Because His Shell Is Empty: Writing Poems about Biology

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In "Poetic Writing in Psychology," the authors suggest that poetic writing offers students taking courses in disciplines other than English unique and valuable ways of learning course content:

> The results of this study suggest the value of poetic writing in a content course. Students found the poetic assignments particularly valuable for exactly the reasons that Britton suggests—poetic writing encouraged them to explore their values and feelings about schizophrenia and permitted them to play with language. . . What would happen if we tried [poetic writing] in a highly technical class outside of the Humanities or Social Sciences? We suspect [it]would be useful in learning scientific and technical material as well. (Gorman, Gorman, and Young 1986, 158)

Our own experiments with students writing poetic expressions of information in an introductory level General Biology course and an upper level Cell Biology course bear out the authors' observations. Not only did the students explore values and play with language, they also exercised several specific kinds of cognitive skills valuable for learning in the sciences. Most significantly, many of the students who participated experienced a kind of understanding that took them more deeply into the subject matter of biology than they or

we were expecting from an exercise with a relatively small investment of time and energy.

This paper will review a poetry writing assignment used in both an introductory level General Biology class of 148 students and in a 200-level Cellular Biology class of 34 students. In addition, it will consider two group-written poems composed in a first-year composition course linked to the General Biology class, demonstrating how writing poetry about technical material not only promotes the acquisition of knowledge but also stimulates critical and creative thinking, leading to a more accurate understanding of the material and to a deeper appreciation of the subject.

What Good is Writing *Poetry* in a Science Course?

Science teachers are fully justified in asking that question. Many science courses, especially at the introductory level, enroll too many students to permit much writing of *any* kind. If the teacher's precious time is going to be taken up with reading student work, shouldn't it be more explicitly scientific writing, or at least expository (i.e., explanatory) prose?

Most of the literature locates the value of writing poetry in the student's general development rather than in course-specific learning. So Joseph Moxley, quoting Dave Smith, points out that "creative writing is one of the few formal opportunities in education for self-discovery and self creation" (1989, xii-xiii), and Gorman, Gorman, and Young cite James Britton's assertion that "poetic writing encourages students to explore their own feelings and values" (1986, 139). While no one would deny the value of self-exploration and discovery, we are asking how writing poetry can help students learn *science*.

In the first place, most poems are short. This makes them useful for focusing intensely on specific processes or ideas and also means that teachers won't have to read prohibitively long papers in large lecture courses. In the second place, poetry is relatively dense for its length; often, a great deal of thought goes into the production of just a few lines. Some of this thought may be expended on purely poetic questions of rhyme, meter, and so on, of course, but some of it will inevitably go to better understanding the scientific processes the student is writing about, to choosing the word or image or analogy that most exactly expresses the understanding the

writer wishes to convey. The tendency of poetry to encourage precision—because it is not expansive and explanatory, one naturally wants to get each word right—is also an effective device for helping students focus on the intricate details of, for example, the Krebs cycle, as we shall see, or the electron transfer chain.

Besides its brevity and focus, poetry also encourages the careful observation of physical details (imagery), a habit of mind particularly valued by the sciences as well as other academic disciplines. In *Researching and Writing in the Sciences and Technology*, for example, Christine A. Hult devotes a whole section of chapter one to "The Importance of Observation in the Sciences," and every lab manual for introductory biology courses stresses the importance of careful observation in the formulation of questions that lead to hypotheses and in the monitoring of actual experiments, as well as in the discussions of their results. Furthermore, the analogical nature of poetry, with its metaphoric and similistic comparisons, promotes careful, detailed thinking about the nature of biological processes. If you compare electron transport to riding in a cab, for example, as one of our students did, thinking about the ways the two kinds of transportation are similar as well as different means that in the end, you have thought a lot about electron transport. Generally, then, poetry focuses attention on the fine details of scientific knowledge in a limited space where other kinds of writing might require many pages.

Poetry also has value for students in the way that it promotes imaginative and emotional connection with the subject matter, as has been well recognized. In several places, for example, Art Young has argued that poetic expression helps students engage with a subject emotionally and appreciate the values at issue (1982; 1997; 1998; 1999; 2000. See these same sources for his discussion of poetry's ability to help students "engage the fine details of the information.") The ability to visualize the implications of a process like cloning, for instance, and to respond to those implications emotionally, out of their own values and beliefs, helps students establish a framework in which everything about cloning, from the mechanics of nuclear cell transference to the ethics of therapeutic cloning of humans for stem cell research, is more clearly understood, as we shall see in one of the poems we consider below.

