

**April/May 2017 Teacher's Guide**

for

***Genetically Modified Foods: Are They Safe to Eat?***

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## About the Guide

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Articles from past issues of *ChemMatters* and related Teacher's Guides can be accessed from a DVD that is available from the American Chemical Society for \$42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher's Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.

## Student Questions

### Genetically Modified Foods: Are They Safe to Eat?

1. What does the acronym GMO mean?
2. What are five examples of common food products that may contain genetically modified ingredients?
3. Name two natural versions of genetic modification.
4. Describe the process of selective breeding or artificial selection in plants.
5. What are four advantages to GMO plants?
6. Why is a *Bacillus thuringiensis* (Bt) gene added to corn genomes?



## Answers to Student Questions (taken from the article)

### Genetically Modified Foods: Are They Safe to Eat?

1. **What does the acronym GMO mean?**

*The acronym GMO refers to genetically modified organisms.*

2. **What are five examples of common food products that may contain genetically modified ingredients?**

*Students may answer any of the following from the article. Examples of common foods that may contain genetically modified ingredients include many:*

- a. cereals,
- b. chips,
- c. tortillas,
- d. soy-based products,
- e. sugary drinks, and
- f. sugary snacks.

3. **Name two natural versions of genetic modification.**

*Two natural versions of genetic modification include plants swapping genes as they reproduce, and plants picking up genes from bacteria as they reproduce.*

4. **Describe the process of selective breeding or artificial selection in plants.**

*Selective breeding or artificial selection in plants involves humans combining plants together in specific ways to produce desirable traits. The seeds from the best plants are saved and planted for next season's harvest.*

5. **What are four advantages to GMO plants?**

*Four advantages to GMO plants are: faster growth, stronger plants, the ability to fight off pests, and resistance to herbicides designed to kill weeds.*

6. **Why is a *Bacillus thuringiensis* (Bt) gene added to corn genomes?**

*A *Bacillus thuringiensis* (Bt) gene is added to corn genomes because the Bt gene produces a toxin in the corn plant that kills a rootworm which damages corn crops and reduces corn yields.*

7. **List the three subunits of DNA nucleotides.**

*The three subunits of DNA nucleotides are a 5-membered ring sugar, a nitrogen-containing base, and a phosphate group.*

8. **Describe the processes used to place a new gene into a corn plant.**

*The process of placing a new gene into a corn plant involves several steps:*

*First, scientists must isolate a gene from another plant or bacterium that can protect the crop.*

*Then, the desired gene is extracted from the DNA of the plant or bacterium by using a restriction enzyme.*

*Next, the corn DNA is cut so that the desired gene's nucleotide sequence complements the corn's nucleotide sequence.*

*Finally, the ends of the new gene are spliced into the corn's DNA completing the process.*

9. **What forces hold the unpaired bases of the donor gene to the complementary unpaired bases in the receiving gene?**

*The forces holding the unpaired bases of the donor gene to the complementary unpaired bases in the receiving gene are hydrogen bonds.*

10. **During protein digestion in the stomach, what happens to the protein molecules?**  
*During protein digestion in the stomach, chemicals in the stomach begin to denature the protein molecules, and pepsin breaks the peptide bonds between the amino acids by the process of hydrolysis.*
11. **How is the process of digesting GMO proteins in the body different from digesting those from conventionally grown proteins?**  
*The process of digesting GMO proteins in the body is **not** different from digesting those from conventionally grown proteins. The whole process works the same for both food ingredients.*
12. **Why do a small group of people consider genetically modified crops harmful to human health?**  
*A small group of people considers genetically modified crops harmful to human health because they incorrectly believe that the crops may introduce new allergens.*

## Anticipation Guide

Anticipation guides help to engage students by activating prior knowledge and stimulating students' interest before reading. If class time permits, discuss students' responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions: *Before reading***, in the first column, write "A" or "D" indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. In nature, plants may pick up genes from bacteria.
		2. Humans have practiced selective breeding since the beginning of agriculture.
		3. GMOs usually refer to gene modification done in a laboratory.
		4. Bt corn has been genetically modified to resist rootworm infestation.
		5. Organic farmers cannot use Bt insecticides on their crops.
		6. Common genetically modified foods include golden rice, soybeans, and canola.
		7. Genetic modification alters the plant's DNA, which causes it to code for specific proteins.
		8. Your body breaks down genetically modified proteins differently from how other proteins are broken down.
		9. The National Academies of Sciences, Engineering, and Medicine concluded that eating food containing GMOs is not risky.
		10. The U. S. Food and Drug Administration does not approve new GMO food crops.

## Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Students' understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

### Teaching Strategies:

- Links to **Common Core Standards for Reading:**
  - ELA-Literacy.RST.9-10.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  - ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., *force*, *friction*, *reaction force*, *energy*).
  - ELA-Literacy.RST.11-12.1: Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
  - ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
- Links to **Common Core Standards for Writing:**
  - ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
  - ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.
- **Vocabulary** and **concepts** that are reinforced in this issue:
  - Chemical reactions
  - Macro- and micronutrients



- Personal and community health
  - Proteins
  - Structural formulas
  - Biochemistry
  - Consumer choices
  - Recycling
- Some of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them in their personal lives.
  - Consider asking students to read “Open for Discussion” on page 4 to extend the information in “Growing Green on the Red Planet” on pages 5-7.
  - The infographic on page 19 provides more information to support the article “Espresso, Café Latte, Cappuccino...A Complex Brew” on pages 10-12.
  - To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
  - You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.
  - The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.

**Directions:** As you read the article, complete the graphic organizer below to describe what you learned about GMOs.

<b>Why are they important?</b>	<b>How are they produced?</b>
<b>GMOs</b>	
<b>How are they treated in the body?</b>	<b>Examples</b>

**Summary:** On the back of this page, use information from the article to write a tweet (140 characters or less) about GMOs.

## Connections to Chemistry Concepts (for correlation to course curriculum)

1. **Hydrogen bonding**—Students typically associate hydrogen bonding with water. However, it is also a significant force in the tertiary structure of proteins and the bonding between the double-helical strands of comprising DNA.
2. **Hydrolysis reactions**—Many students are taught a few general types of reactions such as combustion and double replacement. Sometimes, students have the misconception that only these few types of reactions occur. Including reactions like the hydrolysis of proteins as examples of types of chemical reactions may dispel that misconception and help students relate to the digestion of food as an important chemical reaction and a connection to biology courses.
3. **Organic functional groups**—Typical functional groups introduced in high school chemistry are few and may include hydroxyl, carboxylic acid, and ester. By including the amine group with the others, teachers can assist students' understandings of biochemical molecules, including proteins, DNA, and carbohydrates. Students will better understand the composition of proteins from amino acids that contain both carboxylic acid and amine groups. Also, the base-pairings in DNA depend upon functional groups producing hydrogen bonds.
4. **Acid-base chemistry**—In proteins and amino acids, the carboxyl groups are acids, and the amino groups are bases. Teachers can use these organic functional groups when teaching acid-base reactions, neutralization, and titrations along with the traditional inorganic acids and bases.
5. **Biochemistry**—Teachers can engage high school students with connections to current and interesting news items, including genetic engineering, GMOs, and food chemistry, by incorporating biochemistry examples in their courses. Use biochemical examples of chemical reactions, properties of molecules, temperature dependence of reactions such as digestion, and processes such as scientific investigations of claims of benefit or harm from chemical compounds, methods, or products.
6. **Polymers**—Some of the molecules discussed in the article, DNA and proteins, are examples of natural polymers. The concept of a polymer's composition containing repeated units (monomers) can be reinforced from studying the repeated nucleobases in DNA and from the repeated amino acids in proteins.

