Teachers & Writers

Special Issue!

Bi-Monthly • May-June 1988 Vol. 19, No. 5

SCIENCE WRITING

Editor's note: This special issue of Teachers & Writers *—a follow-up to issue 18/5—is about science writing, but many of the ideas in it can be used in any writing class. Besides, writing-across-the-curriculum should work both ways. For example, English teachers who bemoan the fact that science teachers don't use writing should reexamine their own reluctance to use science.*

Carol F. Peck's article is a response to our call for articles in issue 18/5. Bernadette Mayer and Dale Worsley's contributions grew out of their T & W writing workshops and are from their book about science writing, which T & W will publish this fall.

Visualization & Objective Observation

by Dale Worsley

CLEAR VISUALIZATION IS A KEY TO LEARNING and understanding. Writing can not only show how clearly one understands a concept, but help clarify the image of the concept. Good tools to express visualization are metaphor and simile.

Some of my students have had problems visualizing certain processes, not for lack of imagination, but because the pace of the curriculum was too rapid for them to stop and grasp the facts. When one writing exercise didn't succeed the first time, I repeated it, to make sure the students had the experience of visualizing clearly. I used two examples: a Shakespeare sonnet and an excerpt from a science article in the *New York Times*. The sonnet used ironic metaphors to serve objectivity. Before reading the poem aloud, I had the students compare the parts of a lover to other things, just as Shakespeare did. (He was using the poetic device of listing, which has been employed through the centuries for various purposes. When one lists a lover's good qualities, the poem

IN THIS ISSUE

1 **Visualization & Objective Observation** by Dale Worsley
4 **Science Writing: Questions & Answers** by Bernadette Mayer & Dale Worsley
6 **Science Writing Experiments** by Bernadette Mayer
11 **Science & Poetry Writing** by Carol F. Peck
14 **A Brief Science/Writing Bibliography** by Bernadette Mayer & Dale Worsley

is known as a *blazon*.) This is what my students came up with:

eyes—black onyx
lips—rose
breasts—cotton
hair—silk
cheeks—peaches
breath—peppermint.

Then I read the sonnet (CXXX):

My mistress' eyes are nothing like the sun;
Coral is far more red than her lips' red;
If snow be white, why then her breasts are dun;
If hairs be wires, black wires grow on her head.
I have seen roses damask'd, red and white,
But no such roses see I in her cheeks;
And in some perfumes is there more delight
Than in the breath that from my mistress reeks.
I love to hear her speak, yet well I know
That music hath a far more pleasing sound;
I grant I never saw a goddess go;
My mistress, when she walks, treads on the ground:
And yet, by heaven, I think my love as rare
As any she belied with false compare.

The sonnet is quite a comical stand for objectivity and an appreciation of love. Students like it.

Here is the second example I used, a passage of descriptive writing by Walter Sullivan, on recent discoveries concerning the nature of the center of our galaxy, the Milky Way:

A voyager to the heart of the galaxy would find the sky almost blindingly bright with stars.

According to recent observations by the Very Large Array of radio telescopes in New Mexico of the area within 200 light years of the Milky Way's center, the traveler would enter a region of gigantic, parallel gaseous filaments, arcing around the core, each about 100 light years long. Additional clouds reaching from there toward the core are cut by strange, narrow "threads."

Scientists suspect that this material is in violent motion, but whether it is falling into the core, circling it or being ejected has not yet been determined.

Infrared radiation recorded from closer to the core has shown it is surrounded by a doughnut-shaped cloud of dust and gas tilted slightly from the galaxy's plane. The cloud, about 12 light years in diameter, is heated by energy equal to that from 10 million Suns, but the source is uncertain.

The inner region of this cloud is moving so rapidly that some astronomers believe it is in the grip of gravity from a black hole equal in mass to that of several million Suns. Material squeezed, and consequently super-heated, as it falls into such a hole could heat the doughnut.

