ABSTRACT
Timeline Challenge (https://timelinechallenge.hudsonalpha.org) engages students in a Claim-Evidence-Reasoning (CER) task while they investigate critical advances in agriculture and biotechnology. This freely available digital resource scaffolds students’ investigation of biotechnology by presenting a current and ongoing agricultural problem. The Timeline Challenge utilizes the Progress of Science biotechnology timeline as the backdrop for a series of agriculture-based challenges, such as producing meatier chickens, non-browning apples, or perennial wheat. This web-based module allows students to choose a specific biotech tool to address the challenge and then compare their plan to ongoing modern research related to the challenge. Along the way, students are presented with a real-world complication to encourage thinking about the problem from multiple perspectives.

Key Words: agricultural; biotechnology; history of science; science, technology, and society.

Why Timeline Challenge?
More than one million apples are thrown away each year, along with more than 640 million tons of other fruits and vegetables (Hegnsholt, 2020). Often those fruits are discarded because of blemishes or browning and not because the fruit has spoiled. Minimizing food waste and meeting consumer palates are examples of agricultural challenges that can be used to hook students into taking a closer look at the science behind their grocery-store shelves. Timeline Challenge uses these agricultural challenges to prompt students to investigate the intersection of biotechnology and agriculture. This free web-based activity was developed by the educational outreach team at the nonprofit HudsonAlpha Institute for Biotechnology (Huntsville, Alabama). It places students in randomly assigned agricultural challenges, and uses links in a digital biotechnology timeline to investigate potential tools that could be used to meet the challenge.

Following that investigation, students engage in a modified Claim-Evidence-Reasoning (CER) task to explain how they would use a specific biotechnology tool. CER is a writing strategy that helps students construct scientific explanations (Brunsell, 2012). This relatively simple strategy helps students create explanations based on evidence and think about problems scientifically. However, one critical feature of this activity is “student voice.” Students select a biotech tool to address the assigned agricultural challenge, based on their own values and which elements of the problem they deem more important.

Designed to be completed in a single class period, with students working alone or in small groups, Timeline Challenge offers a scaffolded, purposeful investigation of many of the biotechnologies related to controversial subjects associated with food and modern agriculture. Timeline Challenge has been completed by more than 700 unique users over the past 12 months with minimal educator scaffolding through professional learning opportunities. It has been designed to be intuitive for both the educator and the student. The activity supports Next Generation Science Standards HS-ESS3-4 (“Evaluate or refine a technological solution that reduces impacts of human activities on natural systems”; NGSS Lead States, 2013). It also supports students in developing the science practices of constructing explanations and designing solutions.

In the Classroom
Timeline Challenge is a web-based application that overlays the Progress of Science biotechnology timeline. The Progress of Science Timeline details >200 major accomplishments and milestones in genetics and biotechnology during the past 10,000 years. The digital timeline is an interactive navigation tool that offers details on each major event, and links to other online resources where available. The timeline is frequently updated, keeping the content current for classroom discovery. Access the Progress of Science Timeline at https://timeline.hudsonalpha.org.

Accessing Timeline Challenge through a different web address, students enter the challenge with a code provided by the teacher.
Students are randomly assigned one of six agricultural challenges. Students are guided through an investigation of the tools, using links provided in the Progress of Science Timeline (Figure 1). After investigating the biotechnology techniques or tools, students select a tool they would use to meet the challenge. Students use evidence from the Progress of Science Timeline to construct a reasonable scientific explanation for selecting their tool (Figure 2).

