of Andean civilizations, including the Incas, who started farming the root crop in 200 BC. The Incas also developed many uses for the potato: raw slices were placed on broken bones, carried to prevent rheumatism, and eaten with other foods to prevent indigestion. Incas also used the potato as a time keeper: units were correlated to how long it took to cook a potato.

The Spanish conquistadors brought the root crop back to Europe in 1570, where the potato became a feared vegetable. People attributed poison to its strange shape, and to the fact that it was grown below ground. It was accused of causing a variety of diseases, including leprosy, fever, tuberculosis, and rickets.

When tempers and speculation finally died down in Europe, use of the potato became so widespread that whole populations and races could not live without it. When the potato crop in Ireland was devastated by fungus, causing the "Irish Potato Famine," and forcing many Irish to immigrate. The population of Ireland decreased by nearly two million from 1847 to 1851.

There may be some truth to potato's poisonous reputation, however: its wild relatives are in fact very toxic due to the presence of molecules called glycoalkaloids, which have caused severe human poisonings and near death.

Did you know . . .

Biotech potatoes are already available on the market, and are engineered to be resistant to the Colorado potato beetle, Potato Virus Y, or to Potato Leafroll Virus. In the works: Potatoes with higher calcium or protein content, resistance to late blight, and the ability to grow in near freezing temperatures.

Sources:
http://www.oregonspuds.com/consumer/history.htm. http://www.eat-online.net/english/education/irish_potato.htm, http://www.indepthinfo.com/potato/history.shtml, and Joseph Hotchkiss, transcript from "Harvest of Fear," Cornell University

Peanuts

Peanuts have been around for 2,000 years: from their home in South America, these legumes traveled to Europe and Africa through Spanish and Portuguese traders, before traveling to the North American South courtesy of African slaves.

Did you know...

Although GM peanuts are not yet available on the market, scientists are working to remove the crop's allergens, as well as to make peanuts resistant to fungal infections.

Sources: http://foodreference.com/html/fpeanuts.htm and http://www.vegsoc.org/cordonvert/articles/peanuts.html

Chickpeas

Chickpeas have been grown since ancient times: the Romans ate them, as a broth, or roasted them as a snack; and cultivated several varieties known only as Venus, Ram, and Punic. Chickpeas were even grown in some parts of Germany to serve as a coffee substitute during the First World War.

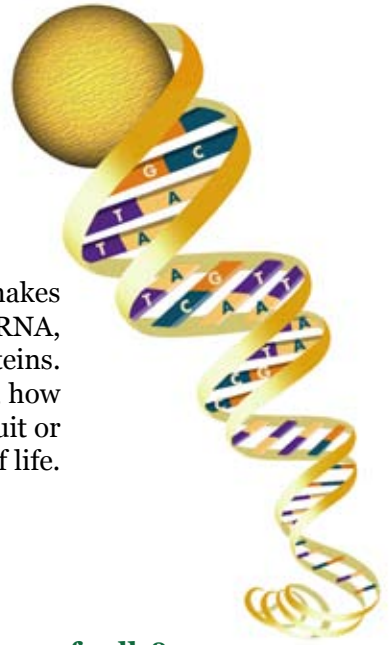
Chickpeas are now the world's most widely consumed legume. They usually come in pale yellow, but India cultivates a few red, black, and brown varieties. Chickpeas also come in a variety of names: they are called garbanzos, grams, and Egyptian peas. In Italy, they are known as ceci; in Germany, as *Kichererbse*; and in Greece, as *revithia*.

Did you know...

ICRISAT is working on chickpeas that will grow even in adverse abiotic conditions, such as drought and floods. ICRISAT also maintains chickpea germplasm, and is currently distributing varieties that mature early, or are resistant to blight, or higher yielding.

Sources: http://foodreference.com/html/fpeanuts.htm and http://www.vegsoc.org/cordonvert/articles/peanuts.html

More than Just Molecules



DNA is more than just a molecule. It makes up our genes, which are transcribed into RNA, which, in turn, are translated into proteins. Thus, our DNA spells how we look, how animals survive, and how plants bear fruit or flower. DNA really is the stuff of life.