Another proposed energy source is radiation from millions of hot young stars formed in a "starburst" 10 million years ago. The explosions of such stars as their brief lifetimes ended could explain why the gas as far as 10,000 light years from the center is moving outward at high velocity.

Observations by radiotelescopes have shown that at or very close to the point around which the entire system rotates is the galaxy's most powerful source of radio waves. More recent observations have shown that the primary emissions are coming from a region smaller than that enclosed by the orbit of Saturn. The radiation is typical of that generated by wildly gyrating electrons, rather than that of a heat-producing star, and some believe the black hole lies within this area.

The article provides many examples of the way language can express clear visualization. Dramatic words such as "blindingly" and "violent" appeal to our senses. Comparisons such as "doughnut-shaped" allow us to form accurate pictures. When I read it to one class, you could hear a pin drop. Here are some of the results, when students described electrostatics and transistors:

Electrostatically charged electrons are like babies ready to be born. Imagine a baby that wants to come out and is kicking. Like the electrons, it is vulnerable and susceptible to anything.

—Shawnel Boone

Electrostatics is the exchange of charges between two objects. Imagine a dance. Five guys are dancing with their girlfriends. If five girls come to the girls' side, they will not attract. If they go to the guys' side, they will. Electrostatic activity is produced when opposite charges touch. Say guys are negatively charged and girls are positive. Two girls will not attract so no charge is changed. Two guys either. But a guy and a girl do attract. When these two charges touch it creates a small flow of electricity.

—Rhea Pulido

A transistor is a speeding train at rush hour. It transports multitudes of people from one station to another, allowing them to go to work. The people are electrons.

—Anthony Babeca

A transistor is as small as a pea and as important as a bridge. It works as a bridge by letting in the cars and making them leave faster than they came in. It has one way in and can let cars leave in two directions, either to the highway or to the street.

—John Paul Rivera

Think of a cylindrical shape and cut it in half from top to bottom. Place the round half so that it looks at you. There are three wires as thin as the thinnest stems in a leaf at the bottom.

—Edgar Tantigua

Objective Observation

Science teachers have a difficult time getting students to make objective observations when the students already know how an experiment is supposed to come out. In their essays, students may also have preconceptions that stand in the way of objectivity. To perceive something accurately is a matter of separating observation from preconception. Here, in the form of a letter to extraterrestrial life forms, is an example of a student's writing that could benefit from more objectivity:

If I were to write a letter to alien life forms, this is what I would say:

Greetings, aliens. I am an Earthling and I come from Earth. I came here to explain my existence and how I came to be.

It all started millions of years ago. A devastating explosion called the "Big Bang" brought all the planets together. By chance, up until now, our planet was the only

one which housed living organisms which advanced throughout the ages. My race was once said to be an inferior race of sub-humans called apes. This, of course, was all a theory. Maybe we can collaborate all our knowledge and create a superior race which can rule throughout the universe.

Together, Alien and Human can reach the end of the cosmos.

Among the several preconceptions in the piece is the notion that apes are "sub-human." Apes' evolution from a common ancestor is parallel to human evolution, and they are different, perhaps less intelligent, but not, objectively speaking, "sub" human.

To address the need for objectivity, I passed out definitions of it (free from personal feelings or prejudice; based on facts; unbiased) and observation (the act or instance of viewing or noting a fact for some scientific or other special purpose). The sheet also contained the assignment for the students to write objective observations, perhaps about themselves or their immediate environment. The students were permitted to use any kind of language they felt appropriate, but I reminded them that metaphor and simile were good tools. I also reminded them that it was impossible to make mistakes at the beginning.

Here are some examples of the results.

There is this big black unknown machine in the front of our English room. I wonder what it is. There are a bunch of knobs and plugs piled monotonously on it. There is a big meter. They look like two power meters on a radio. This machine looks very mysterious and it looks like a machine that Frankenstein would have used to make the monster. It is a very mysterious machine.

