HOW TO DO IT

Too New for Textbooks: The Biotechnology Discoveries & Applications Guidebook

MADELENE LOFTIN, NEIL E. LAMB

Abstract

The Biotechnology Discoveries and Applications *guidebook aims to provide teachers with an overview of the recent advances in genetics and biotechnology, allowing them to share these findings with their students. The annual guidebook introduces a wealth of modern genomic discoveries and provides teachers with tools to integrate exciting content into the classroom. Released annually by the HudsonAlpha Institute for Biotechnology in Huntsville, Alabama, the guidebook presents new findings in jargon-free, student-friendly language. The guidebook is introduced along with strategies for classroom use.*

Key Words: *Genetics; genomics; biotechnology; new discoveries; Human Genome Project.*

Sequencing of entire genomes or exomes (that 2% of the genome that is protein coding) is rapidly becoming an integral component of many research projects. As recently as 2 years ago, fewer than 50 human genomes had been sequenced. As 2012 drew to a close, the National Institutes of Health estimated funding exome or genome sequencing of ~70,000 research subjects (Phimister et al., 2012). Sophisticated computer algorithms comb through the 3 billion bases of sequence information, helping identify DNA variants with potential clinical significance. Similar analyses are exploring the genomes of other animals, as well as plants, bacteria, and fungi. Agricultural, pharmaceutical, and diagnostic companies are using these findings to shape crop selections, develop new drugs, and offer genetic tests to help determine future disease risk. Clearly the era of genomics is upon us.

Against this dizzying backdrop, how do teachers stay current regarding both the scientific and the commercial impact of genomics? Part of the solution is found in the annual *Biotechnology Discoveries and Applications* guidebook produced by the HudsonAlpha Institute for Biotechnology (Figure 1). This free publication provides educators with an overview of the recent advances in genetics and biotechnology, in an easy-to-understand form that can be shared with their students.

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What Is the Guidebook?

The annual guidebook introduces a wealth of modern genomic discoveries that are generally too new to have appeared in student textbooks. HudsonAlpha, a not-for-profit research organization located in Huntsville, Alabama, has a threefold mission that includes genomic research, the potential application of that research, and educational outreach. The education team at HudsonAlpha combs through hundreds of scientific research papers each year to identify high-impact and interesting discoveries. These stories form the backbone of the guidebook, using jargon-free language to make the information accessible for a wide-ranging audience of learners.

New Findings

Recent research announcements are grouped in the "New Findings" section to provide a quick update on the genetics/genomics/biotechnology fields (Figure 2). Some are described in only a few sentences, whereas others get a more thorough explanation. These magazine-style articles represent discoveries, treatments, or applications that have been announced during the past year. The 2012 guidebook highlights 41 recent discoveries, including

- Processes for controlling gene activity across the human genome (ENCODE Project Consortium, 2012)
- Successes in gene therapy after years of disappointment (Nathwani et al., 2011; Bennett et al., 2012; Candotti et al., 2012)
- A possible link between coal formation and white rot fungi (Floudas et al., 2012)
- Collisions between replication and transcription machinery (Helmrich et al., 2011)

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Figure 1. The 2012 *Biotechnology Discoveries and Applications* guidebook.

- The genetic pathway for hair-color patterns in cats (Kaelin et al., 2012)
- Using RNA splicing to treat a form of muscular dystrophy (Goemans et al., 2011; Opar, 2012)
- Insight into the trillions of microbes that live in and on the human body (Human Microbiome Project Consortium, 2012)
- Carrot cell cultures that produce medication to treat disease (Maxmen, 2012)
- Cancer-causing genetic changes and targeted treatment possibilities (Cancer Genome Atlas Research Network, 2012; Curtis et al., 2012; Imielinski et al., 2012)

○ Foundational Concepts

All the new findings are linked to 23 foundational topics, explained in the "Foundational Concepts and Their Applications" portion of the guidebook (Figure 3). This section provides a more in-depth discussion of the underlying science, key technologies involved in genomic research, or the applications of current research efforts. These one-page articles use student-friendly language to bridge the gap between textbooks and new scientific publications. The foundational topics include

- DNA sequencing
- RNA and protein analyses
- Bioinformatics
- Cancer
- Copy number variation
- Epigenetics
- Identifying the genetic influence on disease
- Personal genome analysis
- Personalized medicine
- Pharmacogenomics
- Stem cells
- Synthetic biology

Each foundational article is revisited yearly and updated. Each concept discussed in the guidebook is correlated to applicable science, health, and career technical education (CTE) courses, along with a brief discussion of how the content applies to the objective. Contained in blue-highlighted boxes, these discussions help teachers connect presented content and course-of-study objectives. Although the topics are correlated to Alabama curriculum standards and objectives, the text of each objective is provided to facilitate easy correlation between foundation topics and other state or national standards.