Finally, we would like to add that the role of creative thought in the sciences is sometimes forgotten by the rest of the academic community. Most scientists, though, are familiar with stories of dream-like, visionary inspiration in great discoveries like those of Rutherford (atomic structure), Kekule (the benzene ring), Loewi (chemical transmission of nerve impulses), Watson and Crick (structure of DNA), and Curie (radiation). At a dinner given in 1998 in honor of the great Australian biologist Howard Florey, who first developed antibiotics for use in human beings, Michael Wooldridge, then Minister for Heath and Family Services (Australia), remarked: "I . . . hold to the view that there is no essential difference between artistic creativity and scientific creativity" (1998). Many scientists feel the same way, although those in the humanities tend to see more of a gulf between their subjects and the sciences than scientists do (see Standler, n.d., for example). Writing poetry about biology helps to call attention to the creative impulse present in both areas.

The Assignment

The assignment had two components. In the first component, the 148 students in an introductory level General Biology class and the 34 students in a 200-level Cell and Molecular Biology class were asked to write a poem about a biological process or idea. The choice of the process was left up to them, as were choices about the length and style of the poems to be written. Since the assignment was conceived of as a "writing to learn exercise," students were awarded a small number of points simply for writing the poems and turning them in on time. (In both biology classes, ten percent of the students' grades was based on homework assignments and short quizzes. The poetry writing assignment counted as one of these homework assignments.) This freed students and teachers from concerns about the quality of the poetry as verse and allowed us to focus on using the concision, focus, imagination, and emotion of poetry to learn science.

We expected that all of the students involved in the project would have had enough exposure to poetry in some form that, given the absence of constraints as to style, form, length, or poetic "quality," they would be able to write a poem about a biological process or idea without any explicit guidance. However, since some students tend to appreciate guidance, a more complete set of directions were posted on the Web CT biology

site (see Appendix 1). This guide emphasized two qualities of poetry—*images* and *comparisons* (similes and metaphors)—and suggested that for this exercise, these two qualities were more important than form, rhyme, and meter. As noted above, images were valued because careful observation is one of the hallmarks of the scientific method (as well as being necessary for writing effective verse), and comparisons are powerful tools for both creative and analytic thinking because they often come to mind spontaneously but can then be subjected to close analysis of the point-by-point similarities and differences between the two compared phenomena. Students were not *required* to follow any direction in the writing of their poems, however.

In the second component, students in a first-year composition course linked to the General Biology section wrote a poem as a group going through a directed, in-class activity. The students in this section of composition were also enrolled in the same section of General Biology and were writing papers in composition about subjects and issues raised in the biology course (the scientific method, genetic engineering, evolution, as well as more focused and technical processes like diffusion, cell membrane permeability, biochemical bonding, and so on), so the idea of writing and then commenting on a poem about cloning was not foreign to them. After the group-written poem was completed, students commented on their perceptions of the biological and social issues raised by the poem and on whether or not it changed their understanding of these issues, and if so why.

The Group Writing Experience

Poetry, like all the arts, is essentially a way of creating a state of advanced or heightened awareness in the perceiver. The faculties of awareness, of what we might for convenience's sake call reason, emotion, and imagination are excited, stimulated, raised, and fused into a heightened awareness, an enhanced ability to see into the nature of things. For this reason, poetry might be considered a particularly good vehicle for understanding more fully the nature of controversial biological processes and the social and moral issues they can raise.

This is exactly what happened in the group poetry writing aspect of the experiment. In the composition class linked to the larger General Biology class, students had been read-

ing and writing about genetic engineering, including such issues as genetic screening (looking for genetic disorders in fetuses and embryos), gene therapy (repairing genetic defects), genetic enhancement (introducing traits into plants, animals, and people to improve or alter their physical characteristics/ abilities) and cloning. Of all the technologies, cloning fascinated them the most, as it seems to fascinate (or horrify) the culture at large. In particular, they were interested in the human implications of cloning individuals. Would someone try to resurrect Adolph Hitler, as an old Gregory Peck movie proposed, or would there be multiple Brittany Spears, Brad Pitts, or Michael Jordans populating the future?