—James Amber

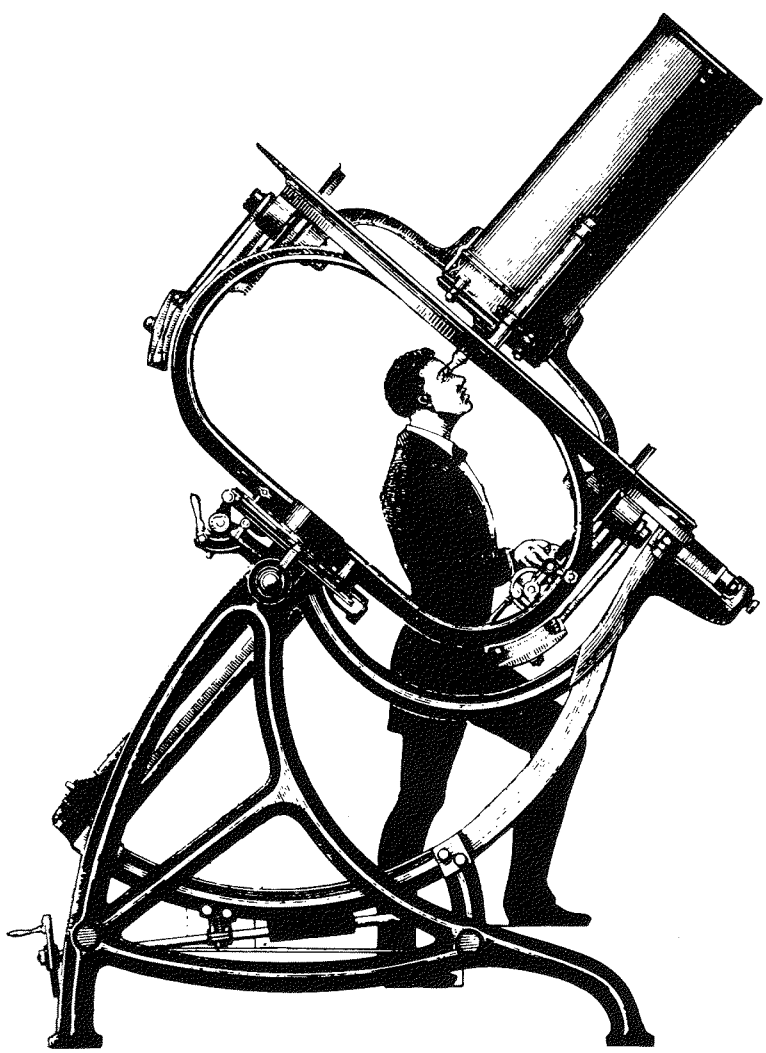
The expressions of the hands at the party were energetic. The hands of one person were like a dog waggling his tail wildly. The people's hands were waving in the air like a bird when it is flying. Then hands were moving with the help of the music.

—Bernell Hollis

In the computer classroom at least 20 or 30 machines moved, with the glare of one machine in the face of another. The keyboards tick. Their faces are blank, as if their hearts were part of the machines.

—Victor Wright

●



Science Writing
Questions & Answers

by Bernadette Mayer & Dale Worsley

What if students write too much?
There may be several reasons for students writing too much. If they are in the first draft of an essay, they may be including ideas that they will discover they need to cut in subsequent drafts. Another student can help them decide what to cut. They may have written too much because they are not paying enough attention to what is truly interesting in their work.

Usually the reason for this is they are not interested in what they are saying. As a teacher, it is not your responsibility to correct the writing at this point, but to help solve the problem of the students' lack of interest. Writers who appreciate the power of writing place a great deal of emphasis on the pleasure of it. Whenever it is becoming too onerous a task for the teacher or the student, something is wrong. A problem has arisen that needs to be solved.

What if students have bad ideas, or wrong ideas?
Any idea is all right in a first draft. If it's wrong, they can change it later. Many students are very anxious because they are asked to have right ideas immediately.