The guidebook's two main sections are separated by an Alabama course-of-study links table (Figure 4), which provides a more complete listing of objectives relevant to genetics, genomics, and biotechnology. This listing is paired with pertinent topics from the guidebook for science and CTE courses. This provides teachers with a single table that ties classroom objectives to these current research discoveries and technological advancements.

○ The Guidebook in the Classroom

The guidebook can be used by educators and students in a variety of ways. It is a useful tool for teachers looking to update their personal content knowledge, providing current resources in the face of rapidly changing research. For many classroom educators, the guidebook serves as a one-stop source for updates in genetics, genomics, and biotechnology content.

For teachers who wish to use the guidebook with their students, the jargon-free language and relatively short length make the foundation articles classroom-friendly reading passages. The guidebook provides a readily available set of content-specific reading passages that can be used with a wide variety of literacy strategies. These passages supplement textbook readings to introduce current research and build on textbook content. The high-interest nature of the passages makes them viable engagement readings to hook students into a content sweep or serve as a pre-lab reading. The shorter science briefs can be used as stems in assessment or to identify student misconceptions. Additionally, the magazine-style format engages readers much like science articles in popular media within the area of genetics, genomics, and biotechnology. For classrooms wishing to explore new findings more deeply, scientific references are provided for each discovery. In most cases, a simple Web search using the article's title will lead to the abstract, which can be freely viewed without a subscription to the publishing journal. Although these abstracts are often jargon dense, helping students decipher the

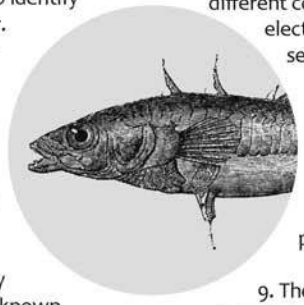
SCIENCE SNAPSHOTS

a quick rundown of 10 genetic and biotech stories

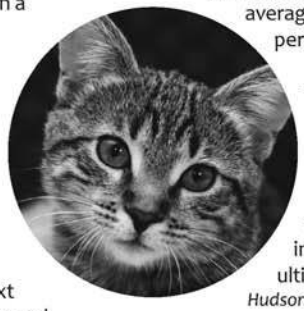
1. The Genetic Testing Registry, created by the National Center for Biotechnology Information, is designed to help physicians, patients and researchers make sense of the many genetic tests that are currently available. The database includes tests for over 2,500 disorders, submitted voluntarily by the testing organizations. Details about a test's purpose and its limitations are also included.

2. At the end of the last ice age, marine stickleback fish separated into different populations across salty oceans and freshwater lakes and streams, evolving different traits such as body length, eye size, skeletal structure and behavior. These differences allowed sticklebacks to thrive in their specific habitat. Sequencing and comparing the genomes across multiple forms of stickleback allow scientists to identify DNA changes related to fish appearance and behavior. Many changes involve large chromosomal inversions. Single nucleotide changes predominantly appear in regulatory rather than protein-coding areas of the gene, suggesting the evolutionary process altered how and when genes were active, rather than directly changing the gene product.

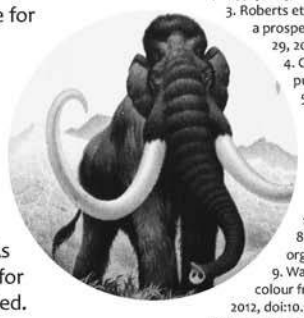
HudsonAlpha researchers Dr. Rick Myers, Dr. Jane Grimwood and Jeremy Schmutz participated in this work.