Currently available challenges include non-browning apples, meatier chickens, perennial wheat, hypoallergenic eggs, hornless dairy cattle, low-lignin poplar for biofuel, and double-muscled cattle. For each of these challenges, several available biotech tools could produce viable solutions. Students are encouraged to consider multiple stakeholders in selecting a tool. During the development of their solution, students encounter a random “real-world” complication. These include tight budget constraints, limitations on the use of live organisms, short timelines, or legal/regulatory requirements. Modeled after perplexing factors encountered in the biotech industry and presented late in the process, this prompts students to think about their proposed solution from more than one perspective (Figure 3). Students may choose any of the investigated tools for any number of reasons. The goal of this activity is to prompt students to justify their selection using evidence and reasoning. Upon submission of their proposed solution, students can compare their selection to the techniques of modern researchers working in an active lab. The teacher should emphasize that there are multiple pathways, and even if a student’s selected technique differs from those used in current research, their selection may be a perfectly acceptable path to a solution.

| Technology/ Tool                  | Timeline Date | Overview                                                                                                                                 |
|----------------------------------|---------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Radiation-induced mutagenesis    | 1930          | Mutations are caused, or “induced,” by exposing seeds to radiation or chemicals that cause random changes in DNA. Only those plants with favorable traits are maintained and bred to develop the next generation. |
| Hybridization                    | 1979, 1926    | Hybridization is specific to plants that tolerate the crossing of similar strains. Plant breeders use hand pollination to manually cross two different strains in efforts to produce offspring that combine desirable traits from both parental varieties. |
| Selective Breeding               | 7000 B. C.    | Selective breeding refers to the process of shaping the traits of plants or animals by deliberately crossing only parents that have desirable characteristics, reinforcing and strengthening the desired trait across multiple generations. |
| Recombinant DNA                  | 1972          | Recombinant DNA forms when two segments of DNA are combined using biotech tools. These DNA segments could not be connected by typical cellular processes. Usually, recombinant DNA involves the addition of DNA from two unrelated organisms belonging to separate species that cannot interbreed. |
| Genome Editing                   | 2015          | Genome editing is the process of using nuclease enzymes to insert or remove short segments of DNA directly into the target’s genome. While CRISPR is the most widely known technique, there are multiple endonucleases that can be targeted to make DNA changes. |

**Figure 1.** Tools and technologies investigated in *Timeline Challenge.*
that students need to log into the system. Students using the digital token linked to an educator’s class have data saved throughout the activity in order to prevent loss of progress in the event that the student is unable to complete the activity in one sitting. With the first login, students are prompted to enter a name. Educators are encouraged to prompt students to use a screen name instead of their given name and provide that screen name to the educator before beginning the activity. While students’ names are visible to educators, they are not accessible by system administrators or developers at HudsonAlpha. Students use their three-word token to log in anytime.

A final report is generated when a student completes the *Timeline Challenge*. Student work is not viewable, and the final report does not populate until the student has completed the activity. However, students’ real-time progress can be monitored in the Teacher Portal. On the right side of the screen is a list of students and the percentage of completion. Student reports are available in two different formats in *Timeline Challenge*, either email or full-text pdf. Educators can access student reports from the Teacher Portal if students have used a digital code. When students play as a guest, they have the option to email a report only. The alternative option is for students to save and print the report upon completion of the activity.

### Conclusion

With the need to feed a growing human population amid changing climate conditions, the issue of food production is a timely storyline to engage students with biology content. *Timeline Challenge* is a free web-based module that empowers students to think critically about agricultural issues and use of biotech tools, all while investigating applications commonly discussed in a typical biology classroom.

### References

Brunsell, E. (2012). Designing science inquiry: claim + evidence + reasoning = explanation. *Edutopia*, September 25. https://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell.

Hegnsholt, E., Unnikrishnan, S., Pollmann-Larsen, M., Askelsdottir, B., & Gerard, M. (2020). Tackling the 1.6-billion-ton food loss and waste crisis. *BCG Global*, August 5, 2020. https://www.bcg.com/publications/2018/tackling-1.6-billion-ton-food-loss-and-waste-crisis.

NGSS Lead States (2013). *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press.

ADAM HOTT is Digital Applications Lead for Educational Outreach at HudsonAlpha Institute for Biotechnology, Huntsville, AL 35806; e-mail: ahott@hudsonalpha.org. MADELEINE LOFTIN is Educator Professional Learning Lead for Educational Outreach at HudsonAlpha Institute for Biotechnology; e-mail: mloftin@hudsonalpha.org.