FEATURE ARTICLE

Using the FRAMER Scaffold Design Framework to Support Students in Learning & Understanding Biology

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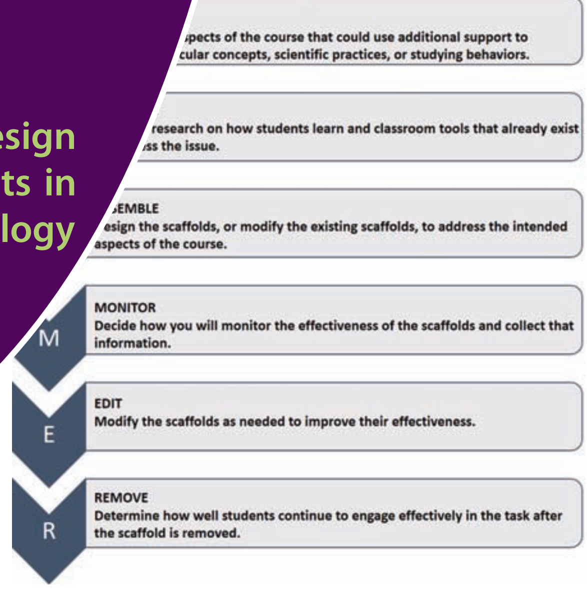

Abstract

Students need support to learn the core ideas, practices, and crosscutting concepts that make up the field of biology so that they can both be successful as biologists and make informed decisions that require biological understanding. One way instructors can support students in these endeavors is to provide students with specific scaffolds the instructors design to structure students' performance on a task or engagement in a behavior. With the focus on both scientific concepts and practices, instructors may also need support to be able to develop scaffolds that align with suggested best practices. I offer a framework, referred to as FRAMER, and suggestions for instructors interested in developing scaffolds for biology courses, and provide an example of a successful scaffold implementation in an undergraduate biology course.

Key Words: *scaffolds; introductory biology; undergraduate students; life science; metacognition.*

○ Introduction

At the undergraduate level, the *Vision and Change* report (AAAS, 2011) outlines five core concepts and six core competencies of disciplinary practice that students should learn and be able to do. These core concepts and competencies are similar in scope to the *Next Generation Science Standards* (NGSS Lead States, 2013), and both focus on students being able to engage in scientific practices and reasoning to be able to solve problems. Regardless of whether students plan to pursue careers in biology, they will need to have a foundation of understanding to make sense of the science they will encounter in their lives to make informed decisions (National Research Council, 2012). Therefore, all students in biology classes need to learn biological concepts and to think within the increasingly interdisciplinary nature of the field by considering core ideas, practices, and crosscutting concepts (AAAS, 2011; National Research Council, 2012; NGSS Lead States, 2013), but they will need support to be able to do so.

> *"A scaffold is a structure that supports learners until they can perform a task or produce a behavior on their own."*

Biological concepts typically belong to one of three levels of organization: macroscopic (organismal), microscopic (cellular), and molecular (biochemical) (Marbach-Ad & Stavy, 2000). While experts can easily integrate these three levels, students often focus on only one level at a time and have difficulty arranging topics into correct levels and making connections across these levels (Bahar et al., 1999; Marbach-Ad & Stavy, 2000). Therefore, students often need support to learn how to reason across levels of organization and to integrate separate parts into dynamic systems. In addition, students may recognize the need to change the way they study or think about these concepts, but may not know what steps to take to improve their understanding (Dye & Stanton, 2017).

While support for students can take many forms, one way is through instructor-designed scaffolds that focus on particular concepts or practices. However, developing effective scaffolds can be difficult, and aligning them with best practices in a changing field may be daunting. While the *Vision and Change* initiative has led to changes in programs and curricula (AAAS, 2015), widespread adoption has been somewhat slow due to some of the challenges associated with change (McLaughlin & Metz, 2016). Previous authors have provided excellent information regarding why *Vision and Change* matters, with suggestions for how undergraduate instructors can begin to incorporate the framework. For example, McLaughlin and Metz (2016) suggested that instructors start with small changes, use existing resources when available, reach out to others for questions and support, get administrative support to make changes, keep doing what is already successful, and incorporate existing literature. Here, I add to those suggestions by offering the FRAMER scaffold design framework with

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an extended example to support instructors in developing scaffolds to address the particular needs of their students using known best practices. FRAMER is an acronym for the steps of the process: Focus, Research, Assemble, Monitor, Edit, and Remove.