Okay, let's get serious. Is writing *really* that important to science and mathematics?
Many of the brightest math and science students have enormous trouble making the transition from plugging numbers into formulas to understanding the science and math in higher levels of education and the professions. They fail because, at higher levels, they can't relearn everything immediately. The loss to themselves and to society is tremendous—and unnecessary. Writing can help them avert this failure, because it enables them to approach their subjects the way real scientists and mathematicians approach them.

How can students' science writing be more beautiful?
Often the beauty of science writing comes as a surprise to students who have read predominantly textbooks. My approach is not to speak of the writing as beautiful (or not), but to give many examples of great writing, then expect the students' writing to be more beautiful. Here is an example of beautiful writing (though in translation) from Leonardo da Vinci's notebooks:

> **What Sort of Thing the Moon Is**
> The moon is not of itself luminous, but is highly fitted to assimilate the character of light after the manner of a mirror, or of water, or of any other reflecting body; and it grows larger in the East and in the West, like the sun and the other planets. And the reason is that every luminous body looks larger in proportion as it is remote. . . . And if you could stand where the moon is, the sun would look to you, as if it were reflected from all the sea that it illuminates by day; and the land amid the water would appear just like the dark spots that are on the moon, which, when looked at from our earth, appears to men the same as our earth would appear to any men who might dwell in the moon.
>
> *—Translated by Mrs. R.C. Bell*

How can mathematics papers become more lively and experimental?
Mathematics papers and textbooks, though well illustrated, often miss the mark for students. They seem dry and, of course, profuse with abstractions. On the one hand, it is useful to encourage students to become even more abstract, rigorously sprinkling their papers with more and more equations, diagrams, and calculations, which have great beauty when neatly rendered. On the other hand, students can experiment with introducing ideas with lighter, less formal tones and styles, as in Franklin White's piece below. It is useful and often compelling to write a math paper in the first person—to define the development of the concept as the author sees it, even to tell in what room, in what class it was first perceived, how other students reacted, and so on—the "surroundings" of the idea.

Here are some examples:

> I'm not done yet. Fibonacci began thinking again. (This is getting dangerous!) What if he could apply his set of numbers (which he so egotistically named after himself instead of after those poor rabbits) to Pascal's Triangle? Are you wondering what Pascal's Triangle is? Wonder no more! I'm here to save your brain from exploding with wonderment!
>
> *—from "Fibonacci Numbers" by Rachel Fluty*

> It has been discovered that in plants there are spiral arrangements of seeds on the face of certain varieties of sunflowers. The numbers of spirals in the two sets are different and tend to be consecutive Fibonacci numbers. There has been a discovery of one mammoth sunflower with 144 and 233 spirals.
>
> *—from "Fibonacci Numbers" by Franklin White*

Here is the conclusion of a paper on Pascal's Triangle by Dean Austin:

> When you have a problem included within the triangle, you know that one way or the other through trial and error, you'll get to the right answer. This can also be used in everyday problems. You'll face your problems knowing that there is an infinite number of ways to solve them. You should list your problems and attack them through every corner until finally you're enlightened by a most convenient solution. One must have patience and flexibility of mind to get by in life, and the triangle, Pascal's Triangle, if I may say so, is a good beginning.

A worthwhile collaboration would be a math textbook written by a student or group of students in collaboration with a teacher/mentor. Also, publishing a math newspaper or journal could become a good exercise in ingeniousness and humor.

Is there danger in the controversial nature of science?
Sometimes in science writing, the most popular subjects among students will be highly controversial, for instance the questions of evolution or current issues relating to human reproduction. Of course the danger for science writers and teachers is in loving the excitement of the controversialism of the subjects at the expense of objectivity. Yet both students and teachers can part with their objectivity for a while and then regain it. All this makes the life of science exciting and full of risk.

