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Book Review: Cell and Molecular Biology for Minors

Enjoy Your Cells Series: *Enjoy Your Cells*, *Gene Machines*, *Have a Nice DNA*, and *Germ Zappers*, by Fran Balkwill and Mic Rolph, 2002, Cold Spring Harbor Laboratory Press (Woodbury, NY); http://www.cshlpress.com/

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Elementary school students are fascinated by science. They are particularly excited about topics that are immediately relevant to them—topics around the human body and what it is made of, basic bodily functions, how and why they look the way they do, and why they get sick and how they get better. As such, science is a powerful tool for getting students excited about reading and for challenging them to apply their developing reading skills to deepen their understanding of topics that are of interest.

Author and cancer researcher Fran Balkwill and artist Mic Rolph have teamed up to bring these topics to children in their beautifully illustrated series *Enjoy Your Cells*. This series includes four books. *Enjoy Your Cells* introduces readers to "an amazing hidden world just beneath your skin. A world of living cells that work together to make you." *Gene Machines* introduces the concepts of genes and gene-based inheritance. *Have a Nice DNA* introduces "a very important chemical substance called Deoxyribonucleic Acid." Finally, *Germ Zappers* is a primer on the cells of the immune system and how they fight infection. The publisher recommends these books for children ages 7 and up.

In addition to reviewing the books ourselves, we gave them to 10 students from the San Francisco Unified School District to review. The students included three second graders: Angela (age 7), Felix (age 7), and Tony (age 7); three third graders, Makayla (age 8), Sandy (age 8), and William (age 9); two fifth graders: Molly (age 10) and Jordan (age 11); and one seventh grader, Quran (age 13). In addition, one student, Ryan (age 7), was given the books for his mother (an engineer) to read to him. Each of the readers, including Ryan's mother, provided written commentary on the books. This review attempts to capture the students' voices and opinions, their excitement, confusions, and questions that arose from reading the books.

Students are constantly bombarded with sound bites based in modern science. They are told that something is "in their genes," they hear tidbits of news releases about the Human Genome Project, genetic engineering, and human cloning, and they are confronted on a regular basis with disease, their immune systems, vaccinations, and antibiotics. These topics are interesting and relevant to students. They are also extraordinarily complex and abstract—the subject of entire college-level courses. Here the authors attempt to distill the essence of molecular and cellular biology and of immunology into digestible chunks. Nonscientist adults who read the series commented that the books present "rather complicated information in a straightforward, easy to understand manner" and that, for adults, the books provide a thorough refresher on their college biology classes taken many years ago. The challenge lies in presenting this abstract information in an accessible fashion to children, who at this age both struggle with the abstract and are full of misconceptions about how the world around them works. Books written for younger readers should end at a point where students are left wanting to learn more—not after having pushed the readers into information overload.

Authors writing a series of books always struggle with whether individual books in the series should stand alone. The *Enjoy Your Cells* series reads as if there is an intended order for the books, yet that order is not readily apparent. A clear order would help students build a linear understanding of the subject matter. Additionally, the authors who wisely uses repetition to strengthen student understanding, would then have the luxury of referring back to earlier topics and summarizing "take-home messages" rather than repeating complete topics. This helps students realize that what they read previously is relevant to the material they are currently learning, serving to tie the books and topics together in the students' minds. A concrete example of this is found in the treatment of DNA. DNA is introduced to students in three of the four books. In *Enjoy Your Cells* students are introduced to DNA as "a secret chemical code" in the chromosomes and informed that structurally DNA is a double helix that unzips to be copied and that it codes for proteins. *Have A Nice DNA* introduces DNA as "a very important chemical substance," and reports that chromosomes are made of DNA, that DNA is made of four nucleotides that pair according to specific rules, that structurally it is a double helix that unzips to be copied, that DNA codes for proteins, and that these protein recipes are called genes. In *Gene Machines*, students are once again introduced to DNA as "a marvelous molecule" that makes up chromosomes and told that genes are recipes for making proteins, that DNA is made of four nucleotides that pair according to specific rules, and that structurally it is a double helix that unzips to be copied. Both *Gene Machines* and *Enjoy Your DNA* go into further detail describing how the DNA code is translated