○ What Is a Scaffold?

A *scaffold* is a structure that supports learners until they can perform a task or produce a behavior on their own (Pea, 2004). This structure helps a student accomplish a task or solve a problem with support and is removed when the student no longer needs it (Wood et al., 1976; Puntambekar & Hubscher, 2005). Scaffolds help learners by providing guidance and assistance to support them in moving beyond what they currently know to reach more advanced understanding.

When Wood et al. (1976) first presented the idea of scaffolding, they focused on one-on-one interactions of tutors with children to support them in achieving higher levels of performance than they would have been capable of on their own. Over time, this definition of *scaffolding* has expanded to include various types of tools that support student learning, but the concept is still connected to the original idea of supporting students to achieve higher levels of performance (Davis & Miyake, 2004; Puntambekar & Hubscher, 2005). Scaffolding now includes types of support such as technology in the classroom, as well as elements of curriculum designed to support students in learning particular concepts (Puntambekar & Hubscher, 2005).

Various types of scaffolds have been used to support students in learning science. Some examples include a 3-D game-based curriculum to teach water quality concepts (Barab et al., 2009), software to help students learn to use concept maps (Novak, 2003) or understand evolution and natural selection (Zembal-Saul et al., 2002), and an online assignment with in-class discussions to support undergraduate preservice teachers in learning to use formative assessment to evaluate students' ideas (Forbes et al., 2015; Sabel et al., 2015). Scaffolds may also help students with learning to study, such as through enhanced answer keys with added reflection questions to support undergraduate biology students as they learn to engage in metacognition and consider their own understanding (Sabel et al., 2017a). Alternatively, scaffolds may provide students with a framework to help them consider and make decisions regarding socioscientific issues (Dauer & Forbes, 2016; Dauer et al., 2017; Sabel et al., 2017b). An important consideration with any scaffold is that students may need multiple exposures to topics to retain the information and reach deep understanding (Smith & Knight, 2012), and that students may exist along a continuum of readiness to engage in certain learning practices, such as metacognition (Stanton et al., 2015). While many other examples of scaffolds exist, the scaffold that each individual instructor chooses to develop will depend on the particular needs of their students given the context and content of the course.

Here, I present FRAMER and offer suggestions for developing scaffolds based on experiences with designing, implementing, and evaluating them in undergraduate biology courses. These suggestions are intended to guide instructors in their own development of scaffolds to address their students' needs. Following the steps and guidelines, I have provided an extended example of a scaffold that was designed and tested using this framework. This example is intended to put the FRAMER steps into a specific context to help instructors see how to apply each step of the framework.

○ Steps to Developing Effective Scaffolds

The acronym FRAMER indicates each of the steps of scaffold development: Focus, Research, Assemble, Monitor, Edit, and Remove. See Figure 1 for a simplified version of these steps.

1. **Focus: Consider the aspects of the course that could use additional support to enhance particular concepts, scientific practices, or studying behaviors.**
   - What skills or scientific practices do your students struggle with or need support in developing?
   - If your students are not currently succeeding at particular scientific practices or engaging in desired learning behaviors, what steps could you take to support that development?
   - Do you currently have embedded activities that could use additional structure to support students as they learn to engage in a skill or task?
2. **Research: Consider research on how students learn and classroom tools that already exist to address the issue.** Conduct searches and ask colleagues for resources that already exist to address the issue you have identified. It may be that existing scaffolds could be utilized as is, or with little modification, in your classroom. If you do need to build a new scaffold, consider the support and resources you will need to most effectively engage students in the task or behavior. You may need to conduct additional literature searches to identify what is already known about the specific task or behavior you are trying to scaffold so that you can approach it with best practices.
3. **Assemble: Design the scaffolds, or modify the existing scaffolds, to address the intended aspects of the course.** Consider the best way to deliver this to students. Perhaps it is a worksheet or a flipped class period so that you can directly help students as they engage in the process. In the example below, the scaffolds are structures that students can use outside of class to help with studying. The format may look very different for each type of scaffold you develop. Be sure to determine what results you want to achieve and consider how you will assess the success of the scaffolds.
4. **Monitor: Decide how you will monitor the effectiveness of the scaffolds and collect that information.** It is important to consider how you will determine whether the scaffold had the intended results. The first implementation of the scaffolds may not achieve the results you intend, and revisions and variations to the scaffolds will likely be necessary. Collecting information on how students used the scaffolds or the extent of their effectiveness will inform future iterations. For example, you might survey students on their use of the scaffolds or examine assignment products to gauge student understanding.
5. **Edit: Modify the scaffolds as needed to improve their effectiveness.**You will likely determine some improvements you will want to make after the first implementation. You may also find that you will need to make changes even as you are in the

