Rediscovering Biology: Molecular to Global Perspectives

Preliminary Review Results—FINAL REPORT

Prepared for

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May 2003

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Preliminary Review Results—Final Report

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Project Overview

Through a grant from Annenberg/CPB, Oregon Public Broadcasting (OPB)—in cooperation with a cadre of biology content experts—is developing Rediscovering Biology, a series of 13 instructional units designed to update the content knowledge of in-service, secondary school biology teachers. The goals of the project are to:

1. Help teacher-learners deepen their understanding of current advances in life science in a way that emulates how new knowledge is actually gained by researchers: through inquiry, questioning, investigating, analysis, and exposure to new ideas.
2. Provide teacher-learners with a rich, interactive experience learning about the latest technological advances in the life sciences.
3. Enrich teacher-learners' understanding of the bioethical issues arising from advances in technology and research areas.

These units are to serve as a professional development content series that will provide secondary school biology teachers with an in-depth exploration of how the understanding of biology has changed in the past 5 to 10 years, the advances that have effected those changes, and how those changes have impacted scientists' perception of the world. The topics addressed by the units are:

1. Genomics
2. Proteomics
3. Comparative Evolution
4. Microbial Diversity and Extremophiles
5. Emerging Infectious Diseases and Viruses
6. HIV/AIDS, Immunology
7. Genetics of Development
8. Cell Biology and Cancer
9. Human Evolution
10. Neurobiology, Brain
11. Biology of Sex and Gender

12. Biodiversity
13. Genetically Modified Organisms

Each unit comprises a 30-minute video episode, an online textbook, and other web-based support materials. The videos serve to:

- Introduce the key concepts and terms for each unit.
- Present the scientists and researchers leading today's biological studies.
- Provide examples of applications of science and technology.
- Generate questions and further interest in the topic.

The text will be available online in Adobe Acrobat (PDF) format or through Annenberg/CPB by late 2003. The online text, which features narrative, illustrations, microscope stills, and photographs, contains information that expands upon the materials introduced in the videos. The web site for Rediscovering Biology provides:

- Activities, learning objectives, and resources that correspond to each unit.
- An archive of all animations for the series, each rebuilt with a stop-and-go feature that allows teacher-learners to work through the processes at their own pace.
- Interactive case studies that incorporate knowledge from multiple units and require users to employ analysis and higher cognitive functions, thereby stimulating learning and modeling appropriate pedagogy.
- An archive of the online text to provide easy, immediate access for users.

All materials on the web site will be available for teachers to use in their own classrooms free of charge for 10 years after publication.

The Review Process

The Portland, Oregon, office of RMC Research Corporation coordinated a cadre of secondary school biology teachers and professional development providers to review 3 of the 13 units and provided formative comments to the development teams.

Solicitation

RMC Research, in cooperation with the project directors, developed a position announcement for both the biology teacher and professional development provider positions (see Appendix A) and corresponding application forms (see Appendix B). In November 2002 the position announcements and application forms were posted on the RMC Research web site and sent to the coordinators of the 6 science museums that make up the Science Learning Network, 12 Eisenhower National Clearinghouse Demonstration sites, 143 Eisenhower National Clearinghouse Access centers, 43 state science coordinators, and the science coordinators at the 28 largest school districts in the United States. This effort resulted in 21 applications for the biology teacher positions and 16 applications for the professional development provider positions.

RMC Research staff reviewed the applications, taking into account position, experience, credentials, involvement in biology, and communication skills. In addition, RMC Research staff sought to select a pool of candidates representative with respect to geographic location, race and ethnicity, and background knowledge in biology. After the initial screening, RMC Research staff made follow-up telephone calls to the candidates' supervisors and references. RMC Research recommended 10 of the biology teachers and 10 of the professional development providers to the project directors. Exhibit 1 shows the demographics of the selected reviewers. RMC Research staff worked closely with OPB staff to establish the necessary contracts.

Exhibit 1
Demographics of the Selected Reviewers

Reviewer	Region		Years Experience		Gender		Race/Ethnicity	
Biology teacher	10%	Northeast	40%	< 10	60%	Male	70%	Caucasian
	20%	Southeast	50%	10–20	40%	Female	10%	Hispanic
	10%	South	10%	> 20			20%	Unknown
	30%	Midwest						
	30%	Northwest						
Professional dev. provider	20%	Northeast	30%	< 10	60%	Male	80%	Caucasian
	20%	South	60%	10–20	40%	Female	10%	African Am.
	10%	Midwest	10%	> 20			10%	Unknown
	50%	Northwest						

Note. 10 biology teachers and 10 professional development providers served as reviewers.

Instrument Development

RMC Research gathered input regarding the needs of the development teams at the first meeting of the project advisory board in April 2002 and developed a prototype set of data collection instruments and procedures. The prototype was shared with the advisory board during the September 2002 meeting. RMC Research drew upon feedback from the advisory board and input from the project directors to finalize the data collection instruments (see Appendices C, D, E, and F). The instruments contained an overview of each unit and items on the videos and online text. A separate instrument targeted the reviewers' perceptions of the entire series based on their experiences reviewing the first 3 units. The units selected for review were genomics, genetically modified organisms (GMOs), and comparative evolution.

In late December 2002 RMC Research sent each reviewer preliminary copies of the videos and drafts of the online text for review along with the corresponding data collection instruments. The instruments were in rich text format to allow reviewers to use any word processing software to compose their responses. All responses were due to RMC Research by January 15, 2003.

In mid-March 2003, OPB provided draft copies of the unit course outlines for the genomics and GMO units and activities for the genomics, GMO, and comparative evolution units. RMC Research sent each of the 10 professional development provider reviewers copies of the draft materials along with the corresponding data collection instrument. All responses were due to RMC Research by April 9, 2003.

About This Document

The remainder of this report is divided into 2 sections. The first section summarizes the reviews of the video and online text for each reviewed unit and the final section summarizes the reviews of the unit course outline and activities for each reviewed unit. The analyses focus on the comments and suggestions that were provided by multiple reviewers, though comments made by only one reviewer are also included. Unless otherwise noted, no substantial differences were evident between the reviews from the biology teachers and the reviews from the professional development providers. Appendixes A through F include the reviewer position announcements and application forms and the evaluation instruments.

Genomics

The Human Genome Project has produced a torrent of genetic data for scientists to analyze. Scientists involved in the project expect to complete the effort to decode the entire sequence of human genes in 2003. This achievement will mark the unofficial start of the next phase of the continuing quest to understand how genetics contribute to human health and well-being. Biologists are familiar with the terms *in vivo* and *in vitro,* used to describe processes that occur in the body and in the test tube. Now they are becoming acquainted with a third term, *in silico,* used to describe a new branch of biology that requires little more than a computer and a connection to the Internet.

Genomics refers to the comprehensive study of genes and their interactions using computers and specialized software. Computer programs can sift through billions of bases of DNA sequence, locate putative genes, and provide clues to the genes' functions. Preliminary results from the Human Genome Project include some surprises, such as the observation that humans have fewer genes than expected—perhaps as few as 35,000. Scientists are using comparisons of gene sequences across species to test and extend ideas regarding evolutionary relationships between organisms. Genomics, through comparisons between human and chimpanzee DNA, promises to help humans better understand what it means to be human. As data from more people are obtained, the extent of genetic variation among humans will become evident. Already genomics has revealed that the biological concept of the human race is uncertain. Human beings are 99.9% alike at the genetic level. Applications of genomics to medicine will be far reaching. The concept of individualized medicine envisions a future in which doctors will be able to access the complete genetic profile of a patient and tailor treatment accordingly.

Genomics is a powerful science and therefore is not without risks. Information contained in genetic databases must be protected and restricted to authorized individuals. Citizens will

be asked to help decide who has legitimate access to such data, how those data may be used, and who should share in the financial rewards that result from their use.

Findings

In general, the reviewers were pleased with the genomics unit. Many of the topics and examples were new to the reviewers, who were very interested in the content. Reviewers requested clarification of micro arrays, more information on the ethical issues surrounding genomics, and the inclusion of human examples. This section details the reviewers' background and interest in genomics, their ratings of the content and structure of the unit materials, the impact of the unit on their knowledge and teaching, and their suggestions for future editions of the video and online text.

Background and Interest in Genomics

Several of the topics in the genomics unit were new to the reviewers, in particular determining gene function, the use of the Basic Logic Alignment Search Tool (BLAST), haplotype mapping, and measuring gene expression with micro arrays. Many reviewers were already familiar with the Human Genome Project and the identification of open reading frames; some were already familiar with single nucleotide polymorphisms (SNPs; see Exhibit 2).

Exhibit 2
Reviewers' Familiarity With Genomics Topics

	New to Me						Review to Me				
	1		2		3		4		5		
Topic	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Determining gene function and BLAST	35%	7	30%	6	10%	2	5%	1	20%	4	20
Haplotype mapping	55%	11	30%	6	0%	0	10%	2	5%	1	20
Human Genome Project	0%	0	5%	1	15%	3	30%	6	50%	10	20
Identifying open reading frames	15%	3	15%	3	20%	4	40%	6	10%	2	20
Measuring gene expression with micro arrays	55%	11	25%	5	0%	0	5%	1	15%	3	20
Use of SNPs	30%	6	20%	4	10%	2	35%	7	5%	1	20

Note. Shading indicates patterns for the majority of responses.

A similar pattern emerged in the reviewers' responses to how familiar their peers would be with these topic areas (see Exhibit 3). In general, the reviewers reported having had more prior knowledge about the genomics topics than their peers. Many were concerned that their peers do not have the background knowledge to fully understand the materials (this issue was common to all units).

Exhibit 3
Peers' Familiarity With Genomics Topics

	Will Be New to Peers						Will Be Review to Peers				
	1		2		3		4		5		
Topic	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Determining gene function and BLAST	61%	11	28%	5	11%	2	0%	0	0%	0	18
Haplotype mapping	67%	12	28%	5	6%	1	0%	0	0%	0	18
Human Genome Project	0%	0	21%	4	16%	3	42%	8	21%	4	19
Identifying open reading frames	28%	5	44%	8	17%	3	11%	2	0%	0	18
Measuring gene expression with micro arrays	83%	15	17%	3	0%	0	0%	0	0%	0	18
Use of SNPs	41%	7	47%	8	12%	2	0%	0	0%	0	17

Note. Shading indicates patterns for the majority of responses.

Exhibit 4 shows that the majority of the reviewers found both the video and online text very interesting. The reviewers reported that their interest was peaked by the examples and their relevance to recent news reports. Several reviewers also reported being amazed by new information they learned from the unit, such as the degree of sophistication of the technology in the field.

Exhibit 4
Interest in Genomics Materials

	Very Interesting		Somewhat Interesting		Not Very Interesting		Not at All Interesting		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	80%	16	15%	3	5%	1	0%	0	20
Online text	70%	14	25%	5	5%	1	0%	0	20

Note. Shading indicates patterns for the majority of responses.

Content and Structure

Almost all of the reviewers reported that the video and online text were at least *somewhat* logical and easy to follow (see Exhibit 5). They liked how the video initially presented the big idea and then progressed to relevant topics of increasing complexity. One reviewer stated, "This eased the transition into more difficult material." The reviewers also appreciated how the video and online text followed the same order and format and could easily be used together. The reviewers did, however, request that all of the examples in the video be included in the online text and vice versa.