## Possible Student Misconceptions (to aid teacher in addressing misconceptions)

1. **“Genetic manipulation of plants for food is a recent event, probably starting in about the 1980s.”** *Genetic manipulation of food has taken place since mankind began domesticating plants and animals by selective breeding. For example, corn as we know it today was not always a large, plump kernel. It started out as a small, grass seed, called teosinite and has been improved by selective breeding for thousands of years.*
2. **“GMO foods are not natural; therefore, they are bad for you.”** *GMO foods are natural. Some GMO foods are advertised as organic or all natural because some of them can be raised without the use of commercial pesticides. The inclusion of beneficial DNA from another plant or bacterium in the GMO food's DNA can reduce or eliminate the need for pesticides to reduce damage to the plant from specific insects and diseases. Eliminating the use of broad-spectrum insecticides and other disease-preventative sprays is healthier for the plant and the environment.*

3. **“Genetically modified plants can go wild and spread across the world causing a danger to our natural food plants.”** *While it is true that some genetically modified food plants contain bacterial DNA, or a different plant's DNA, governmental research has demonstrated that the probability of GMO plants endangering our natural food plants is so low that it poses essentially no risk. The problem of outcrossing (genes from the genetically modified plant spreading to conventional crops or to wild species of the plant) can be an issue. Some countries are making laws that will promote practices to prevent outcrossing and adopting agricultural techniques to prevent the event.*
4. **“All of our foods are contaminated with GMOs.”** *This is dependent upon your diet. If you eat large quantities of highly processed, sugary, or fried foods, then it may be a true statement. Only corn, soybeans, canola (oil), some squash, and Hawaiian papaya are commercially-produced, genetically-modified food plants in large supply. The corn may be found as corn, corn meal, or as high-fructose sweetener used in many sweetened drinks, bakery goods, and snack foods; soy may be found in foods as soy milk, soy protein, tofu, or vegetable oil, and soy flour is a common additive in many processed foods; canola may be found in processed foods or as a cooking oil. However, if you eat more fresh fruits, vegetables, and grains, then you will likely consume few genetically modified food plants.*

## Anticipating Student Questions (answers to questions students might ask in class)

1. **“Is it true that the government does not require GMOs to be labeled? How will I know if I'm eating food with GMOs?”** *Yes, it is true that the federal Food and Drug Administration does not require GMOs to be labeled as such. Their research has shown that the GMOs are not different than conventional food sources. The FDA has approved a voluntary label that food companies can use on meats and liquid egg products that are sourced from animals raised without GMO feed once they have provided satisfactory evidence that they meet the standards. Unless you grow all of your own food, you will likely consume some genetically modified food ingredients as sweeteners, and other corn products, and as soy or soy products.*
2. **“Can GMOs be good for people?”** *Yes. For example, Golden Rice (see Golden Rice in the Background Information section above) is a GMO-containing beta-carotene that can reduce or eliminate certain eye diseases in children living in areas where rice is the primary grain crop. GMOs can also increase crop yields and reduce starvation in the world. GMOs can reduce food damage and spoilage from grower to market to table and cut down food costs and waste.*
3. **“Are there any dangers associated with GMOs?”** *There is nothing without some risk or liability. The dangers associated with GMOs are primarily those stemming from a lack of information and understanding about what they are and what they are not. For about 20 years, much of the corn and soybean products consumed in the United States has come from genetically modified varieties of these foods. The misconceptions and lack of knowledge of GMOs contribute to a fear of them. Research has shown that GMOs do not pose a health risk and that they are not an environmental problem-when planted properly. As with all things, improper planting of GMOs or manipulation by unscrupulous people could result in problems.*
4. **“Is it really illegal to grow GMO seeds?”** *Yes. GMOs are patent-protected organisms which have been developed at great expense by seed or research companies. Just as it would be illegal for a person to copy music or plagiarize a play, it is illegal for a person to grow GMOs from seed they have saved from harvest without buying the new GMO seed or*

*paying the royalty for the seed. Companies typically only pursue individuals who flagrantly violate this rule. Incidental growth of genetically modified plants from errant seed are not likely to be sued.*

5. **“Why do some of my friends call GMO foods ‘Frankenfood’?”** *Frankenstein was a scientist in Mary Shelly's book Frankenstein; or the Modern Prometheus who created a living creature in his laboratory using chemistry, alchemy, and various apparatus. The creature is commonly referred to as Frankenstein even though that was the creature's creator's name. So, Frankenfood is a slang reference to food that has been altered or created in a laboratory.*

## Activities

### Labs and Demos

1. **Virtual lab—designing a transgenic organism:** Students will have the opportunity to insert the gene from one organism into a different organism in "Gene Splicing". The virtual lab is a series of slides that students navigate as they engineer their organism. The Web site provides assistance for students, with diagrams, a help section, and a journal section where students can answer questions.  
([http://www.mhhe.com/biosci/genbio/virtual\\_labs/BL\\_22/BL\\_22.html](http://www.mhhe.com/biosci/genbio/virtual_labs/BL_22/BL_22.html))  
A teacher-generated addition to this virtual lab with additional student directions is located at [http://olympia.osd.wednet.edu/media/olympia/departments/science/baker/biology/unit4/gene\\_splicing\\_activity.pdf](http://olympia.osd.wednet.edu/media/olympia/departments/science/baker/biology/unit4/gene_splicing_activity.pdf).
2. **Paper lab simulation of recombinant DNA:** Students simulate inserting a paper section of plasmid DNA into a paper human DNA sequence in "DNA Analysis – Simulating Recombination". The Web site has a link to the student materials and instructions on completing the activity. Student discussion questions are provided, but there are no teacher support materials or answers.  
([https://www.biologycorner.com/worksheets/DNA\\_analysis\\_recombination.html](https://www.biologycorner.com/worksheets/DNA_analysis_recombination.html))
3. **A paper clip lab to simulate gene splicing:** *Genetic Engineering* includes a lab simulation activity, "Gene Splicing", and a research/discussion activity, "Recombinant DNA", which may be useful for students. The "Gene Splicing" simulation uses colored paper clips to represent the four DNA nucleotides, and directs students to construct a DNA sequence and then splice a plasmid sequence into the DNA strand. Thorough directions with diagrams accompany the lesson. The lesson concludes with questions for the students to complete and discussion starters for small group work. The "recombinant DNA" lesson may be less useful; it is a follow-up to "Gene Splicing", and is a read-and-answer-questions activity.  
([http://staff.4j.lane.edu/~mitchell\\_ja/Mitchells\\_Site/Biology\\_files/Genetics%2038.pdf](http://staff.4j.lane.edu/~mitchell_ja/Mitchells_Site/Biology_files/Genetics%2038.pdf))
4. **Modeling DNA with student bodies and chenille stems:** "Modeling DNA" includes two activities to reinforce student understanding of DNA structure. In the first, students use their hands and arms (with codes on the hands) to represent individual nucleotides. Students line up in a double line pairing with the complementary bases. The lesson is built on the 5E model. The second activity uses colored chenille stems to build a simulated DNA sequence. Teachers could use a bit of creativity to modify the first activity and simulate cutting DNA with restriction enzymes and inserting a new section of gene. Assessment and correlations to NGSS are provided. This is the print version of the article: Robertson, C. Modeling DNA. *The Science Teacher*, 2016, 83 (5), pp 26–32, and the article is available for free at [http://static.nsta.org/files/tst1605\\_26.pdf](http://static.nsta.org/files/tst1605_26.pdf).