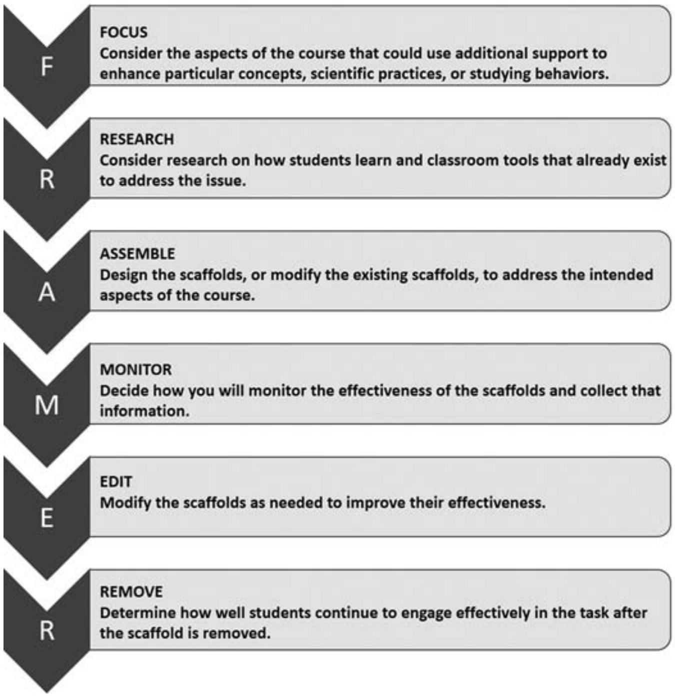

Figure 1. The FRAMER scaffold design framework.

midst of the first implementation, or that you need to start over from scratch. It is common to go through multiple iterations before you find a solution that works well for most students. Continue to make improvements to each scaffold until you have a product that works well for your intended outcome.

6. **Remove: Determine how well students continue to engage effectively in the task after the scaffolds are removed.** A scaffold is truly successful only after it has been removed and the student is still able to continue performing the task or behavior without the support. Keep this longer-term goal in mind as you design and revise your scaffolds. The length of exposure to a scaffold will depend on the complexity of the task or behavior. If you provide a scaffold during a unit, you should be able to test how students do on that task when the scaffold is removed for the exam. If, as in the example below, the scaffold is something that requires longer-term exposure, you may want to work with colleagues to determine how students do in subsequent courses that require similar skills or behaviors.

○ Example of Scaffolds & the Design Process

Although scaffolds can take many forms, the example presented here focuses on engaging students in metacognition as an example of the entire scaffold-development process. The scaffolds in this example consisted of post-assignment enhanced answer keys with added reflection questions that served to support undergraduate students in considering their own understanding of biological concepts, to engage in metacognition and generate feedback for themselves on their progress, and to take steps to enhance their understanding and performance in the course. This example was chosen because it utilized the FRAMER framework during development of the scaffolds and analysis of their effectiveness. Readers can seek out additional information about the study and its findings that are beyond the scope of this article. Rather than report the results of the study itself, the purpose of using this example is to show readers how the FRAMER framework was used throughout the development and evaluation of the scaffolds. See Sabel et al. (2017a) for more information on the scaffold design, data collection, and analysis of the effectiveness of these scaffolds.

○ Course Context

The course of interest was one section of a required introductory biology course for students pursuing a life science major. The course consisted of three 50-minute meetings per week, and the section enrollment was 98 students (primarily sophomores). Students participated in active-learning lecture and in small-group discussions and completed three homework assignments and one exam for each of the four units. The assignments consisted of open-response questions that asked students to take concepts discussed in class and use them to interpret data, engage in scientific practices, and apply concepts to new situations presented in case studies. Exams were in a short-answer and essay format and focused on students' abilities to integrate concepts and transfer information to new and different contexts.