3. Patients undergoing heart surgeries like angioplasty or stenting are often given the drug clopidogrel (also known as Plavix™) to inhibit platelet activity and reduce the risk of post-surgery blood clots. The *CYP2C19* gene codes for an enzyme that activates this drug in the body. A common loss-of-function variant in this gene means that some patients poorly activate the drug and should be given a different medication. In a Canadian study, patients underwent *CYP2C19* genetic testing just after surgery and the results determined medication choice. When compared to a non-tested population, the tested patients had fewer cases of high platelet activity (a risk for post-surgery heart attack and stroke), suggesting this test could be useful at the patient's bedside.



4. Researchers at Harvard and Johns Hopkins universities encoded a 53,000-word book into DNA fragments as a method of digital data storage. The text was converted into binary language, with a series of 0s and 1s representing each character. The binary string was then synthesized as DNA fragments, with nucleotide bases A and C representing 0s, and G and T as 1s. To read the data, the DNA is sequenced and the nucleotide message converted back into binary. The fragments are stable at room temperature for very long periods of time. Using this approach, one gram of DNA can store 700 terabytes of data – the equivalent of 14,000 Blu-ray 50 gigabyte discs.



5. The sequences of 126 proteins, including collagen and albumin, were identified in a 43,000-year old woolly mammoth bone. Modifications in sample preparation maximized the ability to detect trace amounts of protein, which is more stable than DNA. As this technique is refined, it will provide an alternative for analyzing ancient samples where the DNA has degraded.

6. Prized for centuries, Thoroughbred racehorses traced their ancestry to three Arabian stallions and 74 primarily British mares. The breed can be subdivided into sprinters and distance runners. Thoroughbred speed is strongly influenced by a single nucleotide polymorphism in the first intron of the myostatin gene - which encodes a protein important to muscle mass development. Homozygous C/C horses excel in sprinting, C/T heterozygotes compete well in middle distances and T/T homozygotes have long distance stamina. Genetic and pedigree analysis from 593 horses (including bone samples from 18th century stallions) traced the origin of the C allele to a British mare that lived roughly 300 years ago.

7. The race for cheaper and faster DNA sequencing continues as genomic companies introduce new sequencing technologies. Various systems for reading individual DNA bases include different colors of light, tiny changes in pH or disruptions in electrical current. Manufacturers claim some systems can sequence a human genome in less than a day.

8. The FarGen project aims to sequence all 50,000 individuals living on the Faroe Islands, incorporating the information into the country's healthcare system. A pilot study to create the infrastructure and discuss the scientific, ethical, legal and social aspects of the project is currently underway.

9. The HIrisPlex test is an example of forensic DNA phenotyping - predicting visible traits from forensic samples to build a more complete suspect or victim profile. Highlighted in the *2011 Biotechnology Guidebook*, a panel of 24 DNA variants now predicts hair as well as eye color. The technology accurately predicts brown versus blue eye color 94 percent of the time and average prediction accuracy for hair color ranges from 69.5 percent for blond to 87.5 percent for black.

10. Researchers have identified the genetic pathways that explain the molecular basis of hair color patterns in felines from house cats to snow leopards. The studies point to an interaction between two genes called *Taqpep* and *Edn3*. *Taqpep* appears to establish the coloration pattern during skin development. This influences the expression of *Edn3* in the hair follicles, ultimately leading to yellow or black pigment production.

HudsonAlpha researcher Dr. Greg Barsh contributed to these findings.

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Figure 2. Sample page of New Findings.