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into proteins. Despite this level of repetition, before reading *Have a Nice DNA* (and after having read at least one other book in the series), more than half of the students responded that they had never heard of DNA before. After completing *Enjoy Your Cells*, Makayla (age 8) asked, "What is DNA?" And after reading *Gene Machines*, Angela (age 7) stated, "I know that genes make proteins," but when asked why genes are important, she stated, "I don't know," and ended her report with the question, "What are genes?" One student was so overwhelmed by the complexity of the topic after reading *Enjoy Your Cells* and *Have a Nice DNA* that, on seeing the pictures of DNA in *Gene Machines,* he told his mother, "NO more! I can't take any more DNA."

Developmentally, students in the age range recommended by the publisher (7–10) are not ready to be learning about many of the specific details and abstract concepts in molecular biology. The *National Science Education Standards* (National Research Council, 1996), a commonly used guideline for science instruction, suggests gradually introducing these ideas. Before fourth grade (age 9) they limit ideas of inheritance and heredity to students' learning that plants and animals closely resemble their parents. The *Standards* also suggest introducing the study of cells between grade 5 (age 10) and grade 8 (age 14) and that, as students progress through this age range, they will begin to understand that genetic material carries information. Once in high school, students are able to incorporate more abstract knowledge. A compelling example of this is that students as old as 16 still have difficulty understanding the difference between a cell and a molecule. Many students believe that molecules are bigger than cells (Driver *et al*., 1994, p. 25), and some report that living systems are made up of cells but not molecules (molecules are associated with physical science) (National Research Council, 1996, p. 181). Some of this confusion is apparent in the writings of our student reviewers. Quran (age 13) was confused by the difference between DNA and cells—after reading in *Have a Nice DNA* that "97% of your DNA is pretty useless junk," he reported that the most interesting thing he learned is that "97% of your cells are useless." Molly (age 10) was also confused by the difference between DNA and cells. When asked how DNA works she replied, "It works by different cells connecting and working together to make more similar DNA cells. Those are called RNA cells." After reading the book, Ryan (age 7) wanted to know "Why is it so complicated?" and Makayla (Age 8) stated, "I did not understand a lot of the book."

Students reading the books struggled with the amount of information on each page and the layout of the information. A common complaint among adults who read the books was that the books use columns inconsistently. Some pages have columns that are intended to be read horizontally, and others vertically; one page is arranged in a circular fashion, with no order to the information presented (describing how genetic information is translated). Students reported becoming confused and frustrated as they reread the pages trying to determine the correct order for the information presented. Simpler pages with one key idea per page would make the books seem longer but would help students pick out the important ideas and focus on using the visual information on the page to reinforce and clarify the information they have just read.

When writing for this age range, authors also need to be careful about terminology. Just as the word *molecule*, discussed above, can introduce confusion, other tricky words should be used with caution. Unfamiliar descriptive words (such as skulking and waft) put the meaning of an easy-to-understand sentence in doubt and can be frustrating. They can be easily replaced with more familiar words so the student can focus on learning important science vocabulary (such as membrane, DNA, and lymph). The books also suffer by not defining key terms for young readers. Many of these are terms whose definitions adults take for granted. For example, defining DNA as a "secret chemical code" has meaning only if you know what a chemical is—many younger students do not. One way scientific terms have been defined clearly in books for young readers occurs in *The Magic School Bus* series. There the lead character, Ms. Frizzle, has the students in her classroom define key terms as reports—these papers authored by the students frame each page, so that readers may refer back to them as needed.

The books are most successful when they are very concrete. Most of the students who read *Enjoy Your Cells* learned that our bodies are made up of different types of cells and that these different cells have different functions. Some were also struck by their new understanding of size and scale—that we have so many ("one hundred million million") cells and that they are so small ("it would take 25 to cover the surface of a grain of sand"). However, after reading this page, Ryan (age 7) asked, "Aren't grains of sand all different sizes?" Similarly, William (age 9) reported learning in *Have a Nice DNA* that "1 million DNA strands can fit in a sentence [*sic*]. That is a lot." Other students latched onto topics that they found particularly interesting. Two girls were excited to have learned "how I was made." Felix (age 8) was fascinated by the realization that as you grow you get more cells, rather than your existing cells getting bigger. This is a big leap in understanding for a student this age, and this idea could have been emphasized more strongly in the book so that more students would have this realization.