5. **Three lab tests to distinguish DNA from protein:** The *Journal of Chemical Education* published an article where three tests are used to identify whether polymer fibers extracted from foods are either DNA or protein. The tests use temperature, an acid-medium effect, and a qualitative protein test for confirmation. The procedures with pictures, potential hazards, and instructor notes (online) are included. (<http://pubs.acs.org/doi/pdf/10.1021/ed200686e>); note that this link is a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal. The citation for the print article is: López-Valentín, D.; Pulido-Corboda, L.; Chavez-Reyes, A. An Easy Way to Distinguish DNA from Protein: An Experiment for General Chemistry. *J. Chem. Educ.*, 2012, 89 (10), pp 1333–1335.

## Simulations

1. **Simulation of gene expression:** In the PhET simulation, "Gene Expression—The Basics", students can study gene expression, DNA transcription, and protein synthesis as they generate and collect data exploring the factors affecting protein synthesis in cells. (<https://phet.colorado.edu/en/simulation/legacy/gene-expression-basics>)

## Media

### Videos

1. **Artificial selection in corn:** This brief video clip from the Howard Hughes Medical Institute, "Breeding Corn from Teosinte" (0:53), gives a quick overview of how humans have used artificial selection over time to improve the characteristics of corn. (<https://www.hhmi.org/biointeractive/breeding-corn-teosinte>) The video clip is from the longer program, "Selection in Action" (58:29), explaining natural and human (artificial) selection in dogs, maize, and stickleback fish. (<https://www.hhmi.org/biointeractive/selection-action>)
2. **The genetic engineering process:** Another Howard Hughes Medical Institute video clip, "Genetic Engineering" (1:13), provides a nice animation of how a new gene can be inserted into a plasmid loop. (<http://www.hhmi.org/biointeractive/genetic-engineering>)
3. **Amino acids and their structure:** The Khan Academy video "Introduction to Amino Acids" (9:53) provides a biochemistry review for students of the amino acids, their functional groups, side chains, and other details. (<https://www.khanacademy.org/science/biology/macromolecules/proteins-and-amino-acids/v/introduction-to-amino-acids>)
4. **Peptide bond formation:** This Khan Academy video continues the instruction from the one above. "Peptide Bond Formation" (8:25) shows and explains how amino acids are joined together by a condensation reaction forming a peptide bond. (<https://www.khanacademy.org/science/biology/macromolecules/proteins-and-amino-acids/v/peptide-bond-formation>)
5. **Peptide bonds and cleavage:** This Khan Academy video, "Peptide Bonds: Formation and Cleavage" (7:10), is a more advanced treatment of peptide bonds than the one above. (<https://www.khanacademy.org/test-prep/mcat/biomolecules/amino-acids-and-proteins1/v/peptide-bond-formation-and-cleavage>)
6. **Forming recombinant DNA:** Another Khan Academy video, "DNA Cloning and Recombinant DNA" (11:07), focuses more on DNA cloning, but it includes the use of restriction enzymes to cut and splice genes together to make recombinant DNA. (<https://www.khanacademy.org/science/biology/biotech-dna-technology/dna-cloning-tutorial/v/dna-cloning-and-recombinant-dna>)

7. **TEDx video on GMO controversies:** Borut Bohanec (Professor at University of Ljubljana, Biotechnical Faculty, Agronomy Department) speaks about the need for better public understanding of GMOs in "GMO Controversies: Science vs. Public Fear" (16:41). ([https://www.youtube.com/watch?v=mz4\\_TwdaYel](https://www.youtube.com/watch?v=mz4_TwdaYel))
8. **PBS documentary of DNA and genetic engineering:** This video is one of five episodes about DNA. The video "DNA—Episode 2 of 5—Playing God" (53:00) starts with the first genetic engineering experiment in 1973 with Herbert Boyer and Stanley Cohen and looks at genetic engineering's impact, problems, and potential through interviews with key scientists. (<https://www.youtube.com/watch?v=M3wg-W3Slow>)
9. **PBS News Hour on Golden Rice in the Philippines:** "GMO Debate Grows over Golden Rice in the Philippines" (8:24) is a news report by science correspondent Miles O'Brien about vitamin A deficiency in children in the Philippines. He reports on the controversy over growing and eating Golden Rice. ([https://www.youtube.com/watch?v=Ayv\\_EYi43E8](https://www.youtube.com/watch?v=Ayv_EYi43E8))
10. **Molecular biology and genetic engineering:** Paul Anderson, educational consultant and video creator at Bozeman Science, explains the major procedures in molecular biology including genetic engineering techniques in "Molecular Biology" (14:32). (<https://www.youtube.com/watch?v=yYIZqS-L5Sc&feature=youtu.be>)
11. **Genetic engineering:** This video from the Massachusetts Institute of Technology uses scissors and paper strands to model and explain the complex process involved in genetic engineering. View "Genetic Engineering" (7:20) at <https://www.youtube.com/watch?v=nfC689EIUVk>.
12. **Animation of DNA recombination:** The DNA Learning Center is part of the Cold Spring Harbor Laboratory, and they supply this video animation clip, "Mechanism of Recombination" (1:12), showing how a gene is inserted into a bacterial plasmid. (<https://www.youtube.com/watch?v=8rXizmLjejl>)
13. **Briefing on Genetically Engineered Crops: Experiences and Prospects:** The National Academies of Sciences released an important book, *Genetically Engineered Crops: Experiences and Prospects*. A video report briefing, "Genetically Engineered Crops: Experiences and Prospects Release Briefing" (41:40), accompanied the release of the book.
14. **Review of hydrogen bonds:** In "Hydrogen Bonding and Common Mistakes" (8:59), students can review the formation of hydrogen bonds and learn about possible misconceptions or mistakes. (<https://www.youtube.com/watch?v=PyC5r2mB4d4>)

### Infographics

1. **DNA:** The chemistry Web site *Compound Interest* provides a colorful infographic, "DNA", at <http://www.compoundchem.com/2015/03/24/dna/>. The Web site includes a description of DNA composition and structure, research leading to the discovery of DNA, and other interesting facts.
2. **Amino acids:** Another *Compound Interest* infographic, "A Guide to the Twenty Common Amino Acids", provides a pictorial grouping of the common amino acids with their structures, as well as supporting details and further information. (<http://www.compoundchem.com/2014/09/16/aminoacids/>)
3. **Chemical reactions:** A summary of condensation and hydrolysis reactions is included in "Chemical Reactions—Part II" from *Compound Interest*. The Web site gives a synopsis and an example of the reaction types, as well. (<http://www.compoundchem.com/2014/05/11/chemical-reactions-posters-part-ii/>)
4. **Pros and cons of GMOs:** "The Good, the Bad, and the Ugly: A Snapshot of the GMO Debate" is an infographic presenting the positives and negatives of GMOs. It is presented by

Carrington College, and is located at <http://carrington.edu/blog/student-tips/health/genetically-modified-food-pros-and-cons/>.