The poetry writing component of the composition class offered students the following scenario about which to write a poem that addressed their questions:

> It's 2022. A wife and her husband are unable to have a baby—the husband's sperm seem to be at fault and not even in vitro fertilization techniques are working. So the couple decide to bear a child cloned from just one of them. They both want a little girl, so they decide to clone the wife. A body cell is taken from the wife and its DNA—the blueprint for the whole woman—is extracted. Next, an egg cell is removed from the wife's ovary. It's nucleus, which contains half the amount of DNA necessary to make a new person, is extracted and discarded. The complete DNA taken from the body cell is coaxed into the empty egg cell, which is then implanted in the wife's uterus. Nine months later, she gives birth to a baby girl who is genetically identical to her, who will grow up to look exactly like her and have all of her physical characteristics along with whatever personality traits that are inheritable, though of course the cloned daughter will also be an individual, a person in her own right. Write a poem which looks at four or five interesting moments in the life of the cloned daughter. How do her parents see her at each of these moments? How does she see herself? Write the poem in the past tense, looking back at the events from, say, 2072.

The poem was written on the board as the class members contributed lines, words, ideas, suggestions. Suggestions were

vetoed, voted on, lobbied for, and questioned as the poem progressed. At each point, students were led, with the teacher's guidance, into a consideration of the situation that the family would have faced with each change in the age of the cloned child. Here is what finally emerged:

The Clone

Born in 2022
She was her mother's mirror
Her time machine.

When she was five,
Her mother taught
Herself manners.

When she was 15,
Her father took his teenaged wife
To the father-daughter dance.

When she was 23,
She gave her mother
A grand-niece.

When she was 50,
She watched herself die.

After the poem was composed, the students were asked to reflect on what they had learned about the nature of cloning and about using poetry to explore it. All of the students observed that the act of writing the poem finally cleared up confusions which had existed between their understanding of the mechanics of cloning and the half-superstitious fear and distrust in which cloning is held by the uninformed. (We don't mean to suggest that ethical concerns about cloning are misplaced—far from it. Uninformed people, however, tend to think of cloning as the mysterious production of a Frankenstein monster rather than as a potentially viable form of reproductive science.) One student said, "I always thought that cloning was, like, making a whole person in a lab. When we had to think about what this girl's life would be like, I realized that she would be born just like any other child." Another student said, "I don't see what the big deal about

cloning is. It's just about like *in vitro* fertilization, and they've been doing that for *years*." What struck us was that these students had known how cloning works before they wrote the poem, but still tended to view the process through the lens of their earlier assumptions that cloning was a kind of monster-making. Writing the poem not only reminded them of techniques like nuclear cell transference and facts about diploid and haploid cells, but also personalized that knowledge in the life of a fictional girl they had created. Here was an instance where mixing sharply observed detail with emotional and imaginative responses led to a deeper understanding of a biological process.

Of course, we don't mean to suggest that all of the students became ardently pro-cloning. Many of them, perhaps the majority, agreed with the student who said "It makes me feel that cloning is a miracle breakthrough in science, but that there are a lot of questions and concerns about cloning that deal with the way it will affect people's lives." Several even said, "It [i.e. the poem] made me feel more against the process." Writing the poem crystallized the implications of cloning in human terms, making students better able to respond fully to the conflict between the reasons people might have for using cloning as a reproductive aid and the students' own feelings about family relationships. Although they wouldn't have used these words, it is clear the way "The Clone" makes explicit the Freudian elements in the "family romance" disturbed many of them deeply. The important point is that through writing the poem, students came to understand the *process* of cloning, as well as its controversial *implications*, more clearly than they had before, even after studying the technology in General Biology class and writing a paper on the ethical implications of genetic engineering in their composition class.

One more poem was group-written during the course of this project. In designing the assignment, the composition instructor asked a small group of students from the composition class to collaborate with him in writing a poem that would be used as an example in presenting the assignment to students in the General Biology and Cellular Biology courses. The instructor gave the students the subject of ionic bonding and asked them to compare this kind of atomic behavior to some other sphere that students could understand. Here is the poem that resulted:

Bonding

Ionic bonding is like love.
One gives, because the electric charge
Sizzles in her veins
The other takes because
His shell is empty.