Enhanced answer keys. All students in the course had access to enhanced answer keys after each assignment and exam was graded and returned to them. These began as simple answer keys that the instructors and learning assistants used to grade the assignments. However, as grading proceeded, all graders communicated about common issues and misconceptions they saw in the students' answers and modified the answer keys to include this information. They then added additional information they thought would be useful to help students further understand the question and answer, and occasionally included questions to prompt students to think about the topic in a different or more complex manner. These became enhanced answer keys in that they provided the ideal answer to the question and provided information to help students' conceptual understanding and to prompt them to think further about a topic.

○ Scaffold Design Process

1. **Focus: Consider the aspects of the course that could use additional support to enhance particular concepts, scientific practices, or studying behaviors.** The enhanced answer keys were a normal part of the course, but few students were using them. We wanted students to use them to consider their own understanding and engage in metacognition, but we recognized that many students would need additional support to begin using the answer keys in those ways. Therefore, we focused on particular ways we could support the students in recognizing the utility of using the enhanced answer keys and in using them to consider their own understanding.
2. **Research: Consider research on how students learn and classroom tools that already exist to address the issue.** We searched the literature for examples of scaffolds that students might use to review assignments or exams, to reflect in biology courses, and to engage in metacognition. We found that some

past work had examined the use of posting answers after an exam and how students used rubrics in a general sense (Andrade & Du, 2005; Lake & Chambers, 2009). We also examined a report by Soicher and Gurung (2016), who found that using exam wrappers with metacognitive questions did not increase students' metacognitive awareness over a control condition, at least not in a single semester. However, they suggested that longer exposure to the wrapper may be necessary to see an effect or to make it last. While these findings were useful to our consideration of the types of scaffolds we could develop, we did not find examples of specific scaffolds students could use as assessment tools of their own performance and understanding in the way we intended. Based on these findings, we determined that we would need to create new scaffolds for the intended purpose.

3. **Assemble: Design the scaffolds, or modify the existing scaffolds, to address the intended aspects of the course.** Based on our literature review and the particular skills we wanted to help our students develop, we decided to create a set of reflection questions they could pair with the enhanced answer keys to review their assignments. We primarily applied the literature regarding metacognition and reflection to develop the reflection questions.

Reflection questions. Based on our literature search, we wrote the reflection questions (see Figure 2) to prompt students to reflect on what they understood, what they needed to know to enhance their understanding, what they did not understand, and whether they understood the concept well enough to be able to apply it to a different situation (Wood, 2009). We focused on questions that would prompt students to reflect on their graded assignments using the enhanced answer keys and consider the three dimensions of metacognition as described by Grotzer and Mittlefehldt (2012). These dimensions include (1) "Intelligibility: Does the explanation make sense to me?"; (2) "Plausibility: Do I think that the explanation is a possible explanation?"; and (3) "Wide-applicability: Can I apply the explanation beyond the contexts in which I have learned it?" (Grotzer & Mittlefehldt, 2012, p. 82). We added these reflection questions to the enhanced answer keys following the first exam and throughout the remainder of the semester. A subset of interviewed students received the reflection questions before the first exam and instruction on their use (see below) as a way to distinguish the factors that influenced students' use of the reflection questions.

Instruction on scaffold use. Twenty students participated in interviews. In the first interview, they were asked about their study habits, metacognitive skills, and use of the enhanced answer keys. They also participated in "think-aloud" tasks in which they used an enhanced answer key to analyze a recent assignment and talked through their analysis of their performance and understanding of the concepts. A subset of students received the reflection questions and discussion on how they could use them. In the second interview, they were asked about their previous use of the reflection questions and the extent to which the previous discussion had influenced their use of the enhanced answer key and/or reflection questions.

Instructions:
1. Read through the entire answer key, even for questions that you got correct.
2. Reflect on how your answer aligned with the answer provided on the answer key.
3. Use the following reflection questions to think about what you know now and what you still need to learn more about to fully understand the topic.
4. Adjust your studying to focus on the gaps in your understanding.