### PowerPoint presentations

1. **GMOs:** This 12-slide presentation gives a quick introduction into defining GMOs, differentiating genetically modified and genetically engineered organisms, and common plants that are altered. (<https://www.ces.ncsu.edu/wp-content/uploads/2015/10/1-what-is-a-gmo.ppt>)
2. **North Carolina Cooperative Extension Presentation on GMOs—Part I:** This presentation focuses on North Carolina, but has many slides and much information applicable to any locale. The 54-slide presentation, "GMO Presentation", has useful images and graphics, along with excellent introductory material containing definitions, reasons for using GMOs, and herbicide resistance. ([https://www.ces.ncsu.edu/wp-content/uploads/2015/12/GMO-presentation\\_Edmisten\\_ExtConf2015-part-1.pptx](https://www.ces.ncsu.edu/wp-content/uploads/2015/12/GMO-presentation_Edmisten_ExtConf2015-part-1.pptx))
3. **North Carolina Cooperative Extension Presentation on GMOs—Part II:** The presentation above continues with the second part, "GMO Presentation—Part II". This presentation is also 54 slides in length. ([https://www.ces.ncsu.edu/wp-content/uploads/2015/12/GMO-presentation\\_Edmisten\\_ExtConf2015-part-2.pptx](https://www.ces.ncsu.edu/wp-content/uploads/2015/12/GMO-presentation_Edmisten_ExtConf2015-part-2.pptx))
4. **Genetic engineering:** "Genetic Engineering and Recombinant DNA" is a 33-slide PowerPoint presentation. The slides are simple black and white design with some graphics and color images. The information is straight-forward, and it includes some animal examples. (<http://clt.astate.edu/mgilmore/Biol%201003/13%20Genetic%20Engineering.ppt>)
5. **Transgenic cotton in Arizona:** While the focus may be on Arizona cotton, the information presented in "Transgenic Cotton for Insect Control" includes good information on *Bacillus thuringiensis* use in plants like cotton. The presentation includes 36 slides. (<https://cals.arizona.edu/crop/presentations/ellsworthperu2002.ppt>)
6. **Golden Rice:** "Golden Rice: A Boon or Bane" contains 17 slides providing information and comparisons of Golden Rice 1 and Golden Rice 2 (the improved version). Slides show the beta-carotene pathway problem in plants and other aspects of the rice controversy. (<https://www.ohio.edu/plantbio/staff/showalte/PBIO%20450%20&%20550/Basu.pptx>)
7. **Golden Rice and other golden crops:** This 50-slide PowerPoint, "Golden Rice and Golden Crops", was presented by Peter Beyer (University of Freiburg) at the Pontifical Academy of Science, the Vatican, in 2009. It is a comprehensive presentation on the development of, need for, and the biotechnology of Golden Rice. (<http://www.pitt.edu/~super4/35011-36001/35741.ppt>)
8. **Amino acids and proteins:** This college-level presentation, "Amino Acids, Peptides, and Proteins", is an excellent review of the amino acids and the condensation reaction forming peptide bonds and proteins. There are 32 slides in the presentation, which goes deeper than the Wendel article, but it would be enrichment for some students. (<http://as.vanderbilt.edu/chemistry/Rizzo/Chem220b/Ch25.ppt>)
9. **Review of hydrogen bonding:** for a quick seven-slide review of hydrogen bonding, see "Introduction to Hydrogen Bonding" at <http://www.creative-chemistry.org.uk/presentations/alevel/hydrogenbonding1.ppt>.

### Lessons and Lesson Plans

1. **Genetically modified crops lesson plan:** The National Agriculture in the Classroom organization provides a set of three activities (2-3 hours, total) designed for grades 9–12. The 2016 "Genetically Modified Crops" lesson "... provides students with a brief overview of



the technology, equipping them with the ability to evaluate the social, environmental, and economic arguments for and against genetically modified crops." PowerPoints, student handouts, and links to lesson materials are provided along with suggested companion resources and additional credits and links.

(<http://www.agclassroom.org/teacher/matrix/lessonplan.cfm?lpid=86>)

- 2. Introduction to GMO and genetic engineering lesson:** This 70-minute lesson is written for grades 6–8, but may be useful for high school students, too. "Genetic Engineering and Genetically Modified Organisms: Forming Informed Opinions" is the introductory lesson prior to a two-week independent student research project on GMO topics. Background material with links to Web-based content, vocabulary, links to student materials, and student procedures are provided. Assessment activities include a K-W-L chart, and complementary activities and extension ideas are provided. Three infographics are part of the supplied materials. (<https://www.uaf.edu/case/lessons-1/GMOs.pdf>)
- 3. Lesson investigating GMOs through comparison to jabberjays from *The Hunger Games*:** Students learn about genetically engineered organisms using the jabberjays in the movie, *The Hunger Games* in "Hunger Games' Science: Investigating Genetically Engineered Organisms". The lesson overview states, "... students discuss the definition of genetically modified organisms, learn about the risks and benefits of research on G.M.O.'s, explore the growing do-it-yourself biology movement, and develop proposals seeking to either restrict or permit research into genetically modifying the avian flu virus." Students will need Internet access to use the links in the lesson. No timeframe is provided, but the reading, research, student group work, presentations, and possible extensions would likely require multiple class periods. (<https://learning.blogs.nytimes.com/2012/05/16/hunger-games-science-investigating-genetically-engineered-organisms/?r=0>)
- 4. Role play lesson on genetically modified foods:** "Supertomatoes or Frankenfoods?" requires one or two 50-minute classes to have students identify three different viewpoints about the advantages and disadvantages of biotechnology and foods. The role cards for students and a student record sheet to use during the presentations are included. Only minimal teacher support and background are provided, and assessment is not addressed. (<https://www.cpet.ufl.edu/wp-content/uploads/2013/03/Genetically-Modified-Foods-Role-Play-Lesson-Plan.pdf>)
- 5. Unit on benefits and risks of GMO foods:** A unit of instruction for *The Eyes of Nye* DVD from Disney Educational Products, "Genetically Modified Foods: Benefits and Risks", is a complete guide to investigating GMOs. The lessons aimed at grades 7–12 start with the video clips and use them to motivate student learning and discussion. After gathering information and questioning, students will role play information they gathered as applied to a scenario presented. The 26-minute DVD can be purchased (the current price is \$14.99) at <http://www.dep-store.com/ProductDetails.asp?ProductCode=77C47VL00>. It is also available on YouTube at <https://www.youtube.com/watch?v=GKm2Ch3-Myg>. Further research opportunities for students are included in the 11-page Educator's Guide at [http://wimedialab.org/sites/default/files/episode/guide/Genetically\\_Modified\\_Foods\\_Teacher\\_Guide.pdf](http://wimedialab.org/sites/default/files/episode/guide/Genetically_Modified_Foods_Teacher_Guide.pdf).
- 6. Lessons and resources for the NOVA video "Harvest of Fear":** The 2001 NOVA video, "Harvest of Fear" explains how scientists use genetic engineering, the possible benefits, and opposition to the techniques. It addresses the speculation of allergic responses to GE proteins and the need for GE techniques. The video (120 minutes total) can be accessed in 12 segments of approximately 10 minutes each on YouTube at ([https://www.youtube.com/watch?v=\\_XLyzbCwke&list=PLEXHaXFPS255xOoHCqkQsHXi2aHHEEaVR](https://www.youtube.com/watch?v=_XLyzbCwke&list=PLEXHaXFPS255xOoHCqkQsHXi2aHHEEaVR)), or at WatchKnowLearn.org. (<http://www.watchknowlearn.org/Video.aspx?VideoID=38182&CategoryID=11628>). The PBS

Web site that accompanies the "Fear of Harvest" video contains rich resources and links to a multitude of materials, lessons, and interviews. Sections of the Web site include Should We Grow GM Crops, Engineer a Crop, Guess What's Coming to Dinner, and Viewpoints. The Links section contains dozens of Web links to general information, academic and government sites, pro-GMO and anti-GMO sites, and more articles. While some of the articles may be older, they still contain valuable information.