Exhibit 5
Logic and Usefulness of the Order of Genomics Materials

	Very		Somewhat		Not Very		Not at All		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video: Logical order?	68%	13	26%	5	6%	1	0%	0	19
Online text: Useful order?	75%	15	25%	5	0%	0	0%	0	20

Note. Shading indicates patterns for the majority of responses.

About three fourths of the reviewers (70%) reported that the online text had *about the right amount of detail* (see Exhibit 6). Fewer reviewers (45%) felt this way about the video. The reviewers indicated that the video should include more information on 2 topics: (a) the ethical issues surrounding genomics and (b) human genetic disorders and the search for a cure. According to the reviewers, students find these issues interesting and relevant to their own lives. The reviewers also requested more human examples in both the video and online text. In addition, many of the reviewers were concerned that the unit did not include enough basic information for the average science teacher. They suggested adding more detailed information—or, at least, links to basic information. For example, one reviewer noted that the video discussed nucleases and DNA repair without any explanation.

Exhibit 6
Depth and Detail of Genomics Materials

	Way Too Much Detail		A Little Too Much Detail		About the Right Amount of Detail		Could Have Used More Detail		Not Nearly Enough Detail		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	5%	1	10%	2	45%	9	40%	8	0%	0	20
Online text	5%	1	15%	3	70%	14	10%	2	0%	0	20

Note. Shading indicates patterns for the majority of responses.

As Exhibit 7 shows, all of the reviewers reported that the topics in the unit were at least *somewhat clear*. Micro array techniques was the least clear topic for many reviewers, and several reviewers were confused by *E* values. The reviewers requested more graphics throughout the online text to illustrate these and other topics (e.g., an illustration that shows the complete nucleotide sequence or codons).

Exhibit 7
Clarity of Genomics Topics Addressed

	Very Clear		Somewhat Clear		Not Very Clear		Not at All Clear		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	30%	6	70%	14	0%	0	0%	0	20
Online text	45%	9	55%	11	0%	0	0%	0	20

Note. Shading indicates patterns for the majority of responses.

The reviewers rated the level of bias evident in the unit. Three out of 15 reviewers (20%) found significant evidence of bias, 9 (60%) found some evidence of bias, and 3 (20%) found no evidence of bias. The reviewers explained that bias was due to a limited discussion of the ethical issues and the implications of genomics, especially in the video. The reviewers' comments include these:

> "I think some discussion should center on the implications of this technology."

> "All applications of genomic research were presented in a positive light, with no negative connotations mentioned until the ethics section. The ethics section didn't go into all of the problems that even an average American has heard on the news (e.g., problems with patients recovering from gene therapy)."

Impact

The reviewers reported that the most valuable aspects of the unit were the explanations of genomic techniques and research methods and the current and future applications. All of the reviewers reported learning something new and reported believing that their peers would also learn something new from the materials (see Exhibit 8).

Exhibit 8
Genomics Knowledge Advancement

	To a Great Extent		To Some Extent		Only a Little		Not at All		
Variable	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Advance your knowledge	40%	8	40%	8	20%	4	0%	0	20
Advance your peers' knowledge	47%	9	42%	8	11%	2	0%	0	19
Connect your previous understanding and new discoveries	65%	13	25%	5	10%	2	0%	0	20

Note. Shading indicates patterns for the majority of responses.

The following quotations describe some of the reviewers' perceptions of the new information they acquired from the unit:

> "Although I have some background knowledge in the Human Genome Project, I had limited knowledge of how gene function is determined and the databases involved with this."

> "The unit really advanced my knowledge of micro arrays."

> "The text and video did a great job of expanding my understanding of genome research, haplotypes, and micro arrays."

> "I appreciate the experience and have gained new insight into genomics. My AP Biology students will be beginning their molecular biology and biotechnology unit very soon and I know this material has contributed to a stronger, more effective series of lessons that I teach."

> "Unfortunately many teachers limit their instruction in genetics to Mendelian concepts. Hopefully, this unit will provide teachers with some of the content background needed to expand their instruction to include molecular genetics."

Suggestions for Improving the Genomics Unit

Reviewers made the following suggestions for improving the genomics unit:

- Add more information on the ethical issues and the implications of genomics in the video and online text.
- Clarify the meaning of micro array techniques and *E* values in the video and online text.
- Include all of the examples in the video in the online text and vice versa.

Additional Suggestions

Although the following suggestions do not represent patterns in the data (i.e., only one reviewer made each suggestion), some may be important to consider.

Reviewers suggested adding:

- A broad definition of genomics at the beginning of the unit.
- An example of DNA fingerprinting (students love this topic).
- Remarks that describe the context for DNA repair research.
- A brief overview of the mechanics of inheritance.
- A detailed example of how a change in a particular nucleotide sequence can lead to an amino acid substitution that affects phenotype (in the SNP section).

Reviewers suggested providing more information about:

- Haplotypes and micro array experiments.
- The methods of sequencing used by the Human Genome Project.
- Type I and II diabetes.
- Gel electrophoresis and cDNA.
- Final segment on ethical, legal, and social implications.

- Open reading frame.
- Dinococcus radians and DNA repair process.

Reviewers suggested clarifying:

- The relationship between genomics and lab research.
- The possible causes of SNPs.
- The graph that illustrates clone-based sequencing.
- The hierarchical shotgun cloning method.

Reviewers also made these suggestions:

- Combine the Genetic Variation and Genetic Similarities and Differences sections into one section.
- Reference Barbara McClintock's pioneering work on transposable elements in corn (many biology teachers know her work and it would fit in well in this section).
- Provide a link to the Howard Hughes Medical Institute in the section on BLAST.
- Refer regularly to the broader context of genomics, especially in the online text.
- Improve the transitions between topics.
- Clarify the value of understanding how BLAST works if the tool will soon be replaced by another tool.

Genetically Modified Organisms

Technologies based on increased understandings of the structure and function of DNA are providing the tools for humans to change the genetic makeup of organisms from bacteria to mammals. Although humans have been improving species through selective breeding for millennia, new techniques now allow the creation of organisms that combine DNA from species as disparate as bacteria and plants or as closely related as pigs and humans. The creation of these new transgenic organisms raises questions about their impact on the environment and the ethics of human control over evolution.

Successful transgenic organisms may benefit humankind through the bacterial production of human proteins such as insulin, a decreased need for pesticides, faster growing fish and leaner meat, and animal models of human disease for use in medical research. Biotechnologists also anticipate sheep that express human proteins in their milk and pigs with immune markers that make their organs acceptable for transplantation into humans. These advances are not without risks.

The process of creating transgenic mammals is complex, and most attempts fail. When genetic goals are achieved and animals display the desired traits, it is advantageous to be able to reproduce the genotype without the risks inherent to sexual reproduction. The safe production of transgenic organisms therefore becomes an argument for the development of cloning technology. Although cloning technology has been perfected for mice, it remains problematic for other mammalian species. Clones often do not survive, and when they do they experience problems related to development and aging. To clone effectively, scientists need a greater understanding of the molecular biology of reproduction. If scientists learn to clone other mammals, will they develop the skills to clone humans? If human cloning can be done, will it be done? Scientists, ethicists, and citizens will soon face these important questions.

Findings

The reviewers considered the GMO unit the most interesting and well structured of the 3 units (the reviewers also had more prior knowledge about GMOs than the other topics). They requested clarification about gene guns and more examples from human or animal cases. This section details the reviewers' background and interest in GMOs, their ratings of the content and structure of the unit materials, the impact of the unit on their knowledge and teaching, and their suggestions for future editions of the video and online text.

Background and Interest in GMOs

Exhibit 9 shows that the topics in the GMO unit were familiar to most of the reviewers. They reported having followed these topics in the news and having covered many of the issues in their classes. The newest topics to the reviewers were adding nutrients to GMO crops and human health concerns and GMOs. Although the overall topics were familiar, the reviewers reported that several of the examples were new and that the unit had increased their understanding of all sides of the issues.

Exhibit 9
Familiarity With GMO Topics

	New to Me						Review to Me				
	1		2		3		4		5		
Topic	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Ability to add nutrients to GMO crops	0%	0	32%	6	16%	3	26%	5	26%	5	19
Cloning technology and cloning animals	0%	0	6%	1	6%	1	33%	6	56%	10	18
Environmental concerns and GMOs	6%	1	6%	1	17%	3	39%	7	33%	6	18
Human health concerns and GMOs	0%	0	22%	4	39%	7	11%	2	28%	5	18
Inserting genes using plasmid vectors	11%	2	0%	0	6%	1	17%	3	67%	12	18
Recombinant DNA and restriction enzymes	0%	0	0%	0	11%	2	22%	4	67%	12	18
Transgenic organisms	0%	0	12%	2	6%	1	29%	5	53%	9	17
Turning genes on or off with promoters	6%	1	0%	0	17%	3	33%	6	44%	8	18

Note. Shading indicates patterns for the majority of responses.

The reviewers reported having had more prior knowledge about the GMO topics than their peers (see Exhibit 10). They were somewhat concerned that some of their peers do not have the background knowledge to fully understand all of the materials. Reviewers believed that most of their peers would learn new information from the GMO unit.

Exhibit 10
Peers' Familiarity With GMO Topics

	Will Be New to Peers						Will Be Review to Peers				
	1		2		3		4		5		
Topic	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Ability to add nutrients to GMO crops	6%	1	59%	10	24%	4	12%	2	0%	0	17
Cloning technology and cloning animals	4%	1	18%	3	37%	6	25%	4	18%	3	17
Environmental concerns and GMOs	4%	1	43%	7	47%	8	4%	1	0%	0	17
Human health concerns and GMOs	13%	2	19%	3	69%	11	0%	0	0%	0	16
Inserting genes using plasmid vectors	19%	3	13%	2	31%	5	31%	5	6%	1	16
Recombinant DNA and restriction enzymes	0%	0	25%	4	50%	8	19%	3	6%	1	16
Transgenic organisms	0%	0	25%	4	56%	9	13%	2	6%	1	16
Turning genes on or off with promoters	6%	1	44%	7	25%	4	19%	3	6%	1	16

Note. Shading indicates patterns for the majority of responses.

The reviewers were very interested in the GMO video and online text (see Exhibit 11). They reported that the issues were timely and relevant to their current biology curriculum. The connections with the news helped this unit engage students. One professional development provider wrote: "This topic is particularly interesting because it is so current. It is also an engaging topic because it is influenced by economics, politics, and ethical decisions."

Exhibit 11
Interest in GMO Materials

	Very Interesting		Somewhat Interesting		Not Very Interesting		Not at All Interesting		
Medium	**%**	***N***	**%**	***N***	**%**	***N***	**%**	***N***	***N***
Video	80%	16	20%	4	0%	0	0%	0	20
Online text	70%	14	30%	6	0%	0	0%	0	20

Note. Shading indicates patterns for the majority of responses.

Content and Structure

According to the reviewers, the GMO unit was the clearest and most logical of the 3 units; almost all of the reviewers rated the video and online text as *very clear* (see Exhibit 12). They reported ease following the video and online text separately or together because the materials were in the same order and, for the most part, used the same examples. One reviewer wrote: "The order of introduction, definition of GMOs, the technology to create GMOs, the applications, and then the problems and opposition flowed smoothly and logically. I was able to follow each argument and example easily." The reviewers suggested very few alterations to the structure of the materials.