The comparison of ionic bonding to love was almost inevitable—the students played with the idea of bonding for less than a minute before they settled on a love relationship for the central comparison. On analysis, the students decided that ionic bonding did indeed seem very like one kind of love—but not like all kinds—and so the poem tried to capture the relationship between one person full of love and her more parasitic partner. The striking line "because his shell is empty," which gave our paper its title and which refers both to the atom that can accept an electron from another and to a person who has nothing to offer in a relationship, a person who might be characterized as an "empty shell," (a completely different metaphor, though also biological), illustrates the way that using analogy or metaphor helps students better understand the processes they are considering. In discussing this poem, one student remarked that she might get the other kinds of bonding confused, but she would never forget how ionic bonding works.

Results of the Poem Assignment in the General Biology Course

Since the poetry writing (for both biology classes) was a "writing-to learn" assignment, which de-emphasized evaluation in favor of the knowledge gained from the experience, and since we had made no requirements as to length, style or form, we were prepared to find that many of the poems were perfunctory, and indeed many were. Of the 148 poems submitted in response to the assignment in the General Biology Course, some were very short and very simple, while other were just vague, their writers using the occasion to raise questions or to philosophize about the subjects of biology/life. While these poems may have had some value for their writers, they were not what we were hoping the assignment would produce. Other poems were more specific and detailed, and even when very short, reveal some of the educational value

we were looking for. A scatter table at the end of the paper offers a visual impression of the range of the poems and something of a sense of how many students took the assignment seriously and how many did not (see Appendix 2).

Although a number of students responded to the assignment with mild enthusiasm at best, even the weakest efforts helped students to review biological concepts and facts, even if they weren't always accurately expressed; and again the poetic form tended to confer a kind of crystallization or focus on an idea. Consider this sample:

What is Evolution?

Evolution is nature's solution.
Changes that occur to guarantee that a species will survive
Adaptions necessary for life's success.
Because in nature it takes the best of the best.

The rhyming of "evolution" and "solution" and the slant rhyme of "success" and "best," along with the short lines and the stanzaic form (a quatrain) are, though minimal, poetic gestures that reflect some thought, some playing with the possible ways of expressing the idea. Again, we found this evidence of poetic dabbling important not because we cared about the production of "quality" verse but because the demands of form confer a kind of dallying with the subject matter which encourages reflection and ultimately understanding—and the understanding of the idea of evolution is roughly valid, though the poem stresses a sense of predetermined purpose which is absent from Darwinian evolution. (In the poem, the success of the species is seen as a goal of evolution. In Darwinian evolution, the success of the species depends on random mutations, which accidentally improve the chances of the descendants to survive.) By itself, then, this poem was perhaps a modest *aide memoire* for the author. It would have been of even greater value if the occasion had permitted a discussion about the accuracy of the evolutionary ideas. Nevertheless, the evidence of this poem and several more like it suggests that the form and concentration of poetry tend to throw misconceptions about scientific ideas into high relief, making them easy to identify and to discuss with students.

A little over half of the poems reflected the influence of the optional assignment posted on the biology course's Web

CT site, which directed students to focus on imagery and metaphor in writing their poems (see Appendix 1). Some of these poems focused on a single comparison, and though minimalist, were clearly useful to their writers in understanding and remembering biological concepts:

My love is selectively permeable
Like a plasma membrane
Only letting those in worthy of my love.

The biology instructor for this class liked the way this poem captures the essential function of the cellular membrane, to keep in the constituents of the cell necessary to its functions and to keep out unnecessary substances, especially waste products, while allowing necessary substances to pass through its protein gates. Though the poem is very brief, the comparison between love and plasma membranes confirms the student's understanding of the idea of selective permeability.

Another, longer, more detailed poem compares cellular respiration to a track and field event, the triple jump:

Aerobic cellular respiration is like the triple jump.
They take a hop, skip, and a jump to reach their goal.
Glycolysis is the short hop of the triple,
By investing two ATP, it receives only four, and
grosses only two.
The Krebs cycle is the skip of the triple,
For it profits only two ATP.
While the electron transport chain is the long,
Powerful, goalgetting jump of the triple.
By spending only two ATP,
The ETC—
Jumps with energy
With a profit of 32 ATP.
With a short Glycolysis hop,
A Krebs cycle skip,
And an Electron Transport Chain jump
You have the Aerobic Cellular Respiration triple jump.
It uses its energy
And strives for ATP
Resulting in a leap profiting thirty-six
Strong bits of energy, as it lands—in the sand.
It gets up, runs down the approach,
And does it all over again.