Did you know that ...?

- **Your body is made up of billions of cells?**

Make that 1,000 billion cells in all - yes, your body is a mega-machine of amazing proportions. Each cell contains organelles, each of which have their own function, and each of which allow your cell to contribute to making your body work.

DNA makes up your genes?

Do A, T, C, and G sound familiar? They're the four bases that comprise the DNA molecule. DNA stands for deoxyribonunucleic acid, a molecule made up of two strands of the bases twisted into a double helix. A DNA sequence is not random: in the two DNA strands, A will pair only with T, and C will pair only with G.

Our genome consists of billions of these bases strung together, packaged into chromosomes, and stocked neatly into the nucleus or mitochondrion. Our entire genome isn't just made up of genes: some DNA sequences are there to control the activity of genes, and we don't know the function of a large proportion of the DNA sequences that make up the rest of the chromosomes.

(Illustration courtesy of the U.S. Department of Energy Genomes to Life Program)

➤ Every living organism has a different DNA profile - and different amounts of genes and DNA?

All living organisms have DNA, but not all the DNA codes for genes, as you can see in the following table.

Table 1. Amounts of DNA in various living organisms

Organism	Millions of base pairs (approx.)	Number of genes (approx.)
Human	2,800	30,000
Mouse	3,000	30,000
Fruit fly	155	13,601
Yeast	15	6,000
Rice	400	40,000-60,000
Arabidopsis thaliana	125	25,498

Source: http://cnx.rice.edu/content/m11317/latest/

➤ The concept of the DNA double helix is just a little over half a century old?

Gregor Mendel first introduced the concept of the gene as he crossed pea plants in the 19th century. The structure of DNA, however, was elucidated much, much later, in 1953, thanks to the work of Drs. James Watson, Francis Crick, Maurice Wilkins, and Rosalind Franklin. It is from their Nobel Prize-winning work that we have the image of DNA today: a helical molecule, with two strands of nucleotides wound around each other, like a twisted ladder.

➤ These genes are the basis for the body's proteins?

DNA makes up the genes, and we have genes in our chromosomes, but what exactly do genes do, and what do we mean when we say that a gene is expressed?

Soybeans

Soybeans were first cultivated in China in 2838 B.C., where farmers fed it to their families and livestock, and where its moldy form was used to treat skin infections. Its cultivation spread to Japan, Korea, then Southeast Asia, before making its way to Europe in 1712.

In Japan, soybean is processed into miso, a soybean paste which has undergone slow fermentation. Miso is often referred to as the "Wine of the Orient," and has been eaten for over a thousand years. It contains alkaloids which attract heavy metals and expel them from the body. It also neutralizes the effects of smoking and other environmental pollutants, lowers cholesterol, and aids digestion when eaten un-pasteurized.

As for soybean oil, it can be found in margarine, salad dressings, canned foods, sauces, bakery goods, and processed fried foods. Soybean is also used as an environmentally-safe fuel, and is finding use in many city buses and trucks.

Did you know...

GM soybeans are planted on 54.4 million hectares (134.4 million acres) of land all over the world, making them the most widely cultivated biotech crop. GM soybeans are bred or engineered to either have greater amounts of oleic acid or lower amounts of linolenic acid, or to be resistant to herbicides. Work on soybeans never ends: its genome is still being sequenced, and scientists are working on soybean varieties that are tolerant to pests and abiotic stresses, as well as varieties that are more nutritious.

Sources:
http://www.minnesota-china.com/Education/emAgric/Soybean.htm
http://www.foodreference.com/html/artmiso.html
http://agnews.colostate.edu/index.asp?url=food_for_thought

Eggplant

Eggplants are native to southern India and Sri Lanka, where they were first grown as bitter fruit. Now, however, after years of cultivation and crosses, farmers have succeeded in improving the flavor of the crop. Asia produces some 78% of the world's total eggplants, while Turkey churns out more of the crop than all of Europe combined.