Exhibit 12
Logic and Usefulness of the Order of GMO Materials

	Very		Somewhat		Not Very		Not at All		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video: Logical order?	85%	17	15%	3	0%	0	0%	0	20
Online text: Useful order?	90%	18	10%	2	0%	0	0%	0	20

Note. Shading indicates patterns for the majority of responses.

The majority of the reviewers were also satisfied with the depth and detail of the video (70%) and online text (85%). Several reviewers wanted more information and clarity about the gene gun discussed in the video. The reviewers also requested more examples of gene therapy in humans as opposed to focusing on plant examples.

Exhibit 13
Depth and Detail of GMO Materials

	Way Too Much Detail		A Little Too Much Detail		About the Right Amount of Detail		Could Have Used More Detail		Not Nearly Enough Detail		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	0%	0	0%	0	70%	14	30%	6	0%	0	20
Online text	5%	1	5%	1	85%	17	5%	1	0%	0	20

Note. Shading indicates patterns for the majority of responses.

The structure of the materials and the reviewer's familiarity with the topics contributed to their ratings of the clarity of the materials. About two thirds of the reviewers rated the video *very clear* and half rated the online text *very clear* (see Exhibit 14). The gene gun example in the video did, however, confuse many of the reviewers (the gene gun example in the online text was clearer). The reviewers also reported that more graphics would help the unit.

Exhibit 14
Clarity of the GMO Topics Addressed

	Very Clear		Somewhat Clear		Not Very Clear		Not at All Clear		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	68%	13	32%	6	0%	0	0%	0	19
Online text	50%	10	45%	9	5%	1	0%	0	20

Note. Shading indicates patterns for the majority of responses.

Very few of the reviewers (3 of 20) reported bias in the video. Although one of these reviewers believed that the video was overtly pro-GMO, most of the reviewers praised the video for its thorough coverage of all sides of the GMO issue. One reviewer wrote: "You addressed the controversial issues, provided time for the oppositions' views and left it up to the viewer to come up with his/her own conclusions. You rode the fence well."

Impact

The reviewers reported that the most valuable aspects of the unit were the examples (e.g., Bt corn, gene gun, golden rice) and the social and political critiques of GMOs. All of the reviewers reported that the unit advanced their own knowledge at least a little and would also advance their peers' knowledge. Many reported that the unit reinforced what they already knew and added to their understanding of all sides of the issue (see Exhibit 15).

Exhibit 15
GMO Knowledge Advancement

	To a Great Extent		To Some Extent		Only a Little		Not at All		
Variable	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Advance your knowledge	10%	2	65%	13	25%	5	0%	0	
Advance your peers' knowledge	39%	7	61%	11	0%	0	0%	0	
Connect your previous understanding and new discoveries	85%	17	15%	3	0%	0	0%	0	

Note. Shading indicates patterns for the majority of responses.

The reviewers' comments indicated that the unit had impacted their approach to teaching this topic:

> "I will utilize the examples . . . for instance, I will now refer to Bt corn, golden rice and goat's milk that contains vaccinations in my teaching. I am sure that my peers will also benefit from the extensive examples."

> "I appreciate the addition of the criticisms of GMOs to help balance out my own presentation in class. Other teachers will hopefully gain a better understanding of how GMOs are made and be able to simplify this topic for all levels."

Suggestions for Improving the GMO Unit

The GMO unit was well received. Although the reviewers did not suggest any changes to the overall structure of the video or online text, reviewers suggested the following improvements:

- Clarify the gene gun example in the video.
- Add more human and animal examples in the video and online text.

Additional Suggestions

The following suggestions do not represent patterns in the data (i.e., only one reviewer made each suggestion).

Reviewers suggested adding:

- An indication of the amounts of lab time, effort, and funding teachers should anticipate expending to pursue the study of the GMO topics.
- A discussion of monopolies of food and seed supplies.
- A discussion of government regulation of GMO technology (or the absence thereof).
- A description of how restriction enzymes work.
- A description of the insect resistance management plan (to the online text).
- A description of the research scientists conducted to make the discoveries described in the unit.
- Specific examples of eukaryotic gene expression in prokaryotes (to the online text).
- Tables (to the online text) that summarize the differences between genetic recombination and cloning.
- A flowchart that illustrates the process of modifying bacteria to express eukaryotic genes.
- A flowchart that illustrates process steps of recombination.
- A diagram that illustrates marker genes and cloning rectors.
- A diagram that illustrates knockout technology.

Reviewers suggested providing more information about:

- The science research techniques and instruments used by genetic engineers.
- Monsanto's role in GMO technology.
- The issue of gene patents.
- Cloning and transgenic animals.

- Head-to-tail concatamers.
- The health and social concerns regarding golden rice (in the online text).
- The southern blots process (see www.ang.kfunigraz.ac.at).
- Harvard mouse.
- Superweeds resulting from the genetic drift of herbicide-resistant genes between species.

Reviewers suggested clarifying:

- How scientists introduced beta carotene into golden rice.
- Whether Bt corn can pollinate non-Bt corn.
- The difference between breeding and genetically modifying organisms and the implications and limitations of each process.
- How cDNA is produced.
- The role of restriction enzymes (in the online text).
- Whether all plant cells divide and form undifferentiated callus.
- Whether coronary artery disease is in part attributed to genetic factors.

Reviewers also made these suggestions:

- In the video, address the pros and cons of GMOs in a closing discussion.
- In the video, provide a more vibrant narration.
- Produce a separate video dedicated to animal and human cloning.
- Spend more time on the science of GMOs rather than the applications of GMOs.
- Reduce the explanation of the biochemistry of transgenic rice and the 4-gene pathway.
- Reduce the emphasis on the anti-GMO demonstrations in Europe.

Comparative Evolution

The genetic revolution in biology has generated a tremendous amount of information concerning the evolutionary relationships among organisms. Traditional views of organismal diversity have primarily focused on different groups of multicellular organisms. Scientists now understand that most of the genetic diversity on earth is among unicellular organisms. Furthermore, humans' understanding of the evolutionary relationships within plants and animals continues to develop through new molecular data. Coupled with the emergence of these data are new methods of data analysis that provide an analytical framework for reconstructing evolutionary relationships and testing hypotheses of evolutionary change. The result of this data analysis, the phylogenetic tree, has become a central feature of evolutionary and molecular studies. These methods also allow estimates of rates of evolution and evolutionary divergence times.

The genomic analysis of a wide variety of organisms has lead to a rebirth in comparative approaches to understanding biological function. Scientists' understanding of gene function, cell signaling, development, and neurobiology have all benefited from this new comparative framework. Scientists now recognize that a comparative evolutionary framework is one of the best approaches to understanding biological function. Recent developments in genetic and phylogenetic theory are helping to establish this framework.

Findings

The comparative evolution unit was slightly more difficult for the reviewers than the other 2 units. The reviewers praised the presentation of the 3-domain classification system and the case examples (e.g., whales and anthrax), but many of the reviewers struggled with other topics. This section details the reviewers' background and interest in comparative evolution, their ratings of the content and structure of the unit materials, the impact of the unit on their knowledge and teaching, and their suggestions for future editions of the video and online text.

Background and Interest in Comparative Evolution

The reviewers had varying levels of prior experience with the topics addressed in the comparative evolution unit. The 3-domain classification system and lateral-horizontal gene transfer were new to more reviewers than were other topics. Reviewers with less background knowledge reported struggling to understand some of the materials (see Exhibit 16).

Exhibit 16
Familiarity With Comparative Evolution Topics

	New to Me						Review to Me				
	1		2		3		4		5		
Topic	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
3-domain versus 5-kingdom classification system	16%	3	21%	4	16%	3	21%	4	26%	5	19
Applications of phylogenetic methods	10%	2	15%	3	20%	4	30%	6	25%	5	20
Cladistics as a tool for inferring evolutionary patterns	11%	2	11%	2	22%	4	33%	6	22%	4	18
Lateral or horizontal gene transfer	25%	5	0%	0	25%	5	25%	5	25%	5	20
Use of molecular systems in studying evolution	11%	2	0%	0	27%	5	37%	7	26%	5	19
Use of phylogenetic reconstruction in studying evolution	5%	1	11%	2	11%	2	47%	9	26%	5	19

Note. Shading indicates patterns for the majority of responses.

The reviewers reported that their peers also had a wide range of prior experience with comparative evolution topics—overall, slightly less experience than the reviewers themselves. They reported that although some of their peers would be very familiar with these topics, the majority would need extra time and assistance or both to fully understand the materials (see Exhibit 17).

Exhibit 17
Peers' Familiarity With Comparative Evolution Topics

	Will Be New to Peers						Will Be Review to Peers				
	1		2		3		4		5		
Topic	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
3-domain versus 5-kingdom classification system	22%	4	33%	6	17%	3	17%	3	11%	2	18
Applications of phylogenetic methods	6%	1	44%	8	39%	7	6%	1	6%	1	18
Cladistics as a tool for inferring evolutionary patterns	11%	2	17%	3	39%	7	22%	4	11%	2	18
Lateral or horizontal gene transfer	33%	6	22%	4	28%	5	17%	3	0%	0	18
Use of molecular systems in studying evolution	18%	3	35%	6	29%	5	12%	2	6%	1	17
Use of phylogenetic reconstruction in studying evolution	6%	1	22%	4	33%	6	33%	6	6%	1	18

Note. Shading indicates patterns for the majority of responses.

Regardless of their background, almost all of the reviewers found the comparative evolution unit interesting and credited the examples with keeping their interest (see Exhibit 18). For example, the anthrax example at the beginning of the video captured the reviewers' attention and other examples (e.g., whales) helped make an otherwise dry topic interesting. One reviewer wrote, "Normally, this is not the most exciting content to study, but using the anthrax case as an introductory component was a real attention grabber." Several reviewers suggested presenting the anthrax example in its entirety at the beginning of the video rather than presenting part of the example at the beginning and the remainder at the end.

Exhibit 18
Interest in the Comparative Evolution Materials

	Very Interesting		Somewhat Interesting		Not Very Interesting		Not at All Interesting		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	60%	12	30%	6	5%	1	5%	1	20
Online text	40%	8	45%	9	15%	3	0%	0	20

Note. Shading indicates patterns for the majority of responses.

The comparative evolution unit was at least *somewhat interesting* to almost all of the reviewers. The video was more interesting to the reviewers than the online text—in fact, several reviewers suggested adding examples from the video to enliven the online text. One reviewer wrote: "Why didn't you use the whale phylogeny study as an example in the online text? This was good science and would have made a stronger connection between the video and text if it had been added."

Content and Structure

As Exhibit 19 shows, most of the reviewers reported that the video and online text were logical and easy to follow, although many agreed that the anthrax example would be more effective uninterrupted. One reviewer commented: "The flow of information within each section was smooth. For example, the discussion of whale evolution was logically done, as was the section on the determination of the 3 domains."

Exhibit 19
Logic and Usefulness of the Order of Comparative Evolution Materials

	Very		Somewhat		Not Very		Not at All		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video: Logical order?	65%	13	30%	6	5%	1	0%	0	20
Online text: Useful order?	75%	15	20%	4	5%	1	0%	0	20

Note. Shading indicates patterns for the majority of responses.