Reflection questions:
1. Do all of the answers on the answer key make sense to you? If not, what steps can you take to make sense of the concepts in the answers?
2. Do all of the answers provided seem like possible explanations to you given what you know about the topic? If not, what steps can you take to reach a greater understanding of the topic and the explanation?
3. Could you apply the explanations to a different context other than the one in the assignment? If not, what steps can you take to advance your understanding of this topic and be able to apply the explanations to other contexts?
4. Do you feel like you have a complete understanding of the concepts from this assignment? If not, what steps could you take to increase your understanding?
5. What connections can you make from the ideas in this assignment to the previous content you have learned in class?
6. What could you have done differently before or while you completed this assignment to better understand the topic?
7. What are some possible questions you might see on an exam about this topic? What steps can you take to reach greater understanding to be able to effectively answer those exam questions?
8. If you were to explain the topics on this assignment to a friend, what would you say? How well would you be able to explain it? Where would you struggle?

Figure 2. Reflection questions added to enhanced answer keys (Sabel et al., 2017a).

4. **Monitor: Decide how you will monitor the effectiveness of the scaffolds and collect that information.** We wanted to examine whether students were using the reflection questions, how they were using them, and the extent to which they needed individualized instruction (as provided in the interviews) to see utility in using them. We administered three surveys throughout the semester: one at the beginning, one at midterm, and one at the end of the semester to see how students used the reflection questions and enhanced answer keys over the semester. We also collected grades at the end of the semester to determine how students who engaged with using the scaffolds performed in the course. We found that the enhanced answer keys helped students see their own mistakes and adjust their thinking to understand concepts better. The reflection questions helped students consider their own ideas and to adjust their thinking and studying behaviors. Finally, the instruction on scaffold use made students more likely to use the scaffolds. Students who used the scaffolds made changes to their studying as the semester progressed that indicated they were considering their own learning to a greater extent than earlier in the semester. For more details about these results, see Sabel et al. (2017a).

5. **Edit: Modify the scaffolds as needed to improve their effectiveness.** We identified two major areas for improvement after the first semester of implementation. First, the interviews provided evidence that students were more likely to use the scaffolds if they had individual instruction on their use. Unfortunately, it is difficult to provide individual instruction to each student in a large course. Therefore, we introduced the reflection questions in class and provided a video on the importance of engaging in metacognition and how to use the reflection questions within the first survey the students completed at the beginning of the semester. Preliminary analysis suggests that this presentation of the

instruction is effective for only a small subset of students. Therefore, ongoing work is exploring how to reach more students with the instruction and encourage them to use the reflection questions. Second, not all courses have the extensive enhanced answer keys that were provided to students in this course. Therefore, we wanted to explore how the scaffolds would work to accompany other course features. We are currently testing how these reflection questions work when paired with practice exams.

6. **Remove: Determine how well students continue to engage effectively in the task after the scaffolds are removed.** As metacognition is a developed skill, the scaffolds in this example were provided for the entire semester for sustained engagement. Therefore, scaffold removal can only be explored in subsequent courses the students take. In a longitudinal study, we are currently examining the extent to which students who used the reflection questions during the semester of use continue to engage in reflection as they progress through a biology major. Preliminary evidence suggests that those students who are more likely to use the reflection step in the introductory class are also likely to continue to engage in those behaviors in upper-level courses, even without the scaffolds. We are currently exploring how to engage those students who are not using the scaffolds in early semesters to see if reluctant adopters display different behaviors in upper-level courses.

○ Conclusion

I have provided a structure for developing new scaffolds to support students in new skills or content knowledge and have provided an example of scaffolds that were developed using this structure. Results from studies associated with these scaffolds indicated that instructor-designed scaffolds can help undergraduate students reach more complex understanding and generate and use their own feedback about their learning progress. Moving forward, new scaffolds must be developed to support students in the variety of efforts required within science learning environments. Importantly, the scaffolds themselves – as well as the environments in which they are implemented – will need to be flexible to support the various learners who will be using them and the learning environments in which they will be used. Students may require multiple exposures, and some may be readier than others to engage in particular practices (Smith & Knight, 2012; Stanton et al., 2015). These factors impact both the design of the scaffolds themselves and the information instructors will need to consider as they design and implement scaffolds.