Student comprehension of *Gene Machines* was very mixed. A couple of students were fascinated by the realization that "XX = girl and XY = boy" (Makayla; age 8), and others seemed to understand, as Molly (age 10) stated, that genes "make you the way you look." But William (age 9) was confused by the title, and that resulted in his leaving with a powerful misconception: "We are a gene machine. I didn't know that we are machines." As students in this age range are already struggling to understand the difference between living and nonliving things (Driver *et al*., 1994), this use of common biology jargon appears to have further confused a difficult subject for William. Finally, at least one student was confused by the similarity between the words "genes" and "jeans." This may have been compounded by the joke on page 5, "I'm wearing mine!" When Felix (age 8) was asked what your genes do, he reported, "You can wear them and do things."

The concept of genes is one that is really fascinating to this age group (7–10), particularly the difference between girls and boys and the similarities between identical twins. However, this book misses the chance to explain or teach to this age group by being too complex and trying to cover information that is not yet at their developmental level. Yet one page in particular (page 16) does a nice job by describing simply and visually the effects of some genes on eye color, hair color and texture, and skin color. This page is right on target for this age group. The more complex discussion of human cloning

could be an entire other book, and mentioning the presence of bacterial genes in the human genome only confounds young students. Finally, although much of science needs to be simplified to introduce topics to students, statements that are incorrect should be avoided. It is true that identical twins do look very similar; however, they do not have the same fingerprints as is stated in the book.

The students' hands-down favorite book was *Germ Zappers* (only one student, Molly, chose a different favorite book). Students again each learned something different from this book, but also had similar questions. Jordan (age 11) was fascinated by the fact that it is hard for germs to get into your body. He thought that since "most germs are small, it should be easier [for germs to get in]." The students were again struck by topics of size and scale. William (age 8) said, "VIRUSES are 100 times smaller than bacteria. That's weird." Students were surprised to learn that "some [germs] are good and some are bad." Although the students could acknowledge that there are different components of the immune system, it was unclear if they realized that these components are in fact different types of cells ("What are germ zappers made of?"—Makayla, age 8). Ryan's mom was concerned that the text of *Germ Zappers* states that our bodies fight off most viral infections easily—yet the viruses illustrated on page 19 include "ebola, smallpox, polio, leukemia, and encephalitis, which are not easily destroyed but rather very deadly." Another adult reader was also confused by the graphic on this page—some of the viruses pictured have "scientific" names such as Ebola, but others appear to be named by the symptoms they cause (*e.g.*, diarrhea). Finally, the authors could get even more buy-in from readers by exploiting topics with which students are intimately familiar. For example, students have extensive experience with fevers, yet their biological function is mentioned only in passing. The topics of antibiotics and the function of vaccination could also be further elaborated.

Although the illustrations are very striking and clearly engaged the students, they were, in a couple of instances, responsible for introducing misconceptions. When asked how cells are different, Jordan (age 11) responded, "Some are different colors": clearly he didn't notice the disclaimer about false coloring in small type on the page with the copyright information. Molly (age 10) finished *Germ Zappers* believing that natural killer cells "stick to bad germs and the germs leak out air" (the illustration on page 12 shows a deflating cell with a dialogue bubble saying "HISSSS"). Once acquired, these types of misconceptions can be very difficult for students to let go of.

Enjoy Your Cells is an ambitious undertaking, and the series may try to do too much, ultimately undermining the power and beauty of the authors' approach. Students came into this project fascinated by the subject matter and engrossed by the illustrations. Along the way they were distracted by the sheer volume of information that is presented in each of the books (and on each page). The individual books lack a focused take-home message for readers. Rather, they jump from topic to topic, often without critical transition and summary statements, which would help students to understand how what they just learned is relevant to what is about to come. Finally, the books assume an advanced vocabulary. Stumbling over both reading and the meaning of difficult words can be frustrating to young readers. In combination with the complex subject matter, this makes these books more appropriate for a considerably older audience.

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