[\(http://www.pbs.org/wgbh/harvest/\)](http://www.pbs.org/wgbh/harvest/)

A related PBS Web site for the video provides viewing ideas, a classroom activity with materials and answers for the teacher, additional ideas from classroom teachers, related NOVA resources, and a student interactive at

[http://www.pbs.org/wgbh/nova/education/overviews/28gm\\_harvest.html](http://www.pbs.org/wgbh/nova/education/overviews/28gm_harvest.html).

- 7. Lessons for PBS video "Food, Inc.":** The PBS video, "Food, Inc." (1:33:44), first aired in 2010. The video may currently be rented for viewing on You Tube for \$2.99 at <https://www.youtube.com/watch?v=iRp71BwRW8c>, or it may be available from other sources, too. The film details the vast changes in American agriculture including animal feed lots, large food producers, and problems with a mechanized and centrally-controlled food system. Eric Schlosser, *Fast Food Nation* author, was an on-and off-screen advisor for "Food, Inc." The PBS Web site for "Food, Inc." (<http://www.pbs.org/pov/foodinc/film-description/>) links to a GMO quiz, a lesson plan (grades 6–12, 50 minutes) for "The Impact of Genetically Modified Seeds" (<http://www.pbs.org/pov/foodinc/lesson-plan-3/>), and a link to many other Web sites and books.
- 8. FFA Lesson plan for genetically modified foods:** The Future Farmers of America created a 90-minute lesson plan in 2015, "Genetically Modified Foods". The lesson includes a video (link supplied); Common Core State Standards for reading, speaking and listening, writing, and math practices; and the lesson directions for a debate on GM foods. A scoring rubric is included with the lesson.  
([https://www.ffa.org/SiteCollectionDocuments/myjourney\\_explore\\_productionag-gmo.pdf](https://www.ffa.org/SiteCollectionDocuments/myjourney_explore_productionag-gmo.pdf))
- 9. Lesson comparing selective breeding and transgenic manipulation of plant crops:** "Bioengineered Foods?" is a PBS Learning Media lesson where students "compare the processes of selective breeding and transgenic manipulation of plants. They consider the pros and cons of growing genetically modified crops." The lesson requires 4–5 class periods and includes links to videos, teacher instructions, and an extension art project.  
([http://pbslearningmedia.org/resource/tdc02.sci.life.gen.lp\\_bioengfood/bioengineered-foods/](http://pbslearningmedia.org/resource/tdc02.sci.life.gen.lp_bioengfood/bioengineered-foods/))
- 10. PowerPoint lesson on agricultural biotechnology:** The 17-slide PowerPoint presentation "What is Agricultural Biotechnology?" includes speaker notes and is a discussion lesson for students. The lesson centers on the question of why agricultural biotechnology is so controversial, while other types of biotechnology are less so.  
<http://www2.ca.uky.edu/brei/Teach/NSTA%20II.ppt>)

## Projects and Extension Activities

- 1. Internet research on patenting a DNA sequence and exploring opinions on GMO foods:** This activity is designed for higher education but is appropriate for high school, too. "Genetically Modified Food: Future Hope or Frankenfood" directs students to use the Internet to research the appropriateness of patenting a DNA sequence, Web sites discussing GMO foods, writing two arguments both for and against GMO foods, and writing their own opinion on whether GMO foods should be removed from the market. The activity claims to take about two hours to complete. The lesson includes a scoring rubric, student worksheets, student directions, resources, and teacher recommendations.

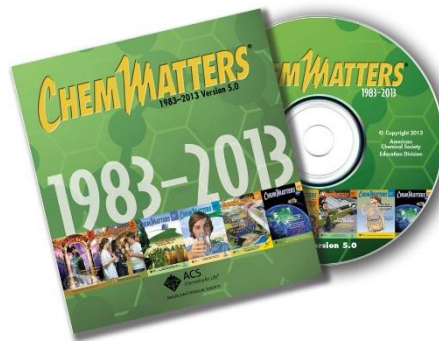
<http://www.k12science.org/pathways/rwlo/search.php?filter=science&keywords=GMO&submit=Search>)

2. **Lab testing grocery store foods for the presence of GMOs:** This lab procedure is not practical in typical high school settings. However, in cooperation with a university, the procedure would be interesting for students as an extension project. "GMO: Yes or No? Genetically Modified Food Organisms in Our Food" is a 2009 project with the Howard Hughes Medical Institute and the University of Miami. Participants took food samples from Whole Fresh Market and Publix grocery stores, extracted DNA from the food samples, used polymerase chain reaction to increase the sample size, and ran gel electrophoresis tests on the samples. The processes are described, but detailed procedures are not provided. Students would need to research detailed procedures and protocols for completing this activity. ([http://www.bio.miami.edu/ecosummer/eco2009/finalpaper\\_foodies.pdf](http://www.bio.miami.edu/ecosummer/eco2009/finalpaper_foodies.pdf))
3. **Build a DNA model with origami:** As an extension or a refresher for students on DNA, they can construct an origami model of DNA. "Origami DNA", (4:18), is a short video to use with the provided color or black-and-white student template. The site provides downloads for both templates and printed instructions. (<http://www.yourgenome.org/activities/origami-dna>)
4. **Internet research project on vetting GMO Web sites:** Teachers can provide students a list of (or students can identify their own) Web sites regarding GMOs. Students will cite and describe the content of each Web site, and the students will identify the site's content as pro-GMO, anti-GMO, or neutral. In addition, students will develop a rubric (as a whole group or as individuals) to make a determination of whether the site comes from a reputable, reliable source backed with scientific data or is opinion based and without vetted data.

## References

### (non-Web-based information sources)

The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles published from the magazine's inception in October 1983 through April 2013; all available Teacher's Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for \$42 (or \$135 for a site/school license) at this site: <http://www.acs.org/chemmatters>. Click on the "Teacher's Guide" tab to the left, directly under the "*ChemMatters Online*" logo and, on the new page, click on "Get the past 30 Years of *ChemMatters* on DVD!" (the icon on the right of the screen).



**30 Years of *ChemMatters* !**

**Available Now!**

Selected articles and the complete set of Teacher's Guides for all issues from the past three years are available free online at the same Web site, above. Click on the "Issues" tab just below the logo, "*ChemMatters Online*".

"Corn: The A'maiz'ing Grain" is an interesting article that supports the Wendel article. The history and importance of corn in mankind's existence is explored. Also, the subsection of

the article, "Genetically modified corn— isn't that frankenfood?" discusses GE or transgenic corn and the controversy surrounding it. (Haines, G. Corn: The A"maiz"ing Grain. *ChemMatters*, 2006, 24 (4), pp 4–7)

The December 2006 Teacher's Guide for "Corn: The A'maiz'ing Grain" (see above) directs readers to material on GMOs in the "Web sites for Additional Information" section. Over one dozen links include questions answered by the World Health Organization, Roundup Ready® Soybeans, and GE techniques.