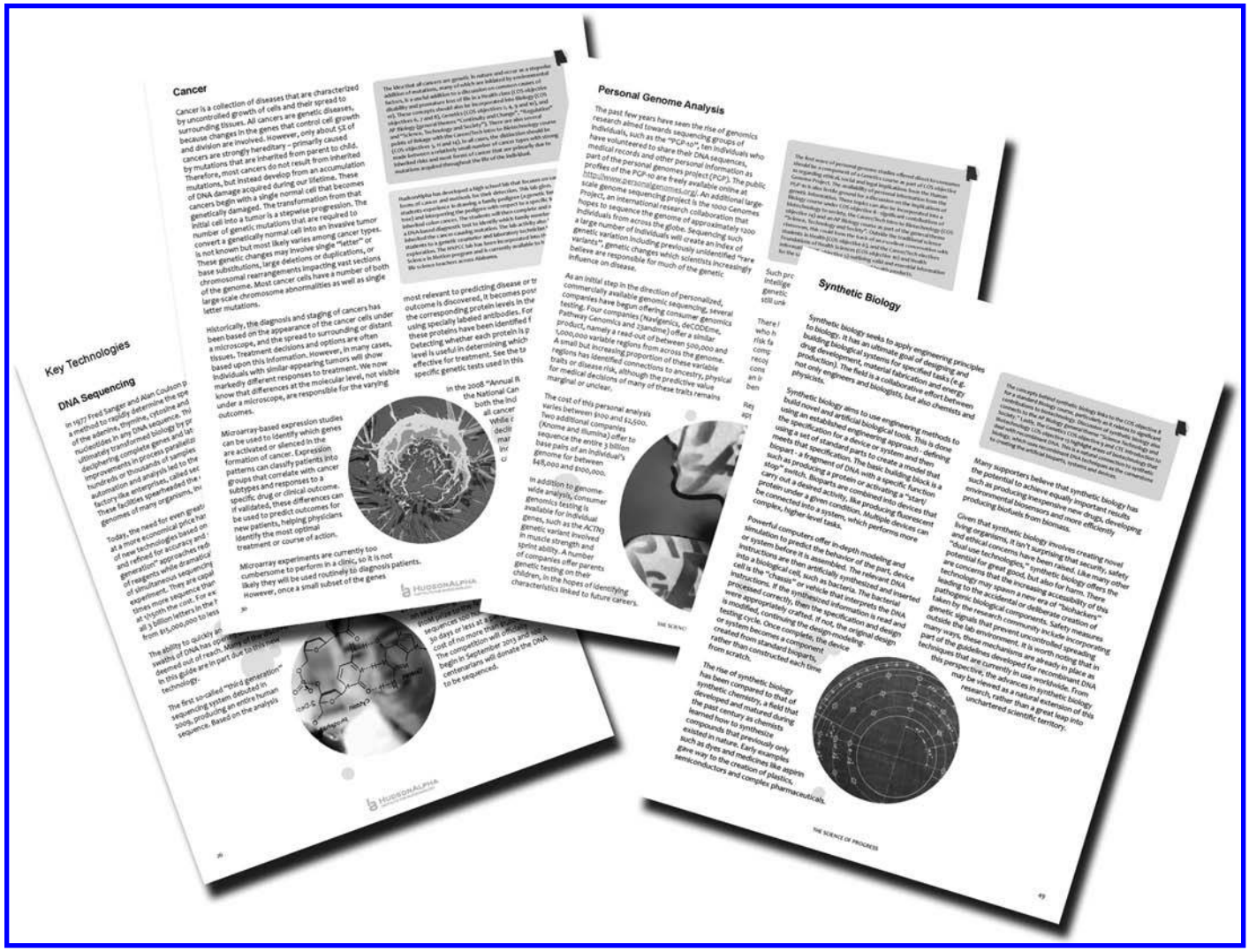


Figure 3. Example Foundational Concepts articles showing shaded course-of-study links. Where applicable, content is also linked to other resources from HudsonAlpha.

primary literature can be a powerful way to introduce them to the process of scientific advancement.