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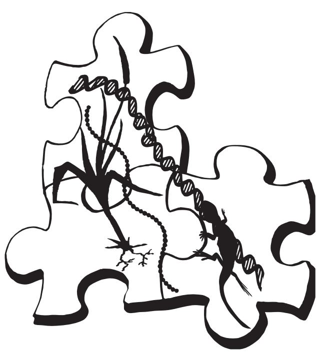

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- Communications will be directed to only the first author of multiple-authored articles.
- At least three individuals who have expertise in the respective content area will review each article.
- Although the editors attempt to make decisions on articles as soon as possible after receipt, this process can take six to eight months, with the actual date of publication to follow. Authors will be emailed editorial decisions as soon as they are available.
- Accepted manuscripts will be forwarded to the Copy Editor for editing. This process may involve making changes in style and content. However, the author is ultimately responsible for scientific and technical accuracy. Page proofs will be sent to authors for final review before publication at which time, only minor changes can be made.

continued

Writing & Style Guidelines

The *Chicago Manual of Style, 14th Edition* is to be used in regards to questions of punctuation, abbreviation, and style. List all references in alphabetical order on a separate page at the end of the manuscript. References must be complete and in *ABT* style. Please review a past issue for examples. Use first person and a friendly tone whenever appropriate. Use concise words to emphasize your point rather than capitalization, underlining, italics, or boldface. Use the SI (metric) system for all weights and measures.

NOTE: All authors must be current members of NABT or a charge of $100 per page must be paid before publication.

Several times a year the *ABT* has issues that focus on a specific area of biology education. Future focus issues will be published in the *ABT* and online at www.NABT.org. The editors highly encourage potential authors to consider writing their manuscripts to align with the future focus topics.

Thank you for your interest in *The American Biology Teacher*.
We look forward to seeing your manuscripts soon.

William McComas, Editor-in-Chief, ABTEditor@nabt.org
Valerie Haff, Managing Editor, managingeditor@nabt.org

Preparing Figure Artwork

General Requirements

- When your article is accepted, we will require that figures be submitted as individual figure files in higher resolution format. See below for file format and resolution requirements.
- **NOTE:** Authors should be aware that color is rarely used within the journal so all artwork, figures, tables, etc. must be legible in black and white. If color is important to understanding your figures, please consider alternative ways of conveying the information.

Halftone (photographic) figures

Digital files must meet the following guidelines:

- Minimum resolution of 300 DPI, though 600 DPI is preferred.
- Acceptable file formats are TIFF and JPEG.
- Set to one-column (3.5″ wide) or two-column size (7″ wide).
- If figure originates from a website, please include the URL in the figure caption. Please note that screen captures of figures from a website are normally too low in resolution for use.

Line art figures

- Minimum resolution of 600 DPI, though 1200 DPI is preferred.
- Acceptable file formats are TIFF, BMP, and EPS.
- Set to one-column (3.5″ wide) or two-column size (7″ wide).

If you have any questions, contact Valerie Haff at managingeditor@nabt.org.

Submitting *ABT* Cover Images

Submissions of cover photographs from NABT members are strongly encouraged. Covers are selected based on the quality of the image, originality, composition, and overall interest to life science educators. *ABT* has high standards for cover image requirements and it is important for potential photographers to understand that the required size of the cover image generally precludes images taken with cell phones, point-and-shoot cameras, and even some older model digital SLR cameras.

Please follow the requirements listed below.

1. Email possible cover images for review to Assistant Editor, Kathleen Westrich at kmwestrich@yahoo.com.
2. Choose images with a vertical subject orientation and a good story to tell.
3. Avoid cropping the subject too tightly. It is best to provide an area of background around the subject.
4. Include a brief description of the image, details of the shot (i.e., circumstances, time of day, location, type of camera, camera settings, etc.), and biographical information in your email message.
5. Include your name, home and email addresses, and phone numbers where you can be reached.
6. Please ensure that the image meets the minimum standards for publication listed below and has not been edited or enhanced in any way. The digital file must meet the minimum resolution of 300 pixels per inch (PPI)—preferred is 400 PPI—and a size of 8.5 x 11.25″. We accept TIFF or JPEG images only.
7. For exceptional images, the editors will also accept sharp, clear, color 35 mm slides. Submit only the original; duplicates will not be accepted. Be sure to clearly label slides with your name and contact information in ink. Contact Assistant Editor Kathy Westrich beforehand to discuss the possibility of submitting a 35mm slide or other non-digital format for consideration as an *ABT* cover.