The use of DNA vaccines, where an engineered plasmid containing an antigen is injected into the body, has similarities to the genetic engineering of plants. A section of "Promising New Vaccines" describes the DNA vaccination. (Boughton, B. Promising New Vaccines. *ChemMatters*, 2009, 27 (1), pp 16–17)

A useful graphic of DNA showing the hydrogen bonds between the double nucleotide strands and a brief description of polymers associated with an artificial pancreas might be of interest to some students. (Karabin, S. Changing the Course of Diabetes. *ChemMatters*, 2011, 29 (4), pp 12–13)

The Open for Discussion department in a previous issue of *ChemMatters* includes a brief dialog about genetically modified and certified organic foods. A chart of beneficial and uncertain effects of GM foods is presented. (Sitzman, B., Goode, R. Labels and Logos: "Genetically Modified" and "Certified Organic". *ChemMatters*, 2013, 31 (4), p 5)

A sidebar, How Mussels' Bioglue Works, in the article, "Stuck on You", briefly describes hydrogen bonds and London dispersion forces in protein structure. A diagram indicating hydrogen bonds in mussel proteins helping them to attach to various surfaces is depicted in the sidebar. (Anger, M. Stuck on You. *ChemMatters*, 2016, 34 (1), pp 8–10)

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This article from *The Journal of Chemical Education* targets elementary and middle school science students, but the ability to have a physical demonstration model of DNA constructed from building blocks and magnets might be useful to high school students, too. The article includes a link to *JCE Online* for construction videos and templates. (Cox, J. A Unique Demonstration Model of DNA. *J. Chem. Educ.*, 2006, 83 (9), pp 1319–1321; <http://pubs.acs.org/doi/pdf/10.1021/ed083p1319>; note that this link is a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

Two simple models of DNA are described in this *Journal of Chemical Education* article. One model uses a paper ribbon (template supplied online) and a yo-yo model shows the compact form of the supercoiling in DNA. Two short movies are also available to support the article and activity which are suitable for high school students. (Van Horn, J. DNA Structure and Supercoiling: Ribbons and a Yo-Yo Model. *J. Chem. Educ.*, 2011, 88 (9), pp 1264–1267; <http://pubs.acs.org/doi/abs/10.1021/ed100887p>; note that this link is a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

## Web Sites for Additional Information (Web-based information sources)

### GMO foods

A special edition blog in August 2015 from Harvard University, *GMOs and Our Food*, contained an introduction and 15 well-researched and well-written articles related to GMOs (several are referenced in this Teacher's Guide). The articles are:

- How to make a GMO
- A History of GMOs
- GMOs and Natural Genetic Diversity
- The Technology and Safety of BT Crops
- RoundupReady Crops and the environment
- The Allergenic Effects of GMOs
- Pesticides and Our Food
- Will GMOs Harm our Organs
- Acquiring GMO Patents
- GMOs and Farming Culture
- How GMOs Are Regulated
- Feeding the World with GMOs
- Can GMOs Combat Malnutrition
- Genome Engineering: An Interview with Dr. Dan Voytas
- New Technology in GMOs: Epigenetics & RNAi

(<http://sitn.hms.harvard.edu/signal-to-noise-special-edition-gmos-and-our-food/>)

*Live Science* presents "GMOs: Facts about Genetically Modified Food" on their Web site. The safety, politics, and labeling of GMOs is discussed.

(<http://www.livescience.com/40895-gmo-facts.html>)

"The Truth about Genetically Modified Food" is an informative article from the September 1, 2013 issue of *Scientific American*. Research suggests that GMOs are safe to eat and can help feed millions of hungry people in the world. The risks and benefits are examined in this dependable publication. (<https://www.scientificamerican.com/article/the-truth-about-genetically-modified-food/>)

*Scientific American's* November 29, 2013 article, "Study Linking Genetically Modified Corn to Rat Tumors is Retracted", reports on a 2012 article published in the journal *Food and Chemical Toxicology (FCT)* that was retracted due to scientists' scorn of the weak evidence used in the *FCT* article. The journal retracted the article when the authors refused to do so, in spite of near-universal disapproval by other scientists.

(<https://www.scientificamerican.com/article/study-linking-genetically-modified-corn-to-cancer/>)

This site has a brief article on GMO foods, but it has a great diagram in the style of a basketball playoff bracket pitting GMO versus organic. (<https://sites.jmu.edu/gbio103/how-and-why-do-humans-produce-organic-and-genetically-modified-food-march-madness/>)

The *Journal of the Royal Society of Medicine* weighs in on the debate with "Genetically Modified Plants and Human Health". The article gives an overview of plant genetic engineering and addresses food safety, the environment, gene transfer, and public opinion. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2408621/>)

"Genetically Modified Organisms (GMOs): Transgenic Crops and Recombinant DNA" asks the question, "If you could save lives by producing vaccines in transgenic bananas, would you? In the debate over large-scale commercialization and use of GMOs, where should we draw the line?" The Web article has a chart of examples of GMOs resulting from agriculture, a history of international regulations for GMO research and development, and their take on risks and controversies. (<http://www.nature.com/scitable/topicpage/genetically-modified-organisms-gmos-transgenic-crops-and-732>)

This 2016 article from the *New York Times*, "Acreage for Genetically Modified Crops Declined in 2015", reports on the slight decline in acres of GMO crops planted in the world. Three-quarters of all GMO crops in the world are planted in the U.S., Brazil, and Argentina. A bar graph shows the acreage of GMO crops since 1996. ([https://www.nytimes.com/2016/04/13/business/acreage-for-genetically-modified-crops-declined-in-2015.html?\\_r=1](https://www.nytimes.com/2016/04/13/business/acreage-for-genetically-modified-crops-declined-in-2015.html?_r=1))

This USDA Web site has Excel data sheets showing genetically engineered varieties of corn, cotton, and soybeans aggregated by state and for the United States for the years 2000–2016. (<https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx>)

Another USDA Web page, "Recent Trends in GE Adoption", gives a line graph of genetically engineered crops in the United States by percent of planted acres from 1996–2016. (<https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption/>)

The World Health Organization's Web site provides questions and answers to 19 "Frequently Asked Questions on Genetically Modified Foods" at [http://www.who.int/foodsafety/areas\\_work/food-technology/faq-genetically-modified-food/en/](http://www.who.int/foodsafety/areas_work/food-technology/faq-genetically-modified-food/en/).

The U.S. Food and Drug Administration's Web site has a volume of information and resources on GMOs. This site gives details on voluntary labeling of GMO foods with sections on background information, general principles and guidance, and extended references. (<http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm059098.htm>)

The Center for Environmental Risk Assessment's Web page focuses on GE organisms used in agriculture and foods. A link on their page (GM Crop database) allows readers to search their database for crop plants, traits, inserted genes, type of approval, country, developer, and year. The database includes GMOs as well as plants with novel traits developed through conventional plant breeding. The site also includes e-learning courses after registration. (<http://www.cera-gmc.org/>)

Genetically Modified Foods are discussed at the Learn Genetics site. The creation of an insect-resistant tomato plant is explained with a simple diagram.

(<http://learn.genetics.utah.edu/content/science/gmfoods/>)

## Other GMO information

A report summary of "Pesticide Use in U.S. Agriculture: 21 Selected Crops, 1960–2008" gives an overview of pesticide use in the U.S. It states that pesticide use largely increased from 1960 through 1981 due to increased acreage of crops planted. However, after 1980, the trend has been decreasing slightly, partly due to GMO crops requiring less pesticide use. The full report is available on the site through a link.