Ever wonder why they are called eggplants, though? The name was first applied to a white-skinned variety of the fruit, and it's been carried on to the crop's descendants, whether purple or not.

Did you know...

The eggplant-fruit-and-shoot borer (EFSB) can often decimate an eggplant harvest. To protect eggplant from EFSB, scientists are now working on Bt eggplant, which will be released very soon.

Sources:
http://www.foodreference.com/html/arteggplant2.html
http://www.foodreference.com/html/feggplant.html

➤ And proteins are what make your body work?

Proteins are not just meats and cheese, or things that you eat to make you stronger. Proteins are important molecules: they make up all your organs, including your red blood cells, nails, hair, and organs. Your enzymes are also proteins: they can break down molecules and assemble others. Because proteins are coded by our genes, these determine our bodies' traits.

Imagine that: a tiny nucleus in a tiny cell contains billions of base pairs of DNA - and this tiny, tiny molecule and its billions of base pairs control how you look, how you survive, and how you live and breathe!

➤ But the environment plays a big role too?

Our traits are not controlled by genes alone. The environment also plays a very important role, and a given trait will result from the combination of genetic and environmental factors. For instance, Siamese cats and Himalayan rabbits have darker extremities because lower temperatures there affect gene expression.

We humans are no different. What you look like now, who you are, how you behave, and how your body functions is not determined by genes alone, but how you were raised, how you spent your childhood, and even the food you like to eat. (Source: http://www.emc.maricopa.edu)

➤ Every cell in our body has exactly the same DNA?

All the cells in your body have exactly the same DNA - the only exceptions are the reproductive cells, the sperm and egg cells, which have half their DNA; and red blood cells, which have no DNA at all.

But if all the cells in your body have the same DNA, why don't these cells look and function like each other? The answer is in the genes that are used. Every cell in the body - again, with a few exceptions - has the same DNA, but a heart cell will use one set of genes, while a skin cell will use another.

Our cells function and work together the way people do in society. It would be impossible to train everyone on earth to be good in all skills and professions, so different people specialize in different tasks, with all of them contributing to society's growth. In the same way, our cells specialize in certain tasks and contribute to making the human body work. (Source: http://www.hhmi.org)

We're not that different from other living organisms?

Humans share 98%-99% of their genes with chimpanzees, 90% with mice, 21% with worms, and 7% with a simple bacterium such as E. coli. Large sections of the human genome also show signs of having once belonged to viruses!

So if you call someone else a monkey, a mouse, a worm, or a germ, not only are you sort of right, but you're no different yourself! (Source: http://www.biotech.ca/PDFs/BTW05_Issue_BetterHealth.pdf)

And we're not that different from plants either?

We share about 50% of our genes with plants. One example is cytochrome C, a protein which helps in important metabolic processes. This protein product is 100% identical in humans, in a pea, and in a cow. (Source: Martina McGloughlin, University of California, Davis)

Millet

Millet is the world's sixth most important grain, and has been around for 8,000 years. It has found use as food, livestock feed, building material, and fuel. About 40% of the world's millet comes from Africa, where it is planted over 5.7 million hectares (14 million acres) to meet the needs of 500 million people.

Millet has also been used in brewing: the 3,000 year old bousa (also known as boza, bouza, and booza) from Egypt is thought to be the source of the word "booze," which now refers to any alcoholic beverage.

In its unhulled form, millet can have as much as 11% more protein than rice. It is also rich in vitamins A and B, iron, phosphorous, magnesium, and manganese.

Did you know...

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is currently working on marker-assisted introgression of drought-tolerance into pearl millet. ICRISAT scientists are also mapping salinity tolerance in the crop, as well as its ability to take up nutrients, and to produce more carotenoids in its grains. These are especially important for growing millet in Africa and South Asia, where millions of people depend upon it for survival.