The majority of the reviewers (60%) believed that the video had about the right amount of depth and detail. The reviewers were not, however, as satisfied with the online text: over

half of the reviewers (61%) reported that the online text had too much depth and detail (see Exhibit 20). A few of these reviewers were overwhelmed by the material. Several stated that many of the topics were too advanced for the science classes they taught. Others reported that too many unnecessary technical terms bogged them down (e.g., *paraphyletic*, *homoplasy*, *monophyly*, *synapomorphies*, and *synaptomorphies*). Some reviewers suggested curtailing the explanation of the history of classification because the topic is review for most science teachers.

Exhibit 20
Depth and Detail of Comparative Evolution Materials

	Way Too Much Detail		A Little Too Much Detail		About the Right Amount of Detail		Could Have Used More Detail		Not Nearly Enough detail		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	5%	1	10%	2	60%	12	25%	5	0%	0	20
Online text	17%	3	44%	8	39%	7	0%	0	0%	0	18

Note. Shading indicates patterns for the majority of responses.

As Exhibit 21 shows, most of the reviewers rated the presentation of the comparative evolution topics as *somewhat clear*. The topics that caused the most confusion—especially in the online text—were the mechanics of horizontal and vertical gene transfer, cladistics, and rooted/uprooted phylogenetic trees. One reviewer stated: "When the online text explained techniques to 'root a tree' the explanation became unclear. Out groups were defined well, but the way in which out groups are used and reasoning behind it was very confusing. The explanation of horizontal gene transfer among eukaryotes [was incomplete]." Reviewers requested more information and additional graphics in both the video and online text to clarify these and other topics.

Exhibit 21
Clarity of Comparative Evolution Topics Addressed

	Very clear		Somewhat Clear		Not Very Clear		Not at All Clear		
Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Video	30%	6	55%	11	15%	3	0%	0	20
Online text	20%	4	65%	13	15%	3	0%	0	20

Note. Shading indicates patterns for the majority of responses.

Because of the controversial nature of the topic of evolution, the reviewers were sensitive to the issue of bias. Of the 15 reviewers who responded, 5 (33%) reported that the comparative evolution unit was unbiased *to a great extent*, whereas 8 (53%) believed the unit was unbiased *to some extent*. The 2 reviewers (17%) who reported that bias was evident remarked that bias on the subject is unavoidable. One reviewer wrote: "It must be kept in mind that this whole concept of evolution, regardless of approach, is still considered a theory. Dr. Woese seems to have a strong conviction that his research is indisputable. However, the text and the video show diversity in research angles and how they are related."

Impact

The reviewers reported that the most valuable aspects of the unit were the explanation of the 3-domain classification system, the whale and anthrax examples, and molecular phylogenetics. All of the reviewers reported at least a little advancement in their own knowledge and strongly believed that the materials could advance their peers' knowledge (see Exhibit 22). They were also able, at least to some extent, to connect previous scientific understanding of the concept of evolution to the newer content and discoveries presented. Reviewers made the following comments:

> "The idea of horizontal transfer definitely changed my perception of the base of the universal tree."

> "The unit has expanded my knowledge and understanding of phylogeny, cladistics, and the 3-domain system."

"Most of this information was new to me. I especially appreciate the information explaining Carl Woese's work on the 3 domains of life. Also, I learned a great deal about the methods of using DNA comparisons to answer questions about evolution."

Exhibit 22
Comparative Evolution Knowledge Advancement

	To a Great Extent		To Some Extent		Only a Little		Not at All		
Variable	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Advance your knowledge	20%	4	70%	14	10%	2	0%	0	20
Advance your peers' knowledge	55%	11	40%	8	5%	1	0%	0	20
Connect your previous understanding and new discoveries	53%	10	42%	8	5%	1	0%	0	19

Note. Shading indicates patterns for the majority of responses.

Most of the reviewers reported that after completing the unit, they planned to begin teaching the 3-domain system rather than the 5-kingdom system. They also intended to use the whale and anthrax examples with their students. One reviewer noted that his state's science curriculum committee was so impressed by the whale example that it had incorporated the example into the new Grade 10 unit on the nature of science and evolution. In contrast, a few reviewers questioned the relevance of some topics or reported having insufficient time to address all of the topics in class. One reviewer indicated, for example, that the topic of cladistics is not covered in secondary school biology classes. A few reviewers were overwhelmed by the unit and frustrated with the level of difficulty. One of these reviewers wrote: "I was left after 2 viewings of the video with little to no clue about what I was to comprehend. I had to really, really study the text and review the video over to feel better about the unit."

Suggestions for Improvements to the Comparative Evolution Unit

Reviewers made the following suggestions for improving the comparative evolution unit:

- Present the anthrax example in its entirety at the beginning of the video rather than presenting part of the example at the beginning and the remainder at the end.
- Include all of the examples in the video in the online text and vice versa.
- Include more graphics in the video and online text (e.g., a diagram of an ankle bone).
- Decrease the number of unnecessary technical terms.
- Simplify and clarify these topics: lateral/horizontal gene transfer, phylogenetic trees, and cladistics.

Additional Suggestions

The following suggestions do not represent patterns in the data (i.e., only one reviewer made each suggestion).

Reviewers suggested adding:

- Information on how cladograms and phylogenics are constructed.
- A reference (in the online text) to Aristotle's earliest divisions and a timeline that shows the timeframes during which the various systems have existed.
- A diagram with examples of mono-, poly-, and paraphyltic clades. Examples to differentiate between synap- and synaplesiomorphies.
- A video segment on Henning's work.

Reviewers suggested providing more information about:

- How rRNA and ATPase determine that archea and eukaryotes are closely related.

- SNPs (because not all viewers will have completed the genomics unit prior to the comparative evolution unit).
- The reconfiguration of the tree of life.
- Archaebacteria characteristics.

Reviewers suggested clarifying:

- Why microorganisms are classified an entirely different branch of organization (in the video).
- The comparison between stem/branch and cladistics in the video.
- The exact nature of the evidence presented in the whale example (i.e., the DNA sequences or proteins that were used in the analysis).
- The dayhoff/paralogous section in the video.
- The uses of out groups.
- How scientists discovered the existence of gene transfers and how scientists know that the genes are bacterial in nature rather than similar genes within the eukaryotic clade.

Reviewers also made these suggestions:

- Further stress the importance of multiple lines of evidence in strengthening and modifying theories.
- Use a more linear approach to the organization of the topics in the video.
- Curtail the explanation of the history of classification.
- Eliminate the example of classification as a separation of milk and eggs in the refrigerator.
- Use examples rather than definitions only in the online text sections on cladistics and classification.
- Eliminate the discussion of why scientists do not use primitive characteristics.

Overall

This section discusses the overall findings of the review of 3 of the units from the Rediscovering Biology series: genomics, GMOs, and comparative evolution. A discussion of the similarities and differences among the unit reviews is followed by a discussion of the issues raised and suggestions made by the reviewers.

Ratings

The majority of the reviewers were interested in all 3 units. Interest was highest when the topics were (a) relevant to the reviewers' biology curriculum and standards, (b) connected to timely, real-world examples, (c) clearly and thoroughly presented, and (d) new to the reviewers. The videos usually received higher interest ratings than the online text materials, which might be due to a preference for the video medium. Exhibit 23 shows that the reviewers gave the highest interest ratings to the genomics and GMO videos and the lowest interest ratings to the comparative evolution online text.

Exhibit 23
Overall Interest in Units

	Very Interesting		Somewhat Interesting		Not Very Interesting		Not at All Interesting		
Unit/Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Genomics video	80%	16	15%	3	5%	1	0%	0	20
GMOs video	80%	16	20%	4	0%	0	0%	0	20
Comparative evolution video	60%	12	30%	6	5%	1	5%	0	20
Genomics online text	70%	14	25%	5	5%	1	0%	0	20
GMOs online text	70%	14	30%	6	0%	0	0%	0	20
Comparative evolution online text	40%	8	45%	9	15%	3	0%	0	20

Note. Shading indicates patterns for the majority of responses.

The reviewers' prior familiarity with the units and the topics varied, but no major differences were evident between the teachers and the professional development providers

in terms of familiarity with the topics or overall ratings of the units. The genomics unit had the most topics that were new (or fairly new) to the reviewers, followed by the comparative evolution unit. The reviewers were most familiar with topics in the GMO unit. All of the units increased the reviewers' knowledge, although the extent of the increase varied (see Exhibit 24). The reviewers reported that their peers had slightly less prior experience with the topics and would gain more knowledge from all 3 units than the reviewers themselves. They estimated that each unit would take their peers 1 to 3 hours to review and suggested that some of their peer would need to review the materials several times.

Exhibit 24
Overall Knowledge Advancement

	To a Great Extent		To Some Extent		Only a Little		Not at All		
Unit	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Genomics	40%	8	40%	8	20%	4	0%	0	20
GMOs	10%	2	65%	13	25%	5	0%	0	20
Comparative evolution	20%	4	70%	14	10%	2	0%	0	20

Note. Shading indicates patterns for the majority of responses.

Of the 3 units, the GMO unit received the highest ratings on the qualities of order, clarity, and connection between previous knowledge and new knowledge (see Exhibit 25). Reviewers also reported that the GMO video and online text were the most compatible (i.e., they followed the same order and could be used simultaneously), flowed smoothly, and provided a good balance of background material and new information.

Exhibit 25
Overall Clarity of Topics

	Very clear		Somewhat Clear		Not Very Clear		Not at All Clear		
Unit/Medium	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	***N***
Genomics video	30%	6	70%	14	0%	0	0%	0	20
GMOs video	68%	13	32%	6	0%	0	0%	0	19
Comparative evolution video	30%	6	55%	11	15%	3	0%	0	20
Genomics text	45%	9	55%	11	0%	0	0%	0	20
GMOstText	50%	10	45%	9	5%	1	0%	0	20
Comparative evolution text	20%	4	65%	13	15%	3	0%	0	20

Note. Shading indicates patterns for the majority of responses.

In general, the reviewers wanted the videos and online text materials to resemble each other more closely. One reviewer wrote, "If the video is designed to clarify and animate the text, then there should be a closer match between the content, applications, and examples in the 2 sources." For all 3 units the reviewers asked that all of the examples in the videos be included in the online text materials and vice versa. The reviewers also believed that presenting a clear outline of the goals and objectives at the beginning of each unit would increase comprehension.

Issues

The reviewers raised the following 6 issues in their appraisals of all 3 units: the background knowledge required to understand and effectively teach the units, the relevance of the units and their teaching applications, the pedagogical approach of the units, the structure of the units, cultural and gender sensitivity, and the possible uses of the series.

Required Background Knowledge

The reviewers were concerned that many of their peers would not have the background knowledge to fully understand the materials. They were concerned that teachers who had been out of school for awhile, taught only basic biology courses, or had never studied these topics would be lost and frustrated by some aspects of the units. Slightly more

professional development providers than teachers voiced this concern, which applied to all 3 units, as illustrated by the following quotations:

> "The average Biology I teacher won't grasp a lot of this information because they're missing the preliminary information that facilitates understanding." *(Professional development provider, genomics unit)*

> "There is an assumption that secondary school biology teachers will have a college-level understanding of evolution. Although this is optimal, it may be unrealistic. Many teachers who teach introductory courses do not teach cladistics to any great depth in their courses, and probably cover just the basics of classification. Therefore, unless they read and study classification on their own, they may not have been exposed to the background material necessary to understand this unit." *(Professional development provider, comparative evolution unit)*

> "Much of this information is relatively new, and teachers who may not have attended specific seminars, or updated knowledge through classes, would be unfamiliar with many of the terms, if not the concepts." *(Teacher, GMO unit)*

The reviewers suggested including a review section (e.g., "Before You Begin"), links to background information (in the online text), and clearly stated background knowledge requirements. Several reviewers felt strongly that the goals and objectives of each unit should be clearly stated in both the video and online text. They also suggested that the material might be best used in an environment (e.g., a course or small study group) with access to experts or colleagues capable of answering questions. Some of the reviewers reported having referred to college and high school biology textbooks for background information while conducting the unit reviews.