All of us liked the way this poem *embraces* the complexity of cellular respiration with a comparison that offers readers a visual and tactile approximation of the steps. The analogy may not be perfect, but it is very good, as are the poetic devices—control over the monetary metaphor in line four, the music of "skip of the triple," and the concentration of energy down into the two shortest lines of the poem to describe the moment when the most energy is produced:

> **The ETC—**
> **Jumps with energy**

We also liked the way the poem repeats the process in brief after it has explained it in detail. One senses the writer understanding the process well enough to play with it, to present it in various forms, long and short, the way a professional writer might, and to decorate it with poetic effects. Like a basketball player whose ball-handling abilities allow her to show off fancy moves or a violinist who plays fast because he can, the poetic flourishes here demonstrate mastery of understanding.

Metaphor clearly offered an intellectual playground to both these students, and in both cases the sense of play with the comparison spills over into an effective explanation of the phenomena with which they are concerned.

Still another comparison came from the textbook, Krogh's *Biology*, which compares certain chemicals involved in the electron transport chain—NAD (and NADH) and $FADH_2$—to taxi cabs ferrying electrons back and forth (2000, 133). The student cleverly explores the details of the metaphor and sets the whole scene to a hip-hop beat, transforming the intracellular activities of energy production into a lively urban street scene:

> **The never stopping cab, Always on the job**
> **Never passing any needed ride. Hey Mr. Electron just get inside**
> **Only when the cab isn't full it will stop**
> **But you know because the plus sign will be highlighted on top**
> **Get on in, the ride is smooth, Mr. Electron get ready**
> **To be oxidized and let's cruise.**
>
> **Sorry the ride is now full and can't stop,**

We all know that
You all want to be oxidized too, but look now there
Isn't a plus sign but an H on top.

The overly anxious passengers are ready to be dropped off
Oh!! Great this is your stop, here ya go so let's hurry
Up so the cab pick up some mo!

The sharp observation of detail—in this case, the changing positive and negative charges on the molecules that transport electrons down the chain—is effectively captured in the analogy between the molecule's charge and the cab's company and in-service signs, which are merged in the poem. It's instructive that the student took liberties with the physical reality of cabs (the sign on the top shows the company's name—the sign in the window shows if the cab is available or engaged), not with the physical reality of electron transport. In writing the poem, it was more important to him to get the science right, a sign that he understood the thrust of the assignment.

Some of the poems were quite witty in their application of scientific method to life experience. The following cleverly and accurately encapsulates the scientific method (a popular theme) as a lens for understanding how to pick up boys at bars:

Scientific Method for Approaching a Man

As I sit on a stool at the bar
I observe a handome man from afar
I tip the bartender and down my Coors
And ask another admirer, Is he yours?
Do I approach him and risk rejection—
Or sit quietly and risk losing his affection?
As the buzz of my drinks catches up with me
I make an educated guess to go to him and see
I decide to experiment and risk my pride
And attempt a seduction instead of running to hide
When I introduce myself, he starts to walk away
And I conclude: It's not my fault—he must be gay.

This poem accurately reflects the main steps in the scientific method (observation, question, hypothesis, experiment, re-

sults, conclusions). In playing with the steps, the writer masters them, to the extent that she can reflect them clearly while applying them to a non-scientific setting. "Wit" used to mean "understanding" as well as "cleverness"; here, the writer's ability to play with the elements of scientific process confirms her thorough understanding of them.

The last category of poems we would like to discuss is one that is framed by Art Young's comments on the poetic function of written language when students are attempting to relate new knowledge to their value systems (1982, 78). Young argues that when students encounter new ideas that may run counter to their system of beliefs, poetic use of language helps them assess this knowledge and stand in relationship to it. The poet asks questions, establishes a sense of distance from the material, fictionalizes it, plays with it in ways that resemble an animal exploring a new object, visually, tactilely, to see if it is good or useful.

One of the most powerful poems we looked at examined the author's troubled relationship with his father in light of his new knowledge of what being a biological son implies about his own identity and about the possibilities inherent in his future fatherhood:

Gene Therapy

I was in my Dad's gonads . . .
And he is still in mine
I continue to carry on his traits
Even the ones I still hate

Half of his DNA I will pass on . . .
If I could subtract that half
Then it would be half gone
I could castrate myself . . . Cut it all off!
Would you like to watch?
See me here, with my
Barbie doll crotch . . .
Snippity snip!