Sources:
http://www.foodreference.com/html/fmillet.html, http://www.trivia-library.com/a/information-about-grains-millet.htm, http://www.beerbooks.com, http://www.cgiar.org/impact/research/millet.html, and http://www.syngentafoundation.org/what_is_pearl_millet.htm

Sorghum

Sorghum is the world's fifth most important cereal crop: about 2/3 of it is consumed as food, whether in the form of porridge, couscous, or even beer! It is also Africa's leading cereal grain, as it can grow even in the drought and heat of the continent's arid plains.

Sorghum can be classified into four major groups: the *grain sorghums*, cultivated as food; *grass sorghums*, grown as hay and pasture feed; *sweet sorghums* (or Guinea corn), used to produce sorghum syrup; and *broom corn*, which is fashioned into brooms

Did you know...

Because sorghum can grow in extreme conditions, scientists are interested in its genome, as it can be the source of genes to improve other important cereal crops. Australian scientists, in particular, are working to produce sorghum with increased yields, better grain quality, and resistance to midge, an important sorghum disease.

Sources:
http://www.cyberspaceag.com/kansascrops/grainsorghum/grainsorghumtrivia.htm
http://en.wikipedia.org/wiki/Sorghum

Microbes can be our Friends, too

They can make you sick or take you down, but they can also help you grow your food, and keep you healthy! Microbes, whether they are bacteria, viruses, or parasites, really are little machines, and they, too, are out to save the world.

Did you know that ...?

- **Microbes have been here for the longest time?**

They've been roaming the earth even before humans did! According to research, microbes may well be the oldest life form on the planet, and have been on it for 3.8 billion years. They can be found almost anywhere and everywhere on earth!

- **Microbes can be found ANYWHERE?**

About 60% of the earth's biomass is made up of microbes. They generate at least half the oxygen we breathe everyday. According to the Centers for Disease Control, the average human comes into daily contact with a million species of bacteria and 5,000 viruses. (Source: http://www.er.doe.gov/Sub/speeches/speeches/Trading_Genes.htm)

- **Most microbes do not cause disease?**

The number of microbial species capable of creating a deadly plague can be counted on one hand. Most microbes are in fact not deadly – killing a host organism would, in effect, often kill the microbe, as well as its chances of passing its traits on to more generations of microbes. (Source: Holman W. Jenkins, Jr., "Fun Facts to Know and Tell About Biotechnology," 1999)

Humans have been eating DNA and microorganisms since humans started to eat?

Since all living organisms contain DNA and their own share of microbes, everything we've been eating has its own share of DNA and microbes, too. We have been eating plants, animals, and microbes – and their DNA – for hundreds of thousands of years.

Humans continually ingest antibiotic-resistant microorganisms as well. These microbes are present in raw salads, and can be found in the intestines of an average person. (Source: http://www.microbe.org/microbes/at_work.asp)

➤ Microbes can keep pests away from plants?

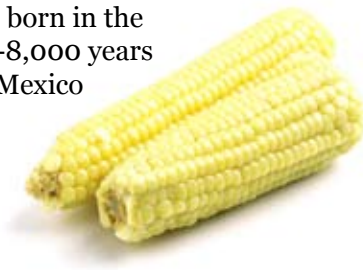
Pesticides are useful to keep pests out of your garden, but did you know that microbes are proving to be a less expensive alternative to your sprays? In a process called biocontrol, scientists use one living organism to kill or control another.

For instance, scientists can harness the power of parasites, such as fungi, which infect insects. By spraying fungal spores on insects, they can control insect pests without introducing chemical pesticides to the plant, or to the environment. (Source: http://www.herbarium.usu.edu/fungi/funfacts/ant_fung.htm)

➤ Bacteria can actually keep you safe?

About 99% of all bacteria are helpful, and the remaining harmful 1% can actually help boost your immune system. How? Dead or weakened bacteria are used to make vaccines, to protect you from a real bacterial infection.

Corn



Corn and popcorn were born in the Americas. About 7,000-8,000 years ago, settlers in Central Mexico domesticated *teosinte*, a wild grass. From Central America, corn spread to the Southwestern United States and Peru, then on to Europe with returning conquistadors.