Relevance and Application to Teaching

The reviewers were most interested in materials that were relevant to their classes and of interest to their students. Materials that were too advanced for the students or outside the scope of the curriculum—no matter how fascinating—were not as useful. For example, teachers reported that the information on the 3-domain classification system met their immediate teaching needs more than the information on cladistics. One professional development provider wrote: "Cladistics is not in the Biology I curriculum and is only barely covered in the advanced placement curriculum. It will be hard to justify great explanations of rooted, unrooted, etc., when there is no need to know."

Although many of the reviewers reported plans to begin using examples covered in the units (e.g., whales, Bt corn) with their students immediately, they requested that the units pay more attention to classroom applications. Many reviewers reported that translating the information covered in the units to lesson plans and student-level activities would be a challenge, especially because the online text provided few examples of interactives. The reviewers also wanted to know how the topics relate to state and national standards. One professional development provider wrote, "I am not satisfied unless I have left with something which meaningfully impacts my teaching: new ideas, new materials to share with my students, new activities to teach updated concepts."

Pedagogical Approach of the Units

Many reviewers described the units' approach as traditional or didactic and requested more interactives that promote the inquiry approach they use in their classrooms. Many of the reviewers seemed unaware that accompanying interactives were under development, although the introduction to the units mentions this fact. One reviewer wrote: "I think that the units don't employ the teachers to discover the concepts for themselves, but are rather the old school approach. Some real solid, active hands-on activities need to be developed to allow the teacher time to question, process and discover the information, much like they ask of students."

Structure of the Units

Overall, the reviewers were pleased with the order and structure of the units. Because the materials were in draft form at the time of the review, many of their structural suggestions (e.g., the inclusion of animations, a glossary, etc.) were already under consideration or development. Some of the suggested structural changes sought to facilitate the simultaneous use of both media. For example, reviewers wanted the online text to more closely follow the video and suggested providing more subheadings in the online text and using a counter or other tracking device to align the online text with the video. The reviewers also requested that all examples in the video appear in the online text and vice versa.

Cultural and Gender Sensitivity

Exhibit 26 shows that over one third of the reviewers reported that the materials were not sensitive to cultural diversity. Many explained that although women and people of color were present in some of the video segments, they were almost always in background roles such as lab assistant. They believed the videos were dominated by White males.

Exhibit 26
Overall Sensitivity to Cultural Diversity

	Is Sensitive to Cultural Diversity		Is Not Sensitive to Cultural Diversity		
Unit	**%**	***n***	**%**	***n***	***N***
Genomics	63%	10	37%	6	16
GMOs	56%	9	44%	7	16
Comparative evolution	63%	10	37%	6	16

The reviewers' comments regarding the cultural and gender sensitivity of the units included these:

> "Your choice of talking scientists and the farmer [in the GMO unit] may imply an unfortunate racial, gender, and cultural bias. All were White. The

scientists and farmer who presented the case for using GMOs were male, while the 2 spokespersons for health, social, and ethnical concerns were female. In the segment on golden rice, it would be appropriate to hear a viewpoint from a spokesperson who came from those cultures."

"If you can't build the perception that people of color belong in a laboratory setting, what message will biology teachers take back to their science classrooms?"

"There are no women scientists portrayed in the [genomics] video. One woman appeared to be a technician, and the other looked like a student. This clearly implies that women are not capable of directing serious scientific research. There was one Asian depicted for one second and no Blacks or Hispanics."

Possible Uses of the Series

Reviewers also raised concerns about the possible uses of the Rediscovering Biology series.

Credit Courses—The reviewers agreed that teachers are more likely to devote time to the series if incentives are offered (e.g., course credit). Several professional development providers reported that some of the materials would fit with the courses they were already offering, whereas others suggested designing a new course focused on the Rediscovering Biology series. Most of the reviewers believed that the course must offer hands-on activities and address the issue of classroom applications.

In-Service Trainings—The reviewers believed that the units are appropriate for in-service trainings. Because school in-service time is limited, professional development providers would, however, be compelled to choose which units (or topics therein) to include in in-service trainings. Some reviewers suggested that in-service trainings target specific groups of teachers, (e.g., advanced placement science teachers). The reviewers indicated

that the in-service trainings also must offer hands-on activities and the issue of classroom applications.

Online Learning—The reviewers expressed some disagreement regarding how well suited the units are for online learning. Some reviewers reported that the units are ideally suited for this approach because they allow teachers to move at their own pace and provide adequate information or links to additional information. Other reviewers maintained that the units are not suitable for online learning because of the need for discussion and hands-on activities and the perceived unpopularity of online learning among teachers. A few of these reviewers did, however, suggest that online discussion groups and self-study assessments might support online learning.

Self-Study—Reviewers also had different opinions on the use of the units for self-study. Some reviewers believed that motivated teachers would find the materials extremely useful, especially before teaching a related lesson. Others pointed out that teachers have little time for self-study, especially if incentives are not offered. Adding self-assessments would be especially important if the units were intended for self-study.

Small-Group Study—The reviewers believed that teachers would consider small study groups worthwhile only if they added value to the units by offering a forum for discussion, hands-on activities, and suggestions for classroom applications. The reviewers also indicated that small groups might encounter difficulties finding time to meet.

Classroom Activities—Many teacher reviewers planned to use some of the video excerpts with their students, especially in advanced placement and other high-level biology courses. They reported that the examples and case studies would be especially useful with their students (e.g., whale evolution in the comparative evolution unit, Bt corn in the GMO unit). Other reviewers asked for help translating the high-level materials to a basic level for students.

Recommendations

RMC Research offers the following suggestions based on the reviewers' concerns regarding the draft genomics, GMO, and comparative evolution units of the Rediscovering Biology series:

- Increase the representation of women and people of color in all units.
- Include more basic or background information. For example, a section called Before You Begin might explain the required prior knowledge. Include resources for users in need of review and state the learning goals and objectives.
- Ensure that professional development providers review the interactive materials currently under development.
- Include self-assessments such as quizzes or review sections.
- Implement structural changes that facilitate the simultaneous use of the video and online text. For example, provide more subheadings in the online text, use a counter or other tracking device to align the online text with the video, and use the same examples in the video and online text.

Other Comments From the Reviewers

Many reviewers' comments included words of thanks for the opportunity to review the 3 Rediscovering Biology units:

> "Overall I was very impressed with the units and would be interested in viewing the rest."

> "I feel most teachers would be eager to have the opportunity to expand our knowledge about current science topics in a time efficient and flexible manner, which this series could certainly offer."

"The series is quite informative and offers explanations that are easily incorporated into biology lesson plans. The lack of too many pages with too many words is certainly an attractive aspect about the program."

Genomics Unit Course Outline

Half of the professional development providers indicated that the genomics unit course outline was organized *very* logically, whereas another 40% indicated that it was *somewhat* logically organized. The reviewers liked the way the outline corresponded to the video and built upon the content addressed in the video. Criticisms of the organization tended to address the overall lack of refinement such as inconsistent formatting and unclear phrasing.

The reviewers did not agree on the degree to which the genomics unit course outline was clear and easy to follow. Forty percent indicated that the materials were very clear and easy to follow, whereas the remaining 60% were unsure because the draft version was incomplete. Only 20% of the reviewers reported that the outline contained adequate information for effective implementation in a professional development setting. Most indicated a need for additional details such as descriptions of the activities, setup instructions, and references to related content materials. Several reviewers asserted that effective use of the outline requires substantial background knowledge in genomics that would be a challenge in some settings (i.e., online learning, self-study, and small study groups).

Most of the reviewers indicated that the recommended time allotment (2½ hours) for completing the genomics unit is feasible, though some reviewers suggested that the time would be insufficient for the completion of all of the activities in a structured workshop setting. They pointed out that teachers would need more time to discuss the topics among themselves.

Recommendations

Regarding the genomics unit course outline, RMC Research offers the following recommendations based on the reviewers' feedback:

- Add greater detail to the outline including descriptions of the activities, setup instructions, a glossary of terms, and references to related content materials.
- Increase the recommended time allotment or eliminate some of the activities. Allow more time at the end of the workshop for closure and time for administrative tasks such as course enrollment and workshop evaluation.
- Relate the activities described in the outline to the corresponding segments of the videotape to facilitate use of the video in segments that correspond to major topics or techniques. Showing the entire video in one sitting is not as effective as showing it in segments that each introduce a new topic.

Additional Suggestions

Individual reviewers offered a wide variety of suggestions to improve the unit. Although the these suggestions do not represent patterns in the data (i.e., only one reviewer made each suggestion), some may be important to consider:

- Provide correct but alternate expressions of learner understanding, as well as expressions of understanding that are partially correct or misconceptions.
- Reorganize the unit to promote inquiry-based learning. This reviewer suggested: "Align it around a 5E model for learning[1] and the National Science Educations Standards (NSES) for Professional Development.[2] Sequence the activities into an inquiry experience. An example inquiry experience would begin with the CSI or other appropriate activity, enabling teachers to construct meaning from their experiences rather than frontloading the information prior to the activity with a detailed video and online data."
- Include detailed assessment suggestions.

[1]Trowbridge, L.W., Bybee, R.W., & Powell, J.C. (2000). *Teaching secondary school science: Strategies for developing scientific literacy* (7th ed.). Upper Saddle River, NJ: Merrill Prentice Hall.
[2]National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

- Provide information that helps the professional development provider distinguish between essential activities that address the big ideas and supplemental activities.

Genomics Activities

Most (80%) of the reviewers indicated that the instructions for the genomics activities were at least *somewhat* clear and easy to follow. Many did, however, report that the activities seemed incomplete and would benefit from more detailed instructions. Eighty percent of the reviewers reported that the activities would be very interesting for the teachers, and none indicated that the activities were not interesting. The reviewers liked the variety of activities and indicated that they would appeal to a wide range of participants. They believed that the activities covered many of the essential concepts, and 90% reported that the activities would to a great extent help teachers better understand the concepts addressed. Eighty percent of the reviewers reported that the activities would be challenging but within the capabilities of most secondary school biology teachers.

Comments Related to Specific Activities

Before and After (I.2)—The Before and After activity was one the reviewers specifically indicated interest in using. One reviewer suggested modifying the activity using a K-W-L approach (which asks the questions What do I already Know about the topic? What do I Want to learn about the topic? and What have I Learned about the topic? to capture the before, during, and after components of comprehension). Another reviewer suggested changing the implementation of the Before and After activity. He commented: "I would do the after [segment] in small groups as a review rather than an introductory information activity. I would use other activities to enable the learners to construct their understanding. The video and online experiences would serve to support teachers in their making meaning from the activities. The before [segment] enables the [professional development provider] to understand the level of conceptual understanding across a set of topics." Yet another reviewer suggested expanding the Before and After journaling activity to include descriptions of techniques and their application. This reviewer also stressed the importance

of providing participants with opportunities to revisit and update their journal entries as they refine their understanding of the concepts. One reviewer suggested changing the allocated time for each segment to 15 minutes. Another reviewer suggested a variation of this activity titled Now and Later and providing participants with Now & Later candy. This variation would focus on how changes in technology have caused us to have what we teach now to what is constantly being discovered later. This reviewer continued: "For each new concept, ask teachers what the current lesson plan or curriculum standard is and ask for ways to incorporate the new technology into teaching. This could be extended by asking teachers to project what discoveries may come even later based on the changes in thinking in the last X number of years."