The way this poem plays with the "halfness" of heredity from one parent (we each receive half—23—of our total of 46 chromosomes from each parent) reflects a dawning awareness of how the mechanism of heredity determines aspects of character and identity: "if I could subtract that half / Then it

would be half gone" shows that the student understands acutely the nature of heredity and uses that accurate knowledge to meditate with disturbing power on the possibility of ever eliminating those traits from the world. It is as if the knowledge of how personal traits are passed on has alerted the writer to the degree of control he has—or more properly, does not have—over their transmission to a new generation, which leads to the powerful imagery of the second half of the poem, with castration and the "Barbie doll crotch" representing the only way he can be assured that the "traits . . . I still hate" won't live beyond himself. (Incidentally, the implied voyeurism in "Would you like to watch" and the gender confusion of "Barbie doll crotch" add another psychic layer to this already intensely felt poem.) In this poem, we can see the student/writer thinking (and feeling) his way through the intricate relationship between heredity and personal identity in his own life. For many students, this kind of awareness marks the beginning of their ability to integrate the world-view of biology and of science in general into their lives. Writing poetry offers students the opportunity to personalize biological processes in ways that convince them of the relevance of scientific understanding more effectively than lectures and textbooks can.

Poetry Writing in Cell Biology

Writing poetry in an upper-level, cell biology course raised somewhat different questions than doing so in the introductory biology course. Although the poems were again a writing to learn exercise which was not to be graded and which emphasized learning science rather than writing "good" verse, just as in the introductory course, the higher stakes of the upper-level course, with its expectation that assignments would engage more complex material more deeply, made us wonder if the technical information would lend itself to poetry and if the poetic format would aid in understanding or would enforce a simplification of the material in order to conform to students' ideas of what poetry should look like and be about.

The cell biology instructor had other concerns as well going into the experiment: she expected the assignment to take students outside of their comfort zone and challenge them with its very nature as an assignment quite unlike what they might expect from a biology course—especially an up-

per-level one—and although not constrained to grade the poems on their merit as verse, she still wondered about her own ability to respond to and assess poetry, especially non-classical poetry that lacked clear criteria of rhyme and meter. (She found it more difficult than the others to relegate the poetic to a tool for learning biology and wondered if the poetry didn't deserve to be considered as formally as the science learning did.) In effect, she worried that the assignment could fail either by being too exotic for students in an intensive science course or by producing poetry too exotic for her to evaluate, or by doing both.

In any event, the poems written by the cell biology students resemble the poems written by the students in the introductory course, with perhaps somewhat greater technical complexity and somewhat less concern for poetic technique (see scatter chart, Appendix 3). The cell biology instructor concluded that the poems were well thought out (for the most part) and showed evidence that the students understood the concepts they were writing about. She came to see the poetic dimension differently than she had expected: for her, it became a kind of catalytic base for the assembly of facts and ideas in ways that neither the student nor the instructor had anticipated. Metaphor, simile, imagery, form, meter, and rhyme became the substrate on which new reactions among facts and ideas formed in the students' minds, reinforcing knowledge of the material in ways similar to the ones we saw in the poems written in the General Biology course.

A good example of the new expression of learned ideas may be seen in the following poem about water:

I'm strong yet weak all at once.
I'm the star in the play called life.
I'm always called back for more. I guess
They can't live without me. Being weak
Gives me the ability to do many
Things. I can hold things together.
I can stabilize things. And I expand
When I'm cold. Who said that being
Weak isn't cool. I'm the coolest man
On the earth. I'm versatile!

This meditation on water abstracts the qualities H_20 displays in its relationships with other organic substances and elicits

those qualities with a metaphor ("I'm the star") and a paradox: "weakness" (water's relative formlessness) gives water the ability to play many indispensable roles. What the cell biology teacher liked about this poem was the way the analogy ("star") and the paradox summed up the many varied and crucial roles water plays in the biochemistry of the cell.

At their best, the poems written in the cell biology course, like those written in the general class, use poetic language to make scientific information vivid and memorable:

I am standing on the median
Three ways to go
Which fall shall I take?
I may never know.