([https://www.ers.usda.gov/webdocs/publications/eib124/46736\\_eib124\\_summary.pdf?v=41830](https://www.ers.usda.gov/webdocs/publications/eib124/46736_eib124_summary.pdf?v=41830))

The U.S. Environmental Protection Agency provides a comprehensive Web site on "Introduction to Biotechnology Regulation for Pesticides". The site has an overview of biopesticides and biotechnology pesticide products, registration for plant-incorporated protectants, gene flow assessment, ecological assessment processes, environmental fate, and insect resistance in Bt crops. (<https://www.epa.gov/regulation-biotechnology-under-tsca-and-fifra/introduction-biotechnology-regulation-pesticides>)

The National Academies of Sciences, Engineering, and Medicine has published a book, *Genetically Engineered Crops: Experiences and Prospects*, looking at the debate surrounding GE crops and possible adverse effects on human health, the environment, and ethics. It delves into the complexities of emerging GE technologies. The book can be purchased on the Web site, but it is also available on the National Academies Press site as a free PDF download.

(<https://www.nap.edu/catalog/23395/genetically-engineered-crops-experiences-and-prospects>)

Another book from the National Academies, *The Impact of Genetically Engineered Crops on Farm Sustainability in the United States*, looks at the challenges in farming that may come with excessive reliance on a single technology for our crops. The reduction in diversity of farming practices may also have adverse effect on the potential economic and environmental gains from using GE crops. The book is available for purchase on the Web site but is also available on the site as a free PDF download. (<https://www.nap.edu/catalog/12804/the-impact-of-genetically-engineered-crops-on-farm-sustainability-in-the-united-states>)

An exhaustive Web site centered on GMOs includes links to characteristics, environment, exposure, methods of monitoring, harmful effects, and more.

(<http://enhs.umn.edu/current/5103/gm/character.html>)

The U.S. Department of Agriculture (USDA) has a part of its Web site devoted to Biotechnology Regulatory Services. This site has additional links to regulations, permits, compliance, and a biotechnology quality system.

(<https://www.aphis.usda.gov/aphis/ourfocus/biotechnology>)

Stanford University's *The Tech Museum of Innovation* has a Web page devoted to GMO foods, where people have posed eight questions that have been answered by geneticists.

(<http://genetics.thetech.org/genetic-categories/genetically-modified-foods>)

*Popular Science* published an article in 2014, "GMO Facts: 10 Common GMO Claims Debunked". It can be read at <http://www.popsci.com/article/science/core-truths-10-common->

[gmo-claims-debunked?dom=PSC&loc=slider&lnk=2&con=core-truths-10-common-gmo-claims-debunked](http://www.popsci.com/blog-network/our-modern-plagues/pros-and-cons-herbicide-tolerant-gmos).

Another *Popular Science* article explores "The Pros and Cons of Herbicide-Tolerant GMOs", and this article is located at <http://www.popsci.com/blog-network/our-modern-plagues/pros-and-cons-herbicide-tolerant-gmos>.

The Howard Hughes Medical Institute has a tutorial on "How to Make a Transgenic Plant". The concise explanations are accompanied by graphics. ([http://www.unc.edu/depts/our/hhmi/hhmi-ft\\_learning\\_modules/plantmodule/transgenicplants.html](http://www.unc.edu/depts/our/hhmi/hhmi-ft_learning_modules/plantmodule/transgenicplants.html))

A Web page of FAQs related to transgenic (GMO) plants with links and additional resources can be read at <http://cls.casa.colostate.edu/transgeniccrops/fagpopup.html>.

Authors from India explain transgenic (GMO) plants and discuss the types, benefits, public concerns, and future of GMOs in an article at [https://www.researchgate.net/publication/259139407\\_Transgenic\\_plants\\_Types\\_benefits\\_public\\_concerns\\_and\\_future](https://www.researchgate.net/publication/259139407_Transgenic_plants_Types_benefits_public_concerns_and_future). Please note that the site may request readers to register, but the document will download without registration after a few seconds.

An overview of the plant genetic engineering process is explained with images at <http://agbiosafety.unl.edu/education/summary.htm>. There are additional links on the page for related topics such as gene cloning and DNA extraction.

## Non-GMOs

The Non-GMO Project has a Web page with their list of GMO facts and links to more of their resources. (<https://www.nongmoproject.org/gmo-facts/>)

An organization claiming to be, "The most comprehensive source of GMO health information on the Web", the Institute for Responsible Technology, provides their perhaps biased view of GMOs. One link on the site connects to health risks associated with GMOs, along with references and studies that have not been supported by other scientific research. (<http://responsibletechnology.org/gmo-education/>)

This 2001 article in *The Washington Post* reports on the biotech corn, Starlink, which is claimed to have produced allergic responses in people. Starlink was approved for use in animal feed, but not in human food. However, some corn products were found to contain small amounts of the Starlink corn. ([https://www.washingtonpost.com/archive/politics/2001/03/19/biotech-corn-is-test-case-for-industry/57734822-b8c1-4215-af91-b12267d06dcb/?utm\\_term=.3ee89381e98b](https://www.washingtonpost.com/archive/politics/2001/03/19/biotech-corn-is-test-case-for-industry/57734822-b8c1-4215-af91-b12267d06dcb/?utm_term=.3ee89381e98b))

DNA animations on this site provide videos illustrating many of the complex biochemical processes involving DNA. Subheadings on the page include animations relevant to the Wendel article, such as "Recombinant DNA Technology", "Gene Expression of a Secreted Protein", and "Polymerase Chain Reaction", to list only a few. (<http://bio-alive.com/animations/DNA.htm>)

## *Bacillus thuringiensis* (Bt)



This site provides a complete look at Bt-modified crops. Links include a history of Bt, how it works, and its safety. Additional links guide readers to related topics on GMOs, Bt cotton, Bt corn, and crop refuges. ([http://www.bt.ucsd.edu/bt\\_crop.html](http://www.bt.ucsd.edu/bt_crop.html))

For more information on "Bt-Corn: What It Is and How It Works" see <https://entomology.ca.uky.edu/ef130>.

Monsanto is a major producer of GM seeds. The company's general Web site has information about their products. For information on insect resistance to Bt corn and cotton crops, see <http://www.monsanto.com/newsviews/pages/insect-resistance-to-gmo-and-bt-crops.aspx>.

The U.S. Environmental Protection Agency performed an analysis of Bt crops and concluded that they posed "no significant risk to the environment or to human health." To read an article published in the September 2003 issue of *Nature Biotechnology*, see [https://www.epa.gov/sites/production/files/2015-08/documents/are\\_bt\\_crops\\_safe.pdf](https://www.epa.gov/sites/production/files/2015-08/documents/are_bt_crops_safe.pdf).

## Hydrogen bonding

For more information on hydrogen bonding, including graphs, diagrams, and links to other intermolecular forces, see <http://www.chemguide.co.uk/atoms/bonding/hbond.html>.