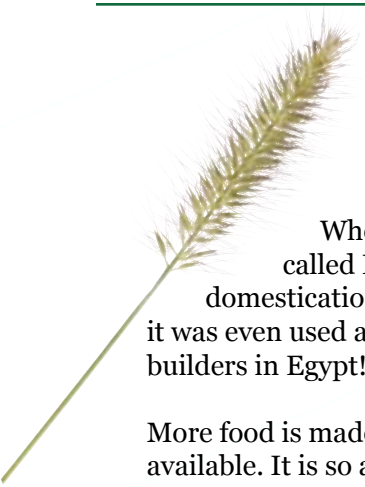
The early Americans also took to popping the larger kernels of the new and improved *teosinte*. Some tribes speared corn cobs with sticks, held them near the fire, and popped corn right on the cob. Popcorn was also used in ceremonies, as garlands to wear while dancing, and as decoration for ceremonial headdresses, necklaces, and ornaments on statues of the gods.

Corn today has an even greater number of uses. Its starches, syrups, and extracts are used to manufacture construction materials, detergents, medicines, candies, drinks, cookies, ice cream, insecticides, preserves, soups, and many more. Corn is also quickly gaining popularity as a source of ethanol – the primary component of environmentally-friendly biofuels.

Did you know. . .

Corn is among the most well studied crops in the world today, and has long been available as a biotech crop. Biotech corn is planted over 21.2 million hectares (52.4 million acres) all over the world, and is engineered to either have higher lysine content, or to be insect resistant, herbicide resistant, or a combination of both. Scientists are now working on making the most of corn as a source of ethanol in order to meet rising energy demands.

Sources:
http://www.foodreference.com/html/fpopcorn.html, http://www.aphis.usda.gov/brs/corn.html, http://www.campsilos.org/mod3/students/c_history.shtmlon, and http://www.iowacorn.org/cornuse/cornuse_6.html



Wheat

Wheat began as a coarse-grained variety called Einkorn, 10,000 years ago in Turkey. After domestication by ancient man, wheat became so widespread, it was even used as payment (in the form of bread) for pyramid builders in Egypt!

More food is made from wheat than any other grain crop now available. It is so abundant, indeed, that every person in Bulgaria consumes about 600 lbs annually (compared with 190 lbs per person annually in the U.S.). A bushel of wheat is made up of 1 million individual kernels, enough to bake 73 one-pound loaves of white bread.

Did you know...

The wheat genome is a large, complicated mix of genes, and has challenged scientists for decades. A good number of projects are now underway to sequence the 17 gigabase-pair wheat genome, as well as to test current varieties for resistance to scab, an important disease of the crop.

Sources:
http://www.kswheat.com/general.asp?id=142, http://www.foodreference.com/html/fwheat.html, http://www.fhsu.edu/kga/Lesson_Plans/WheatSeedsLessonPlans/WheatInFormationAndFacts.doc, and http://wbc.agr.state.mt.us/kids/dotdot2.PDF

Lab is All Around!

What exactly goes on in the laboratory? Why are scientists racing to make the next best crop, or complete the next big genome? Find out why – and how – in this section.

Did you know ...?

- **Genetic engineering didn't begin in the laboratory?**

Selective breeding, or the enhancement of particular genetic traits by breeding them in or out of a population, has been performed for centuries on animals and plants. This practice can improve an animal's or plant's traits, say by making pig's meat leaner by choosing which boars to mate sows with; or by changing flower color, through selecting which flowers should be crossed with which flowers.

Thus, breeders are the local versions of genetic engineers of farms, gardens, and greenhouses.

- **Genetic engineering began with little steps?**

With the invention and advancement of the microscope, scientists first got a glimpse of a world hitherto unseen by the human eye. This curiosity for all things small was complemented with advances in research. At the end of the 18th century, Edward Jenner developed the first vaccine by injecting a healthy boy with cow pox to prevent the spread of deadly smallpox. In 1928, Alexander Fleming discovered penicillin, an antibiotic still in wide use today.

In 1943, Oswald Avery and his colleagues provided evidence that DNA is the material that makes up genes. And, in 1953, the DNA structure was elucidated.