Specialists (I.2)—The reviewers reported that they would likely use the Specialists activity, which they recognized as a variation on a jigsaw activity commonly used in professional development workshops. One reviewer recommended using the standard jigsaw small-group approach rather than having individuals make presentations to the whole group. For example, groups of participants could become specialists on a different technique and then form new groups that include a specialist in each technique who would teach the technique to the group. Another reviewer suggested changing the time allocated for the activity to 30 minutes.

Genomics Weakest Link (I.3)—Many reviewers reported that they would not use the Genomics Weakest Link activity primarily because its approach is limited to the recall of facts and most professional development providers refrain from using competitive activities that could put participants in embarrassing or humiliating situations. Reviewers indicated that if the activity is to remain a part of the genomics course, it should include a list of appropriate questions in true-false or multiple choice format and the allocated time should be increased to 30 minutes.

Find the Hidden ORF (I.4)—Many reviewers indicated that the Find the Hidden ORF activity is one they would likely use because it requires participants to do more than recall facts. One reviewer particularly liked the third variation, asserting that it was an effective

means of checking for understanding. One reviewer suggested: "In addition to scanning double stranded sequences, the students could use colored pencils to mark ATCG. Students could look for patterns in the colors to help them find stop codons quickly and easily." The reviewers recommended allocating 30 minutes for this activity.

Making a Microarray (I.5)—Several reviewers indicated that they would use the Making a Microarray activity to fortify teachers' understanding of microarrays, a new topic for most teachers. One reviewer recommended providing a set of gene sequences for traits that typical secondary school students are more likely to be familiar with. Another reviewer complained the description of the 4 x 3 grid was confusing (the description refers to horizontal rows and vertical rows rather than vertical columns). The reviewers also suggested including sample arrays and increasing the allocated time for the activity to 30 minutes.

CSI (II.1)—The reviewers particularly liked the CSI activity because they found it very interesting and easily adaptable to secondary school biology classrooms. One reviewer recommended that the activity be conducted in small groups. Reviewers also suggested including the SNP and other necessary information to minimize the preparation time for the professional development provider and several reviewers believed that a scenario other than a murder investigation would be more appropriate. One reviewer commented, "Murder investigations may draw television viewers but is unrealistic and is likely to be perceived by some educators as inappropriate." The reviewers' recommended time allocation for this activity ranged from 30 to 60 minutes.

The Amazing Deinococcus (II.2)—None of the reviewers indicated that they would use The Amazing Deinococcus activity, and 2 explicitly stated that they would not use it. One reviewer commented: "I feel this [activity] does not [facilitate] learning of the major concept though it provides a skeleton experience on gene expression. If this activity were coupled to the Deinococcus portion of the video and followed by a subsequent activity through which the student could construct the message that (a) there are fewer genes than we first predicted in the human genome, (b) the genes have similar code, and (c) gene

expression plays a role in variability among and between species gene expression in mammals, then I would think this activity has merit." Another reviewer believed that the content would be better addressed through a demonstration than an activity, and another reviewer suggested sequencing The Amazing Deinococcus activity before the Making a Microarray activity.

You Be the Database (II.3)—None of the reviewers identified the You Be the Database activity as one they would use, and one reviewer indicated that he would not use the activity. One reviewer suggested combining the You Be the Database activity with A Difference of a Few Percent or The Power of Databases. Others suggested including additional support materials to minimize preparation time for the professional development provider.

Scrambled Protocol (II.4)—One reviewer specifically expressed willingness to use the Scrambled Protocol activity and one reviewer indicated would that he would not use the activity. One reviewer suggested printing the steps and objectives on different colored cards that could easily be moved around. Participants could also cut the edges of the cards so that they interlock like puzzle pieces connecting both the relationship of the concepts and the order. The reviewers recommended allocating 10 minutes for this activity.

Haplotype Pedigree (II.5)—Some reviewers liked the Haplotype Pedigree activity, whereas others did not (3 indicated that they would use it, and 2 indicated that they would not). One reviewer pointed out that this activity would be complex and unfairly burdensome for participants with large or blended families. Another reviewer, concerned that some participants might not be comfortable revealing their own family history, suggested that the activity provide the pedigrees of a fictitious family. A reviewer who did not want to use this activity believed it to be too easy for the intended audience. The reviewers' suggested time allocation for this activity ranged from 20 to 90 minutes.

Microarrays and Cancer Diagnosis (III.1)—Many of the reviewers indicated that they would use the Microarrays and Cancer Diagnosis activity, particularly if the accompanying article were interesting and well written (the article was not included in the review

materials). The reviewers emphasized the importance of engaging in discussions of the ethical, legal, and social ramifications of advances in genetics and biotechnology. One reviewer remarked, "Ethics activities are finding wider use in schools in the area I reside, and this activity could contribute to the growing list of resources pending revision to clearly showcase stakeholders viewpoints along with those of your classmates." One reviewer recommended the authors of the activities consult the web site http://hshgp.genome.washington.edu/ for information about Huntington's ethics. Another reviewer suggested that the activity avoid questions that elicit yes or no answers and pose instead open-ended questions (e.g., "How could this information be abused?" "Who or what companies could use this information?" "What are the ethical implications for insurance companies? Hospitals?" "Who else could benefit from this information?"). The reviewers recommended allocating 30 minutes for this activity.

Quick Discussion (III.2)—Several reviewers reported that they would use the Quick Discussion activity, but recommended that the activity include more detailed instructions and provide answers from a variety of perspectives. The reviewers recommended allocating 30 minutes for this activity.

Genomics and Medicine: Discovery and Application (IV.1)—Only one reviewer indicated an interest in using the Genomics and Medicine activity. One reviewer suggested that the activity use the following questions: "What would be the benefit of knowing that you have an incurable disease?" "What are the drawbacks of knowing that you have an incurable disease?" "What decisions or questions would you like addressed before determining if you should have the test?" and "How would you consider these issues if the person in question were a friend, family member, or public figure?"

A Difference of a Few Percent (IV.2)—One reviewer indicated a willingness to use the activity A Difference of a Few Percent. Another reviewer believed that that activity was incomplete and suggested including a master of the FOX kinase article.

Homework: The Power of Databases—The only comment made by the reviewers about the activity Homework: The Power of Databases was a recommendation that the activity materials include the URLs the teachers and students need to use.

General Suggestions

The reviewers made a wide variety of suggestions regarding the genomics activities in general. Although these suggestions do not represent patterns in the data (i.e., in most cases only one reviewer made each suggestion), most warrant consideration. One reviewer strongly suggested that the unit outline and activities employ a constructivist approach to learning. That is, to the extent possible the activities would engage the teachers in using the same skills the researchers in the field used, which affords the teachers a similar experience of discovering the findings. Another reviewer recommended offering activities that are easily adaptable for use with secondary school students. Reviewers also recommended providing handouts and other supplementary materials to the extent possible to minimize preparation time for the professional development provider and clarify the activity instructions. Some reviewers believed that the instructions and support materials provided for the activities reviewed were insufficient. The reviewers' comments also included these:

> "In general, the learning activities for teachers should model of the type of instructional activities we encourage teachers to use in their classrooms. Learning activities should stress concept development over memorization, involve teamwork, and give students responsibility for their own learning. A traditional lecture, take notes, and recall of facts approach is not consistent with what research tells us about the way students most effectively learn."

> "All activities are pencil-and-paper or involve videos, the Internet, or computers. It would be helpful if there were a few easy hands-on laboratory activities included in the suggested activities."

> "To assure high-quality sessions the [professional development provider] must be provided with more information than the authors may feel is

necessary. This must always include results, variations, troubleshooting, explanations of related concepts, applications, and likely student questions."

"Provide objectives for each activity."

"Instruct professional development providers to model activities prior to assigning the activity to the teachers. For example, in the Haplotype Pedigree, instruct the professional development provider to put up his or her own pedigree or an example pedigree on an overhead transparency and show how to list the haplotypes. This will help teachers who need to see the instructions rather than just hear them."

"Provide a closing activity that wraps up the main ideas addressed in the unit."

"I feel that the developers seem to think that explaining a lab technique is an important and defining conceptual gain, whereas my view requires a segue from previous learned situations or context while conceptualizing the lab technique and a subsequently coupled experience in which the learner could apply one or more of these techniques to a problem. Many of the activities I would not use employ lower level thinking and or rote memorization. You are shortchanging the learners by not allowing them to solve problems with their knowledge."

GMO Unit Course Outline

Seventy percent of the reviewers indicated that the GMO unit course outline was organized *very* logically, but others expressed concerns about the organization of the unit. Those reviewers who were satisfied with the organization liked how each activity built upon the previous activity and appreciated having the option of a short or long version, though some suggested that the format made the distinction between 1-hour activities and 2½-hour activities confusing. Most of the reviewers reported, however, that 1 hour was inadequate for fully addressing the topic and believed that allocating 2½ hours was more realistic. The reviewers indicated that the developers underestimated the amount of time required for activities that involve teamwork or discussion.

Most of the reviewers indicated that the instructions were either *very* or *somewhat* clear and easy to follow (50% and 30%, respectively). Fewer reviewers (30%) reported that the unit outline contained enough information for the professional development provider to implement the activities in a workshop setting. Many reported that the outline was incomplete and lacked adequate instructions and detail. They suggested including objectives for the unit, responses to common questions, explanations of key terms and troublesome concepts, and suggestions for troubleshooting.

Recommendations

RMC Research recommends the following changes to the GMO unit course outline based on the reviewers' feedback:

- Eliminate the 1-hour version of the unit.
- Provide more instruction and detail such as an overview of the unit, objectives for the unit, material lists, recommended room arrangements, responses to common questions, and explanations of key terms and troublesome concepts.
- Include activities that involve actions other than reading and discussing.

- Identify articles for teachers to read prior to the workshop to ensure that they are prepared for the discussions.

Additional Suggestions

Although most of these suggestions for improving the GMO unit represent the opinion of a single reviewer, all are worthy of consideration:

- Make the learning materials (including articles, illustrations, and handouts) available online to allow for downloading and duplication for classroom use.
- Place more emphasis on superweeds to help teachers understand how this phenomenon could occur and the possible ramifications.
- Include recommendations for the formative and summative assessment of learning outcomes.
- Include strategies for incorporating activities with the online text and the video.
- Provide more time for wrap-up.
- Encourage the professional development provider to survey the teachers at the beginning of the workshop to determine how many already teach some aspects of GMOs to their biology students. These teachers might be able to share effective activities they have used.
- Include a brief listing of the pros and cons of GMOs to help the professional development provider prepare to lead a discussion of this controversial topic.

GMO Activities

Forty percent of the reviewers reported that the activity instructions were *very* clear and easy to follow, and 50% reported that the instructions were *somewhat* clear and easy to follow. One reviewer asserted that the instructions unclear about when to show the video or what parts of the video corresponded to the various activities. Half of the reviewers indicated that the activities were very interesting, and 40% indicated that the activities

were somewhat interesting. The reviewers suggested that media coverage of the topic of GMOs has heightened interest.