This Web site is similar to the one above, but it has a more extensive set of diagrams, explanations, and tables. Included are sections on properties and effects of hydrogen bonds, viscosity, hydrogen bonding in nature, and factors preventing hydrogen bonding. ([https://chem.libretexts.org/Core/Physical\\_and\\_Theoretical\\_Chemistry/Physical\\_Properties\\_of\\_Matter/Atomic\\_and\\_Molecular\\_Properties/Intermolecular\\_Forces/Specific\\_Interactions/Hydrogen\\_Bonding](https://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Physical_Properties_of_Matter/Atomic_and_Molecular_Properties/Intermolecular_Forces/Specific_Interactions/Hydrogen_Bonding))

This site has a short description of hydrogen bonds, but it also provides a brief animation of H<sub>2</sub>O and ONF with their hydrogen bonds. (<https://www.chem.purdue.edu/gchelp/liquids/hbond.html>)

A scholarly discussion of hydrogen bonds—with an introduction, history, classification and terminology, and a wide collection of analytical data—is located at [http://evans.rc.fas.harvard.edu/pdf/smnr\\_2009\\_Kwan\\_Eugene.pdf](http://evans.rc.fas.harvard.edu/pdf/smnr_2009_Kwan_Eugene.pdf).

The *Journal of Chemical Information and Modeling* published an article, "Characterizing the Strength of Individual Hydrogen Bonds in DNA Base Pairs", that complements the Wendel article. (<http://pubs.acs.org/doi/pdf/10.1021/ci100288h>) Please note that this link is a brief abstract only, the full article is only available to subscribers to the journal.

The *Journal of Biological Chemistry* published this article, "Strength of the C<sup>α</sup>H••O Hydrogen Bond of Amino Acid Residues", explaining that the peptide group traditionally has not been believed to form hydrogen bonds, but under certain circumstances there may be evidence that it does. (<http://www.jbc.org/content/276/13/9832.full>)

"The Quantum Nature of the Hydrogen Bond" is explained in this technical article. (<http://www.pnas.org/content/108/16/6369.full>)

This college-level explanation of hydrogen bonding has a focus on proteins. It provides six rules summarizing of hydrogen bonding.

([http://www.bio.brandeis.edu/classes/biochem104/hydrogen\\_bonds.pdf](http://www.bio.brandeis.edu/classes/biochem104/hydrogen_bonds.pdf))

A thorough explanation of hydrogen bonding in water is explained in "Water's Hydrogen Bond Strength". This 20-page paper (including extensive additional references) covers an introduction, consequences, effects, and tables summarizing data. Although no date is given for the article, the most recent reference included is from 2007.

(<https://arxiv.org/ftp/arxiv/papers/0706/0706.1355.pdf>)

## Golden Rice

The Golden Rice Project has a bountiful Web site describing the organization, the Golden Rice Project, why Golden Rice is important, the science and environmental aspects, and an information center. (<http://www.goldenrice.org/>)

National Public Radio shares information about Golden Rice and the surrounding controversy at <http://www.npr.org/sections/thesalt/2013/03/07/173611461/in-a-grain-of-golden-rice-a-world-of-controversy-over-gmo-foods>.

"Genetically Modified Golden Rice Falls Short on Lifesaving Promises" explains a study stating that that GMO activists are not to blame for the slow introduction of Golden Rice, and the scientific challenges affecting the rice. (<https://source.wustl.edu/2016/06/genetically-modified-golden-rice-falls-short-lifesaving-promises/>)

*The New York Times* published an article detailing the challenges facing Golden Rice and the vandalism in the Philippines and other sites where the rice has an opportunity to affect the lives of millions. (<http://www.nytimes.com/2013/08/25/sunday-review/golden-rice-lifesaver.html>)

Stanford University's *The Tech Museum of Innovation* has a page on Golden Rice in its "Ask a Geneticist" column. (<http://genetics.thetech.org/ask/ask334>)

A history of Golden Rice and its development by Ingo Potrykus was printed in a 2000 *New York Times* article. The information gives a background for a perspective on how far Golden Rice has—or has not—advanced to today.

(<http://www.nytimes.com/2000/11/21/science/scientist-at-work-ingo-potrykus-golden-rice-in-a-grenade-proof-greenhouse.html>)

One of *Time* magazine's cover stories in 2000 was on Golden Rice and Ingo Potrykus. The cover stated, "This rice could save a million kids a year." Read the article at <http://content.time.com/time/magazine/article/0,9171,997586,00.html>.

"Is Opposition to Golden Rice Wicked?" is the question that *New Scientist* seeks to answer. The article states that, "One of the cleverest tricks of the anti-GMO movement is to link GMOs so closely to Monsanto." Read more at [http://www.slate.com/articles/health\\_and\\_science/new\\_scientist/2013/10/golden\\_rice\\_inventor\\_ingo\\_potrykus\\_greenpeace\\_and\\_others\\_wicked\\_for\\_opposition.html](http://www.slate.com/articles/health_and_science/new_scientist/2013/10/golden_rice_inventor_ingo_potrykus_greenpeace_and_others_wicked_for_opposition.html).

This link is another general information article on Golden Rice found at The *Embryo Project Encyclopedia*. (<https://embryo.asu.edu/pages/golden-rice>)

For more information on vitamin A eye deficiency (VAD), including pictures of eye diseases related to VAD see <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3936686/>.

## Hydrolysis (digestion) and proteins

A straightforward explanation of the chemical process of hydrolysis is found at <http://www.chemistryexplained.com/Hy-Kr/Hydrolysis.html>.

The Wendel article addresses digestion (hydrolysis) of proteins. This site specifically explain the hydrolysis of proteins in simple terms with an example. (<http://www.chemguide.co.uk/organicprops/aminoacids/proteinhydrolysis.html>)

A much deeper, collegiate explanation of "Proteases: Hydrolysis of Peptide Bonds: Specificity and Mechanism" is located at <http://www.uta.edu/faculty/sawasthi/Enzymology-4351-5324/Class%20Syllabus%20Enzymology/Proteases.pdf>.

This site also provides a scholarly look at proteins, peptides, and amino acids. Reactions of  $\alpha$ -amino acids and synthesis of  $\alpha$ -amino acids is explained with chemical structures and equations. (<https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/proteins.htm>)

Protein degradation by enzymes is explained in technical terminology, with a few reactions and images for support, at <https://www.rpi.edu/dept/bcbp/molbiochem/MBWeb/mb2/part1/protease.htm>.

The chemistry of the protein building blocks, amino acids, is offered at *The Biology Project Web* site. There are links to additional pages with more details on the amino acids, plus a self-test. ([http://www.biology.arizona.edu/biochemistry/problem\\_sets/aa/aa.html](http://www.biology.arizona.edu/biochemistry/problem_sets/aa/aa.html))

The Royal Society of Chemistry provides a Web page on proteins. It covers their importance, the amino acids, peptide bond formation, structures, and a test of your knowledge. (<http://www.rsc.org/Education/Teachers/Resources/cfb/proteins.htm>)

An overview of protein digestion in the human body is posted by a British teacher. Descriptions with graphics to help with understanding is found at <https://pmgbiology.com/2016/02/14/digestion-of-proteins-a-understanding-for-igcse-biology-2-29/>.

This site provides information on protein digestion in the body, along with a nice flow diagram of the process. (<http://pharmaxchange.info/press/2013/07/digestion-of-dietary-proteins-in-the-gastro-intestinal-tract-gi-tract/>)

## General Web References (Web information not solely related to article topic)

*Bio-Alive* is a vast collection of instructional materials including lectures, seminars, animations, tutorials, labs, and games—virtually everything—for the life sciences. (<http://bio-alive.com/index.htm>)

*Science in the News* (<http://sitn.hms.harvard.edu/>) is published online by Harvard University, The Graduate School of Arts and Sciences. This is an excellent resource for scientific articles. Web readers can view information on various branches of science, the environment, public health, and art. Podcasts, seminars, and other presentations are available.