I see the solutions before me
Each numbered one through three
I can't decide into which one I should jump
For only one will life be

The first solution I see they say is hypertonic
I become better experienced as to what I should do
When I watch my friends dive in, shrink, and die
Definitively this solution I shall not choose

The second solution from which I have to choose they call hypotonic.
This solution they say is a lot less crowded than the last
However, when I see my friends jump in, lysis, and die
I begin to think the solution isn't such a blast.

As I begin to think that things can't get better
I remember I have one solution left
This solution they call an Isotonic one
I hope this one will be the best.

I have chosen my destination
Everyone there is always happy
There is no deathly swelling or shrinking
There is only equality.

All the poetic effects here—the way the poem plays off of Robert Frost's "The Road Not Taken," the lovely line "which fall shall I take," the interesting parallel between the cell lysing (in effect, exploding) and the rhyme word "blast," and most of

all the imaginative way the writer dramatizes the idea of tonicity by anthropomorphizing a cell poised to fall into one of three different solutions—combine to define the idea of tonicity in a clear and memorable way. Students often confuse the kinds of tonicity and their effects on organisms with semipermeable membranes. Few texts manage to make the differences clearer or more vivid than this student poem.

Writing poetry in this more advanced biology course had similar benefits to writing poetry in the lower level course, suggesting that the assignment is not constrained by course level or complexity of information.

Conclusions

Writing poems about biology has proven to be a rewarding assignment for students and teachers alike. Students realize a variety of benefits:

- Reviewing the scientific material promotes retention.
- Analyzing the scientific material promotes understanding.
- Writing poetry about the scientific material promotes greater imaginative and therefore greater emotional intimacy with the subject matter—students are able to see ramifications and possibilities that make the subject more immediate and more real for them.
- Playing with poetic form promotes creativity and imagination, abilities that are as vital to the sciences as they are to the humanities.

On the whole, for a relatively small expenditure of time and effort, students came to a better and deeper understanding of the biology they were studying by writing poems, and they seemed to have fun in the process.

Biology teachers (and other teachers in the sciences) interested in trying this assignment with their students may wish to keep in mind the following caveats:

- Keep the emphasis of the assignment on the science: let students write any kind of poem that appeals to them. The benefits of the assignment will grow out of free poetic play with the subject matter.
- Avoid complex assessments. If possible, make the assignment pass/fail, or, as we did, worth a few of points if done at all. In particular, avoid judging the merits of the poems as poems. They may, however, be critiqued for accuracy of scientific content.

- Consider having the class trade poems and critique the scientific content of each other's verses (something we did not do but will next time).
- In making the assignment, emphasize the qualities that poetry shares with scientific inquiry: close observation of physical detail (imagery), analytic probing of similarities and differences between objects or phenomena (metaphor), and creative impulses developed by method and discipline (form). Downplay the idea of poetry as a way of philosophizing about life. We all felt that the poems that went in this direction were less rewarding than the poems that considered specific processes or ideas.

In closing, we would like to dwell on the value of creative approaches to science. The goal of stimulating students to think creatively is of course highly valued in all educational models. The fostering of critical and creative thinking is a central goal to literacy teachers, teachers in content areas, and to university missions. The Council of Writing Program Administrators (WPA) outcomes list "the uses of writing as a critical thinking method" as one of the core goals of first-year composition courses; a handbook on writing papers in the biological sciences remarks that "biologists need to think creatively about science" (McMillan 1997, iii); and the mission statements of many universities include language like this:

> Our hallmark is a comprehensive university experience that promotes student growth and success through creative strategies . . . , [graduating] students who are knowledgeable, clear-thinking, articulate, and effective in problem-solving. ("Mission" 2001)

English teachers who ask students to write about imaginative literature in the composition classes are often dismayed by the students' inability to fully imagine the people and worlds invoked by the works they are reading. Biology teachers are just as dismayed that the beautiful intricacies of cellular function or the dance of meiotic division remain, for most students, flat, dull, poorly understood textbook illustrations. We would argue that writing poems about biology—or history, chemistry, engineering, marketing, literature, or any subject in any broad area—brings the complexities and the beauty

of that subject to life for students, allowing them to enter into it imaginatively, emotionally, and intellectually.

The connection between poetry and biology in particular, however, surprised us with its peculiar intimacy and power. William Wordsworth, in his famous poem "Lines Composed a Few Miles Above Tintern Abbey," speaks of the power of nature to calm the mind and to produce "that blessed mood,/ In which . . . /We see into the life of things." We suspect that he would claim the same power for poetry to help students of the biological sciences see more deeply "into the life of things;" or in their case, into the things of life.