○ Suggested Classroom Activities

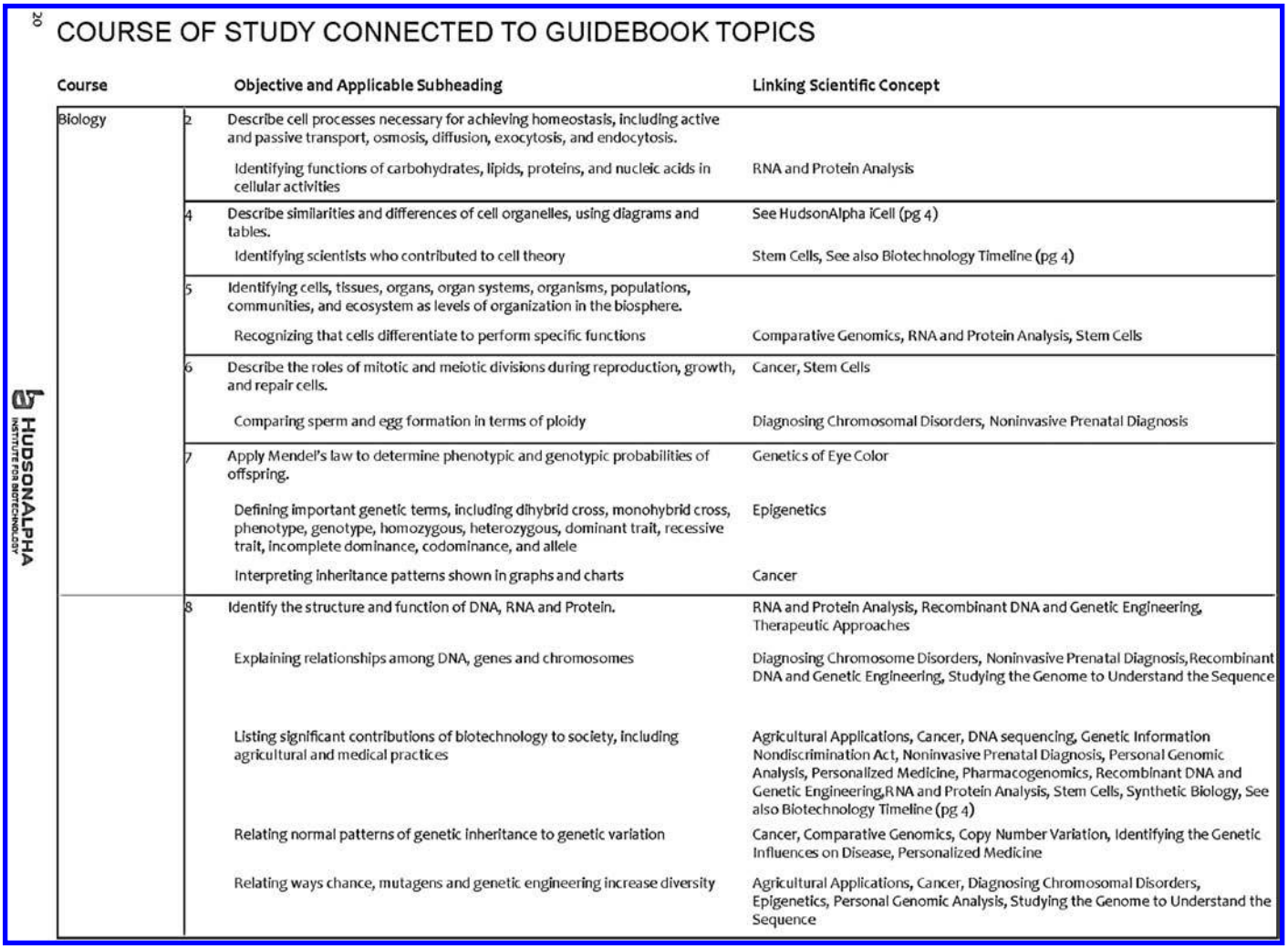
Where Does This Fit? – Given a specific article or section from the guidebook, ask students to evaluate whether the concept warrants inclusion in a textbook. Have students identify where in their textbook the concept should most logically be placed. What prior knowledge or vocabulary is needed to comprehend the article? Is this concept a foundation needed for other concepts? To which unit of study is the article most related, and upon what set of concepts does the article build? To extend this activity, have students refer to both the article and primary literature to rewrite the article as it would appear in future editions of the textbook. The purpose is not to have students critique their textbook or research, but to place the new discovery within the context of current science understandings and to reinforce the accumulative nature of those understandings.

Biotech News Stories – Have students create "news" stories from guidebook articles. These could be for print or video media. To create these stories, students would have to integrate guidebook topics with current topics that are being addressed in the classroom and utilize appropriate vocabulary and science content.

Key Word Comparisions – Have students compare a guidebook article with a related passage from a textbook to identify the common words. Create a list of terms or phrases found in the two readings and have students separate terms into "science vocabulary" and "common language." Ask whether any of the representative language is common to both readings and discuss its usage. Do these terms constitute a list of key words? Should any terms be added to the list?