Modern genetic engineering was born.
(Source: http://www.biodesign.asu.edu/biotech/history/)

➤ Genetic engineering involves modifying or splicing DNA?

Genetic engineering is also called gene splicing – that is, it involves putting DNA molecules from two or more species together to produce a single piece of genetic material. This single piece can then be introduced into the cells of another organism, with the aim of improving the organism.

But how does the cutting and joining happen? To cut up DNA into desired fragments, scientists use molecular scissors called restriction enzymes, which cut DNA in specific places. To join DNA fragments, they employ an enzyme called DNA ligase. And, to introduce the DNA into an organism, they use vectors, such as plasmids or artificial chromosomes, which can carry the gene or genes of interest into a cell. (Source: http://en.wikipedia.org/wiki/Genetically_modified_organism)

➤ There are many ways of getting DNA into a cell?

Transformation describes the process by which cells are made to take up foreign DNA to acquire new genetic traits. The goal of transformation is to produce transgenic plant tissues that will stably inherit the DNA.

Researchers can open cell membrane pores by passing an electric current through a bacterial cell solution; or by keeping cells in solutions with certain cations, such as Ca2+.

Since plants have an especially thick outer cell wall, scientists coat small gold or tungsten bullets with their DNA molecule of choice, then shoot these bullets into cells with a gene gun. This process is called ballistic transformation, or biolistics.

Before you fill your plate ...

... Allow us to introduce you to a few fun food facts that might make your stomach turn, or your appetite run wild!

All the fun stuff you should know about...

Grasses and Grains

Rice

Growing rice began 15,000 years ago in East and South Asia, way back when people settled in the lush, fertile river deltas and domesticated what was once wild rice. Rice is now grown all over the world, except on the icy continent of Antarctica. It is so widespread, in fact, that 50% of the world's rice is eaten within 8 miles of where it is grown.

Rice, however, suffered a near wipe-out in the 1970's as the grassy stunt virus launched an unusually rabid attack on the Southeast Asian rice crop. Thanks to a gene from the wild strain *Oryza nivara*, of Uttar Pradesh, India, the rice crop was saved.

Farmers today are still worried, however, because rice is subject to a good number of major diseases. These include bacterial leaf blight, black sheath spot, brown leaf spot, sheath blight, and stem rot.

Did you know...

Biotech rice, engineered with the Bt gene, is planted over 4,000 hectares (9,884 acres) in Iran. More new biotech rice will be harvested in China in the coming years: scientists there are working on insect resistant rice, as well as a variety of the crop engineered with resistance to bacterial blight. Scientists are also hard at work on developing Golden Rice: a variety with lots of Vitamin A!

Sources: http://www.foodreference.com/html/frice.html, http://edugreen.teri.res.in/explore/facts/bio.htm, http://plantpathology.tamu.edu/Texlab/Grains/Rice/ricetop.html, and http://www.archaeologyonline.net/artifacts/vedic-civilzation.html

➤ Genetically modified crops shouldn't be planted all by their lonesome?

Some biotech crops, such as Bt corn and Bt cotton, have been engineered to produce a toxin which kills a destructive insect pest. When farmers use biotech crops, they are required to plant the crops' conventional counterparts in plots nearby. These buffer zones or *refugia* ensure that insects will not easily develop resistance to the toxin.

➤ It's been ten years since GM crops were first planted?

The year 2005 marks biotech crops' first decade on earth. Since their introduction in 1996, the crops have been planted on an accumulated area of 475 million hectares (1.17 billion acres): that's about twice the land area of Sudan, the world's tenth largest country. Biotech crops were planted over 90 million hectares (222 million acres) in 2005, which is slightly equal to the land area of Nigeria. (Source: Clive James, "Global Status of Commercialized Biotech/GM Crops," 2005)

➤ And the billionth acre was planted just last year?

The 400 millionth hectare, or billionth acre, of biotech crops was planted in 2005 in one of 21 countries. About 8.5 million farmers all over the world cultivate biotech crops – 90% of them, or about 7.7 million, are resource poor. (Source: Clive James, "Global Status of Commercialized Biotech/GM Crops," 2005)

➤ India is getting to be a world leader in GM research?