Appendix 1: Instructions for Writing a Poem about Biology

This is meant to be a fun exercise that will get you to think clearly about a biological idea or process and to write creatively and entertainingly about it.

Poetry isn't really about rhyme, at least not any more. Instead, it's an attempt to use language to speak powerfully about a feeling or an idea. It has several techniques for speaking powerfully, but it especially makes use of *images* and *comparisons*.

Images are vivid, sense descriptions:

> The only other sound's the *sweep*
> Of *easy wind* and *downy flake*. (Robert Frost)

> This old thigh bone is *hard* and *heavy*.
> *Smooth*, but *bumpy* where the long-dead
> muscles attached.

Another way that poetry gets its power is by effective **comparisons**:

> My love is *like a red, red rose* (she's silky, soft, dewy, fragrant)

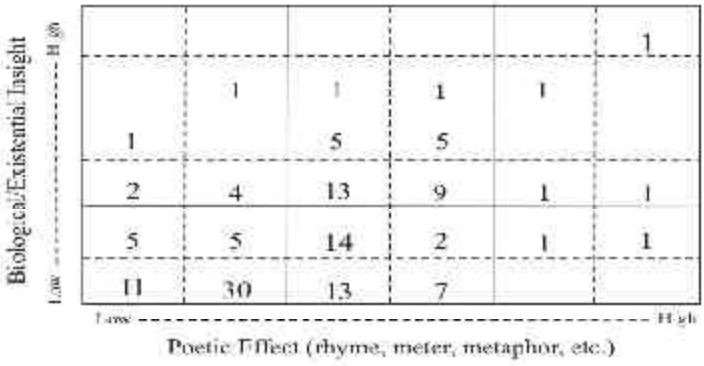
> Ionic bonding is *like love*
> One gives, because she has it to give
> The other takes, because his shell is empty.

For this assignment, write a poem that explains some biological process or idea of your own choosing. If you want, you can answer one of the following questions. Your poem does not have to rhyme. It's more important that you use accurate and vivid descriptions and interesting comparisons.

Some sample topics you could write about (feel free to make up your own):

1) What is life? Why do some scientists think it began in water?
2) What is the scientific method?
3) How do atoms bond to form molecules?
4) Why is carbon so good at forming bonds with other atoms?
5) What is osmosis?
6) What are passive and active transport of molecules across cell membranes?
7) Explain cellular respiration
8) Explain "survival of the most reproductively fit"
9) Explain how traits are combined and passed on in human reproduction
10) How are proteins produced? Why are they important?
11) How do viruses work?
12) What is a symbiotic relationship?
13) How do biologists classify living things?

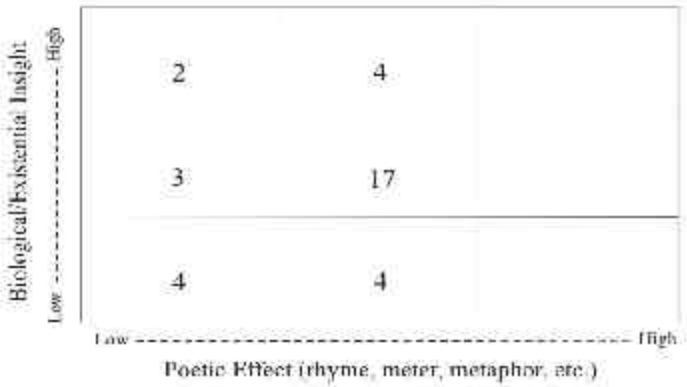
Appendix 2: Scatter Table for Poems written in General Biology



Numerical values indicate numbers of poems out of 148

This chart reflects the relative sophistication of the student poems with regard to biological and/or existential insight and with regard to poetic complexity. Poems with relatively more complex insights, ideas, and information (either about biology or about human experience or about both) occur towards the top of the chart; poems with relatively more complex use of poetic devices like imagery, metaphor, rhyme, meter, stanza, line length, symbolism, and specialized forms (like haiku or sonnet) were listed towards the right side of the chart. For convenience, instead of indicating where each poem fell, just the total number of poems in each segment of the grid is shown.

Appendix 3: Scatter Table for Poems written in Cellular Biology



Numerical values indicate numbers of poems out of 34
(See previous appendix for an explanation of the chart.)

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