○ Accessing the Guidebook

Each year, the newest version of the guidebook is distributed freely through a variety of mechanisms. Print versions of the guidebook are distributed each fall to high schools across Alabama. The most recent version is regularly presented at national teacher meetings, and print copies are distributed at these sessions. Teachers outside of Alabama can request a free print copy of the guidebook by sending a self-addressed, postage-prepaid 9½ × 12½ inch envelope to Education Outreach, HudsonAlpha, 601 Genome Way, Huntsville, AL 35806. Alternatively, the guidebook is available as a downloadable PDF



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COURSE OF STUDY CONNECTED TO GUIDEBOOK TOPICS

Course		Objective and Applicable Subheading	Linking Scientific Concept
Biology	2	Describe cell processes necessary for achieving homeostasis, including active and passive transport, osmosis, diffusion, exocytosis, and endocytosis.	
		Identifying functions of carbohydrates, lipids, proteins, and nucleic acids in cellular activities	RNA and Protein Analysis
	4	Describe similarities and differences of cell organelles, using diagrams and tables.	See HudsonAlpha iCell (pg 4)
		Identifying scientists who contributed to cell theory	Stem Cells, See also Biotechnology Timeline (pg 4)
	5	Identifying cells, tissues, organs, organ systems, organisms, populations, communities, and ecosystem as levels of organization in the biosphere.	
		Recognizing that cells differentiate to perform specific functions	Comparative Genomics, RNA and Protein Analysis, Stem Cells
	6	Describe the roles of mitotic and meiotic divisions during reproduction, growth, and repair cells.	Cancer, Stem Cells
		Comparing sperm and egg formation in terms of ploidy	Diagnosing Chromosomal Disorders, Noninvasive Prenatal Diagnosis
	7	Apply Mendel's law to determine phenotypic and genotypic probabilities of offspring.	Genetics of Eye Color
		Defining important genetic terms, including dihybrid cross, monohybrid cross, phenotype, genotype, homozygous, heterozygous, dominant trait, recessive trait, incomplete dominance, codominance, and allele	Epigenetics
		Interpreting inheritance patterns shown in graphs and charts	Cancer
	8	Identify the structure and function of DNA, RNA and Protein.	RNA and Protein Analysis, Recombinant DNA and Genetic Engineering, Therapeutic Approaches
		Explaining relationships among DNA, genes and chromosomes	Diagnosing Chromosome Disorders, Noninvasive Prenatal Diagnosis, Recombinant DNA and Genetic Engineering, Studying the Genome to Understand the Sequence
		Listing significant contributions of biotechnology to society, including agricultural and medical practices	Agricultural Applications, Cancer, DNA sequencing, Genetic Information Nondiscrimination Act, Noninvasive Prenatal Diagnosis, Personal Genomic Analysis, Personalized Medicine, Pharmacogenomics, Recombinant DNA and Genetic Engineering, RNA and Protein Analysis, Stem Cells, Synthetic Biology, See also Biotechnology Timeline (pg 4)
		Relating normal patterns of genetic inheritance to genetic variation	Cancer, Comparative Genomics, Copy Number Variation, Identifying the Genetic Influences on Disease, Personalized Medicine
		Relating ways chance, mutagens and genetic engineering increase diversity	Agricultural Applications, Cancer, Diagnosing Chromosomal Disorders, Epigenetics, Personal Genomic Analysis, Studying the Genome to Understand the Sequence

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Figure 4. Sample course-of-study links.

from the HudsonAlpha website (http://hudsonalpha.org/education/resources/guidebook). Archives from previous years' editions can also be found at this location. Lastly, plans are underway to distribute the guidebook as an enhanced digital book for eReader, with video and resource links for many of the stories.

It can be daunting for educators to keep pace with science research. By continually reviewing the literature and compiling the annual guidebook, the educational outreach team at HudsonAlpha hopes to make this an easier process, at least for topics related to genetics, genomics, and biotechnology. In turn, the excitement and process of scientific discovery become more accessible for students, with the end goal of increasing scientific literacy. More information about this and other education-related projects can be found on the HudsonAlpha website (http://www.hudsonalpha.org), and the authors welcome comments and feedback on the guidebook and its use in the classroom.

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MADELENE LOFTIN is Education Specialist at the HudsonAlpha Institute for Biotechnology, 601 Genome Way, Huntsville, AL 35806; e-mail: mloftin@hudsonalpha.org. NEIL E. LAMB is Director of Educational Outreach at the HudsonAlpha Institute for Biotechnology; e-mail: nlamb@hudsonalpha.org.