Nearly all (90%) of the reviewers reported that the activities would help teachers better understand the concepts addressed in the unit. They reported that the interactions between teachers would contribute to a greater depth of understanding of the issues provided that teachers adequately prepare by reading and studying. Forty percent of the reviewers indicated that the activities are about the right level of difficulty, whereas another 40% indicated that the activities are challenging but feasible.

Comments Related to Specific Activities

Coming Attractions (I.1)—Three reviewers reported that they would use the Coming Attractions activity, and 2 reported that they would not. One reviewer described the activity as an informal vocabulary quiz. One reviewer suggested a variation that involved bringing to class several examples of processed foods or other products that contain the genetically modified ingredients Bt and non-Bt corn and asking the participants to try to detect their presence and distinguish between the 2 types (the 2 types cannot be distinguished visually, but can be distinguished using certain assays). The reviewers' recommended time allocation for this activity ranged from 10 to 15 minutes.

What's the Difference? (I.2)—Six reviewers reported that they would use the What's the Difference? activity, and 2 reported that they would not. One reviewer believed the activity provided a good review of the important concepts of the GMO unit, and another reviewer indicated that the activity reinforces the terminology teachers need to understand genetic engineering. Several reviewers suggested increasing the time allocation for this activity to 40 or 50 minutes.

Catch-Phrase (I.3)—Five reviewers reported that they would use the Catch-Phrase activity, and 3 reported that they would not. One reviewer who believed that the rules for the activity were faulty stated: "The team that holds the potato when the timer goes off receives 1 point. A nonmotivated team could simply hold on to the potato for the duration of the

game and win 1 to 0 without making any attempt at playing the game. Perhaps the game was meant to be like hot potato where the object is not to have the potato at the end of the round. This approach would make more sense and also explain the use of a potato as a prop." The reviewers suggested allocating 25 to 30 minutes for this activity.

GMO in the Classroom (I.4)—Four reviewers indicated that they would use the GMO in the Classroom activity, and 1 reported that he would not. The reviewers' recommended time allocation for this activity ranged from 10 to 30 minutes.

Total Recall (I.5)—The number of reviewers who reported that they would not use the Total Recall activity was greater than the percentage who reported that they would (5 and 2 respectively). Some reviewers criticized the activity as simply an informal quiz in a competitive format. The reviewers recommended allocating 30 minutes for this activity.

Clone-It-Yourself (II.1)—Most (6) reviewers indicated that they would use the Clone-It-Yourself activity. The reviewers generally liked this relatively simple activity because it is easily adaptable for use with secondary school biology students and, according to one reviewer, provides an opportunity to address misconceptions. In contrast, one reviewer who opposed using the activity was concerned that it required more working knowledge of the cloning process than most teachers possess. One reviewer suggested varying this activity by assigning groups of participants to address different steps in the cloning process and present the steps to the larger group in order. Another suggested variation engaged the participants in creating 3-dimensional models of the steps. The reviewers' recommended time allocation for this activity ranged from 20 to 90 minutes.

Troubleshooting Cloning Experiments (II.2)—Sixty percent of the reviewers indicated that they would use the Troubleshooting Cloning Experiments activity, and 30% indicated that they would not. One reviewer who did not want to use the activity was concerned that it required more working knowledge of the cloning process than most teachers possess. Yet another reviewer stated, "Unfortunately, many of the correct solutions involve simple mistakes in protocol, not major departures from technique." The reviewers' recommended time allocation for this activity ranged from 30 to 45 minutes.

Making a Recombinant Product (II.3)—Four reviewers reported that they would use this activity and 2 indicated that they would not. One reviewer considered the activity's approach to the topic creative, but another reviewer was confused by the instructions. One reviewer suggested presenting the activity as a homework assignment. The reviewers' recommended time allocation for this activity ranged from 45 to 60 minutes.

Daffodils and Bacteria (II.4)—Two reviewers indicated that they would use the Daffodils and Bacteria activity, and 2 indicated that they would not. The reviewers who did not like the activity complained that it overemphasized vocabulary and underemphasized conceptual understanding. One reviewer remarked, "It involves a level of detail not essential for understanding the basic process of genetic engineering." Yet another reviewer commented: "It is doable but pointless. You can not look at cards with the words 'lycopene', 'phytoene,' and 'phytoene desaturase' and derive the order. You either know it or you don't." The reviewers' recommended time allocation for this activity ranged from 10 to 20 minutes.

Two Short Debates on the Pros and Cons of GMO (III.1)—Half of the reviewers indicated that they would use the Two Short Debates activity; none reported that they would not. The reviewers recognized the potential of the debates, but one stressed the importance of teacher preparation to ensure that the debates are based on facts rather than conjecture or ill-informed opinion. The reviewers recommended allocating 20 minutes for each debate.

Transgenic, Selected, or Just Naturally Odd (III.2)—Half of the reviewers reported that they would use the Transgenic, Selected, or Just Naturally Odd activity; none reported that they would not. The reviewers did not suggest any changes. The reviewers recommended allocating 30 to 40 minutes for this activity.

Human Cloning Issues (III.3)—Four reviewers indicated that they would use the Human Cloning Issues activity; one opposed doing so. One reviewer recommended that the developers provide more guidance to help the professional development provider effectively lead the discussion. The reviewers recommended allocating 30 minutes for this activity.

Genetic Engineering Versus X-Rays (IV.1)—Slightly more reviewers would use the Genetic Engineering Versus X-Rays activity than would not (30% and 10%, respectively). The reviewers made no comments or recommendations regarding this activity.

GMO and the Global Economy (IV.2)—Three reviewers indicated that they would use this activity; one opposed doing so. The reviewers made no comments or recommendations regarding this activity.

It's the Law (IV.3)—An equal number of reviewers indicated that they would use the It's the Law activity as indicated they would not (30% for both). One reviewer liked the activity's approach, but recommended providing more guidance and background information. Another reviewer echoed this sentiment, suggesting that the professional development provider might not have enough information to challenge misconceptions. Another reviewer commented that the activity was not very realistic and recommended presenting this activity as a homework assignment. Yet another reviewer indicated that the activity was too open ended to be effective.

The reviewers provided little feedback on the 2 homework assignments GMO in the News! and Botany of Desire.

General Suggestions

The reviewers made a wide variety of suggestions regarding the GMO activities in general. Although these suggestions do not represent patterns in the data (i.e., in most cases only one reviewer made each suggestion), most warrant consideration:

- Provide more detailed instructions and support materials to enable the professional development provider to effectively lead the activities.
- Prepare teachers to engage in informed debate by assigning research homework that develops background knowledge prior to discussions.
- Indicate the objective of each activity.

- Be sensitive to the fact that teachers can feel intimidated by other teachers, particularly when engaging in competitive games.
- Avoid independent reading activities during the workshops.
- Utilize activities that explore complex concepts along with activities that require fact recall or focus on vocabulary.
- Focus on the science concepts underlying GMOs rather than the use of GMOs or the politics surrounding their creation.
- Include more lab activities. Human Cloning Issues, Genetic Engineering Versus X-Rays, GMO and the Global Economy, It's the Law, GMO in the News!, and Botany of Desire are all read, watch, listen, and discuss opportunities.
- Provide more activities that allow teachers to engage in the experience of discovering the concepts for themselves.
- Ensure that the activities can adapted for use with secondary school students.
- Indicate which parts of the video correspond to each activity.

Other Activities

Some of the reviewers suggested the following activities, which could be incorporated into the unit.

- Assign groups of 3 or 4 to design a GMO. Ignoring the scientific complexity of the task, the groups should decide which characteristics the GMO has and answer the following questions: "What problems or consumer demand is the GMO designed to satisfy? What non-GMO would be in competition with this product? Who or what industry stand to gain by your product? Who stands to lose? How will you address concerns and opposition?" Each group then creates a poster that advertises and markets its GMO (and addresses the questions).
- Begin the GMO unit by engaging participants in research on the currently available foods that contain GMOs using the web site http://www.truefoodnow.org/

gmo_facts/product_list/. Participants could personalize the experience by analyzing their own cupboards for foods containing GMOs and comparing the results.

In addition, one reviewer suggested that project staff consult the text *Classroom Assessment Techniques: A Handbook for College Teachers*[1] for strategies that could be incorporated into activities that professional development providers could use to assess teachers' background knowledge.

[1]Angelo, T.A. & Cross, K.P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed.). San Francisco: Jossey-Bass.

Comparative Evolution Activities

Most of the reviewers (6) reported that the comparative evolution activities were *not very* or *not at all* clear and easy to follow. Those reviewers who believed that the activities were not very clear and easy to follow pointed out that the materials provided were not really activities but a series of discussion questions. In addition, the reviewers expressed concern over the lack of a recommended sequence or timeline. One reviewer remarked: "These activities would be the most difficult to implement in a professional development workshop. Much more detailed directions and materials are needed for a professional development provider to implement these activities unless he or she devoted an enormous amount of time in writing and developing classroom-ready experiences for teachers." Another reviewer stated: "In most cases, the suggested activities are not professional development provider friendly. They need to be fleshed out with more direction and include teaching materials." Several reviewers indicated that they preferred the format of the activities for the genomics and GMO units.

Most reviewers reported that the activities were *not very* or *not at all* interesting (5 and 1, respectively). Several reviewers commented that the activities were much less engaging than the activities for the genomics and GMO units (particularly the activities under Goal 1). The comparative evolution activities comprised, for the most part, review or discussion questions that represent a traditional, academic approach which does not employ the team-oriented, inquiry-based, and hands-on instructional techniques that characterize high-quality professional development activities. The reviewers emphasized the importance of the activities providing professional development provider with opportunities to model effective instructional techniques and criticized the fact that the comparative evolution activities did not do so.

Slightly more reviewers (60%) reported that the activities would, at least to some extent, help teachers better understand the concepts addressed than reported that the activities would not. Although the reviewers generally commended the activity questions as thought provoking and open ended, they criticized the materials for not providing any hands-on

inquiry-based activities. They were also concerned that too little background information was provided for the professional development provider. One reviewer commented: "Unless [the professional development provider] has a fairly good understanding of the concepts presented in the video and written materials, most of the questions provided may just point out to them how little they understand. I think more scaffolding is needed that builds from most beginning teacher's content knowledge to this level of comprehension." Other reviewers suggested that the activities were not sufficiently interactive for teachers to construct their own understanding of the topic and recommended that the developers redesign the activities to include more hands-on activities and teacher interaction.

The reviewers were divided on their opinions of the activities' level of difficulty. Four reviewers reported that the activities were challenging but feasible, 4 reported that the activities were at the right level of difficulty, and 2 reported that the activities would be relatively easy for most secondary school biology teachers. The reviewers reported that biology teachers' knowledge of comparative evolution varies widely and asserted that professional development providers must adopt a flexible approach to the topic. The reviewers' primary criticism of the activities' content was the provision of more detail than necessary to grasp the big ideas of comparative evolution. One reviewer remarked, "The high level of nitty gritty seems at the expense of basic concept understanding." Another reviewer commented: "It's not that the activities are difficult. The directions are diffuse and lack a focus. It's not that the participants couldn't do them, but that they wouldn't know what they've done once the activity is completed. How does it relate to the concepts? Also, answering lower order thinking questions is not an activity that will assure learning of difficult concepts."