India is a growing biotech hub: it has a total of 1.3 million hectares of land planted to Bt cotton, an area slightly smaller than the total area of Puerto Rico.

India's biotech arena is rich in up-and-coming products. Public-private partnerships are working on biotech banana, blackgram, brassica, cabbage, cauliflower, chickpea, coffee, cotton, eggplant, muskmelon, mustard, potato, rice, tobacco, tomato, and wheat. Several private companies are also operating in the country and developing biotech brassica, cabbage, cauliflower, cotton, maize, mustard, tomato, pigeonpea, and rice. (Source: Clive James, "Global Status of Commercialized Biotech/GM Crops," 2005)

Another method uses the soil bacterium *Agrobacterium tumefaciens*, which infects plants and incorporates its DNA into their host's genome. This ability of Agrobacterium to transfer genes has been harnessed by scientists, and today, Agrobacterium transfer is routinely used to transform plant cells with the scientists' gene of choice. (Source: http://en.wikipedia.org/wiki/Genetically_modified_organism)

You can knock genes out?

In a process called *gene knock out*, scientists can keep a gene from functioning properly. In some cases, they can completely remove the gene. When scientists knock out genes, they hope to see what genes correspond to what protein or trait, because they assume that the trait for which the gene codes will also be affected.

At the opposite end of gene knockout is the *gain of function* experiment, where scientists increase the function of the gene by allowing it, for instance, to be transcribed at a faster rate or in a different part of the plant. Such gain of function work is sometimes performed alongside knockouts, so that scientists can better establish the function of the gene of interest. (Source: http://en.wikipedia.org/wiki/Genetically_modified_organism)

➤ Genetic modification is actually a natural event?

Nature is the Mother of All Genetic Engineers, and every organism on earth is the product of genetic engineering by nature. Gene sequences in every living thing are also mutated through chemicals, and even ultraviolet light.

These natural mechanisms for genetic change allow an organism to gain new genes and new traits, all while driving the force of evolution.

The first biotech drug came from bacteria?

All human beings need a special hormone called insulin, which converts blood sugar to glycogen for storage in the liver. However, patients suffering from type I diabetes do not produce this hormone, and need therefore daily injections of insulin. For years, diabetics were supplied with insulin extracts from pigs, which were full of impurities; or from cadavers, which were expensive.

To solve the problem, scientists introduced the gene for human insulin into *E. coli*, a common human intestinal bacterium. The transgenic *E. coli* began producing human insulin: all scientists had to do was to allow the transgenic bacteria to multiply, extract the insulin in large batches, and purify it. Thus, human insulin became the first drug to be engineered into and mass produced by bacteria. (Source: http://americanradioworks.publicradio.org/features/gmos_india/history.html)

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New Crops, New Plants

With the help of microbes and molecular biology, scientists have been able to create genetically modified organisms (GMO's), in order to breed new plants and crops that can bear more fruit or withstand environmental stresses, such as drought or soil salinity. It's a whole new ballgame for agriculture from here on, and it's bound to be a big adventure, too!

Did you know that ...?

➤ Almost all our foods are products of natural mutations or genetic recombination?

The wheat in the bread we eat everyday is a product of the combination of DNA from three different species. The corn we eat today is actually derived from years of breeding its primitive relative, *teosinte*. Modern corn looks almost nothing like it.

Both these crops arose from selective breeding techniques, when the first farmers – again, the first genetic engineers – selected the best crops, bred them, and saved their seeds for the next big harvest. (Source: http://www.fraserinstitute.ca/admin/books/files/biotech.pdf)

➤ Genetically modified crops are now being planted all over the world?

As of 2005, biotech soybean, engineered to be resistant to herbicide applications, takes the cake with a whopping 54.4 million hectares (134.4 million acres), and counting. Other major crops include biotech corn, cotton, and canola. (Source: Clive James, "Global Status of Commercialized Biotech/GM Crops," 2005)