Comments Related to Specific Activities

The reviewers had difficulty identifying specific activities they would use primarily because the materials identified only a few distinct activities, focusing instead on discussion questions that fell far short of what the reviewers considered activities. Some of the discussion questions had the potential to serve as the basis for activities, but reviewers

commented that developing the activities would require considerable effort on the part of the professional development provider. The reviewers were most comfortable with the activities that involved creating trees. One reviewer noted: "My favorite activity has the students creating trees using molecular and physical traits. It emphasizes that science is a self-correcting, self-improving discipline. Scientists who examine data from 2 different sources may come to different conclusions. These differences force scientists to look at their work critically in order to resolve differences." A few reviewers commented on other discussion questions or activities. This section of the report identifies the questions or activities by the first few words and the goal.

Here are 4 taxa of animals . . . (Goal 2)—This activity, more than most, met the reviewers' expectations for a professional development activity. One reviewer remarked, "I think it is important that teachers be able to construct trees based on DNA sequences and other characteristics." One reviewer recommended allocating approximately 30 minutes for this activity.

A dentist transmitted HIV . . . (Goal 2)—The reviewers indicated that this question could be transformed into activity with additional structure and information. They stressed the importance of including the necessary data for interpretation rather than requiring the professional development provider to gather or create the data. One reviewer reported that the question was a relevant example of the value of trees taken from the news media. Another reviewer said: "I like this activity because it gives students an authentic situation upon which they can [relate] new knowledge. It shows students that this content matters and has some application for their world." One reviewer recommended allocating approximately 15 minutes for this activity.

Researchers such as Dr. Philip Gingerich . . . (Goal 2)—One reviewer who particularly liked this question commented, "This is a great story about the nature of science (conclusions in science are tentative and subject to modification as new evidence is accumulated) and it emphasizes the value of multiple lines of evidence (morphological and molecular) in establishing the validity of explanations."

Give the participant a hypothetical cladogram . . . (Goal 2)—One reviewer remarked: "The construction of a cladogram from DNA data is a great activity incorporating kinesthetic and visual components of learning, but there is nothing here to give a feel of what is expected of the learner. Constructing 2 separate trees based on 2 different types of data is a great start, but there is little here to assist participants in knowing how to construct the tree. What kind of molecular data? DNA fragments? Similar enzymes? RNA's? What kind of physical characteristics?"

Does the Florida HIV case imply . . . (Goal 3)—One reviewer stated, "This is a good practical application example."

Human Evolution: How does the use of . . . (Goal 4)—One reviewer commented, "It is important to include activities involving human evolution."

Emerging Infectious Disease: How can we use . . . (Goal 4)—One reviewer remarked, "The current concern with SARS reinforces the need to discuss the emergence and spread of pathogenic organisms."

Other Suggestions

The following suggestions were made by individual reviewers.

- Provide an in-depth response to every question (because the content background of professional development providers varies significantly).
- Provide a video guide to answering the questions.
- Convert as many of the discussion questions as possible to activities that better engage the participants. Provide activities that allow participants to explore the new concepts, use them for problem-solving, and interact with peers to develop a broad understanding of comparative evolution.
- Provide activities that (a) involve the use of molecular data (DNA and amino acid sequences) to compare organisms (whales and hippos, bats and birds, pandas and polar bears, and so on), (b) engage teachers in constructing phylogenic trees, and

(c) help teachers understand the characteristics that differentiate and characterize the 3 domains.

- Provide at least one activity that professional development providers can use at the beginning of the professional development session to gain a sense of the prior knowledge of the teachers (e.g., a K-W-L activity).
- Ensure that activities stress the big idea that modern classification systems organize living things into a branching tree based on their ancestral or evolutionary relationships. This idea supplants a view commonly held by many teachers that classification is an artificial or contrived hierarchal system based merely on similar observed characteristics with little attention given to evolutionary relationships.

Other Activities

The reviewers made these activity suggestions:

- Create a family of fictitious animals (e.g., nematodes? turbellarians?) and assign a group the task of constructing a cladogram using their physical characteristics. Form another group to construct a cladogram using use the fictitious animals' DNA fingerprints. Ask a spokesperson for each group to describe and defend the construction and lead a discussion of the similarities and differences.
- Organize a field trip to the zoo and ask groups of participants to photograph (or sketch) the variety of animals of various types (e.g., bears, primates, felines, etc.) and write the scientific names of the animals on the back of the pictures. Arrange the pictures in a cladistic tree and flip the pictures over to reveal the genus and species. Lead a discussion of the question: Is it possible to discern relatedness based on the scientific names? If a field trip is impractical, take a virtual field trip by visiting Internet sites.

Overall

The data collection instrument completed by the reviewers required them to rate the unit course outlines and activities with the understanding that all 13 units in the Rediscovering Biology series will include similar materials. The reviewers outlined a wide variety of possible uses for these unit course outlines and activities, including professional development sessions and content certification and renewal courses through colleges and universities. The reviewers' comments include these:

> "After viewing each video, I would use no more than 3 activities. The first would be a simple vocabulary/question session to insure content understanding. Then I'd use a 30- to 45-minute activity to underscore the important concepts, preferably a lab-oriented activity that allowed participants to underscore the important concepts, preferably a lab-oriented activity that allowed participants to handle a manipulative—some sort of kinesthetic learning activity that allows more than just a pencil-paper response. Allow participants to see color changes, or lab results that reinforce the points of the lessons. The last activity would be a wrap-up that reinforces the major ideas."

> "In addition to professional development opportunities for secondary school biology teachers—which might be part of a class offered for university credit—I would also use one or more of the video sequences with the accompanying activities as part of a science methods class for future science teachers."

> "I would use most of the activities in lengthy professional development setting such as a 3-hour block of time where the time is given to really discover the concepts."

> "I would use these activities in 3-credit university courses, Nature of Science and Evolution and Genetics/Biotechnology, and in follow-up professional

development workshop sessions. These courses and workshops are collaboratively designed by university professors, teachers, and curriculum specialists to enable biology teachers to implement instructional units developed around Delaware's Science Content Standards and Performance Indicators. Activities selected for the courses upgrade subject matter content, model acceptable pedagogy, and give teachers skills and confidence in implementing the unit's learning activities. Teachers are provided with most of the instructional materials and lab apparatus necessary implement the activities in their classrooms. The Rediscovering Biology activities I select, in most cases, would be those that relate directly to Delaware curricular units."

"I would combine these activities with the video and text in a sequence that both builds on teachers' experiences and content knowledge and utilizes a variety of reading, writing, discussion, and hands-on activities."

"It is always a good idea for students to examine their preconceived notion before they read a chapter or view a video. Some of the activities are discussion prompts which I would use leading into an activity. The best activities require students to examine a concept, analyze the context of the concept, reapply their understanding to a new situation, and test their knowledge through peer review."

When asked for suggestions for professional development providers preparing to conduct a workshop or study group using the unit course outlines and activities, many reviewers stressed the importance of being very familiar with the content. The reviewers offered these suggestions:

- Determine the level of experience and background knowledge of the teachers before or at the beginning of the session.
- Familiarize yourself with the applications of the materials to local curricula and standardized tests.

- Remember the needs of your audience and the needs of their audience. Design workshops use materials that can be utilized in the classroom.
- Adjust the time allotted for activities to meet the needs of teachers.
- Ensure that you have all the equipment, reference materials, worksheets, and answer keys well in advance.
- Attempt the activities yourself before conducting them with a group.
- Do not hesitate to stop the video and emphasize content that will be the focus of a later discussion or activity.
- Ask participants to provide feedback on their experiences.

The vast majority (7%) of the reviewers reported that the activities were suitable for an in-service workshop, but most indicated that the professional development provider would need to select activities that fit in the available timeframe. Others stated that they would augment the activities with some that employ a hands-on, inquiry-based approach. The reviewers were less enthusiastic about the suitability of the materials for a formal distance learning course (2 of the reviewers had little experience with distance learning and did not feel qualified to comment). Three reviewers reported that the all of the materials were suitable for a distance learning course and 4 indicated that only some materials were. The reviewers observed that the effectiveness of some activities is dependent upon interaction among participants, which can best be achieved in person. Forming local study groups or online discussion groups are possible strategies for promoting such interactions, but these strategies might be difficult to implement.

Many reviewers believed that the professional development activities did not employ effective pedagogical methods and did not model the instructional practices teachers are encouraged to use in the secondary school biology classrooms. A primary concern was the lack of hands-on, inquiry-based activities that help participants construct an enduring understanding of the concepts—the reviewers considered the activities in the genomics and

GMO units to be better that the activities in the comparative evolution unit in this regard. The reviewers' comments included these:

> "Good pedagogy addresses a variety of learning styles. The video appeals to auditory and visual learners. Little is done for the kinesthetic learner. Any activity that required manipulation of some three dimensional object would help kinesthetic learners, adult or adolescent. It would also be wise to address adolescent learning needs, since many teachers attend workshops to acquire activities, information, and ideas that can be incorporated into their current curriculum."
>
> "I would say that the best method, regardless of age, is solid activities that allow the listener time to DISCOVER the concepts. This is the method they are asking their students to use in the classroom!"
>
> "Activities MUST be both challenging and engaging if they are to promote adult learning."
>
> "Good pedagogical methods take a variety of learning styles into account. It is best to incorporate video, discussion, and hands-on activities to engage adults as well as kids."
>
> "The activities that do the following employ good pedagogy: connect to the lives and experiences of the teachers, break difficult material down into manageable pieces and then build on it, provide multiple avenues for learning (kinesthetic, visual, auditory, etc.), address common areas of misconceptions, provide a means for developing classroom material based on this work, and make the material more interesting and engaging."

Recommendations for the Unit Course Outlines and Activities

RMC Research makes the following recommendations based on the feedback provided by the reviewers:

- Enhance the unit course outlines with objectives, activity descriptions, setup instructions (including recommended room arrangements), glossaries, responses to frequently asked questions (and common misconceptions), handout masters, and other resource materials. Because the unit course outlines must accommodate professional development providers with varying degrees of content knowledge and professional development experience, more information is better that too little.
- Increase the time allocation for each unit and allow time for administrative functions and closure.
- For each portion of each unit course outline, provide references to the corresponding segment of the video.
- Increase the number of hands-on inquiry-based activities that model the instructional approaches teachers are encouraged to practice in their classrooms.
- To the extent possible, include some optional wet-labs appropriate for a typical secondary school science lab.
- Include formative assessment questions or instruments that enable professional development providers to assess the teachers' level of understanding.

Other General Suggestions

The reviewers made a wide variety of suggestions regarding the unit course outlines and activities in general. Although these suggestions do not represent patterns in the data (i.e., in most cases only one reviewer made each suggestion), most warrant consideration:

- Provide a preassessment activity for each unit to help professional development providers gain an understanding of the level and range of the teachers' backgrounds.

- Provide the addresses of a web site that teachers and professional development providers can access for additional information on each topic. Offer a separate section of the web site for professional development providers and ensure that they can easily download instructional materials.
- Develop a separate workshop for professional development providers.

Appendix A
Position Announcements

Appendix B
Application Forms

Appendix C
Unit Response Forms—Genomics

Appendix D
Unit Response Forms—Genetically Modified Organisms

Appendix E
Unit Response Forms—Comparative Evolution

Appendix F
Overall Response Forms

Appendix G
Course Guide and Activities Response Forms