Should all student writings be corrected?
No. Notebooks and samples of freewriting, if they are perused at all, should definitely not be subjected to traditional correction on the basis of spelling and grammar. Also, exploratory work, notes, and investigations in writing in various forms should be left alone, so that students won't have to worry about questions of judgment or audience while writing in these ways. The main thing is to let words reflect thought, to let divagations occur, and to let the mind become interested in structure and transitions. Sometimes, writing that is intentionally non-grammatical can lead to new ideas. When it comes time to edit a final piece or essay, it's fun to let the students edit each other's papers and to see how they handle it.

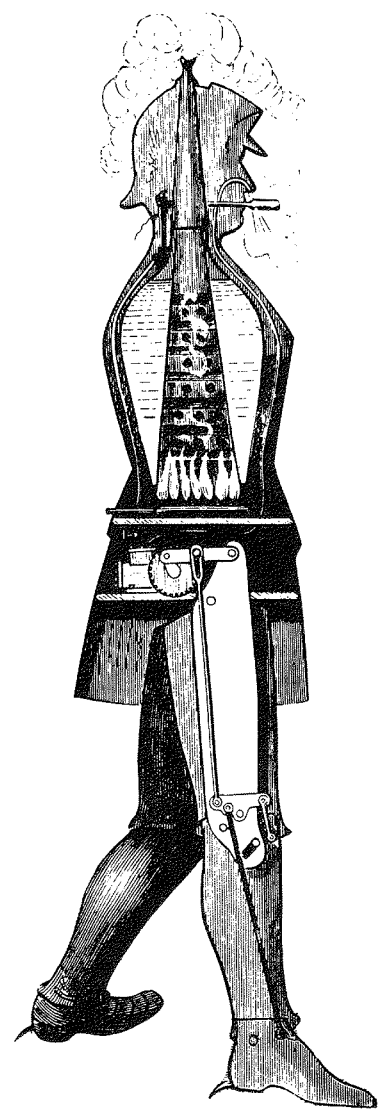
Why are students so busy? Is there time for speculative work?
The speculative, the theoretical, the impractical, the risky, the uncertain. I think students who have eight 40-minute periods in a day have little time for this sort of learning or pondering.

As a poetry teacher who often goes from class to class rapidly, without time to think about what came before and what is to come, I find that this pace interferes with my own writing abilities. This aspect of the current American school is one of the reasons to make use of freewriting techniques, which provide peaceful and valuable thinking time in the course of a sometimes intellectually ravaged day.

What do you do when writing becomes boring?
It's good for students to know, at some point, that writing can be a tedious task. When writing and writers come into a school or class for the first time—or when teachers allow time for writing—the enthusiasm, break from routine, and exciting exercises introduced, along with the chances for class readings and publications, can lead to the idea that writing doesn't ever have to be hard work. There's a difference between "This is boring because I hate writing" and "This is boring because it's difficult." If difficulty becomes an issue, I've found it useful to have students work at home, where sometimes they can concentrate better. Not all students will do writing at home if grades aren't being given, but those who do will have fun. If boredom is the issue, it sometimes helps to bring a large number of science texts to class and leave them lying around for students to peruse. Also, younger students sometimes love what older students find boring, and vice versa.

Why do so many schools ignore writing as a tool for expression and the understanding of concepts?
I don't understand it. When my daughter Marie was in the fifth grade, I asked her teacher why Marie was considered to be a good student when she couldn't really write, though she read a lot. The teacher replied that that was the way it was nowadays. Later I asked an eighth-grade teacher in a school where I was working why writing could not be a five-days-a-week class in the school, even if it could not yet be introduced "across the curriculum." Her answer was that there was no teacher qualified to teach it and that, if there were, that person wouldn't want to have so many papers to correct. A twelfth-grade student who had attended schools in three foreign countries told me, "In those schools, all we ever did was write, all day long."

I don't know the whole answer to this question, but I do know that memorizing facts and getting good test results seem to have supplanted reasoning and writing in many American schools, perhaps because of the increasingly job-oriented nature of the American school. ●



Science Writing Experiments

by Bernadette Mayer

Experiments with dailiness

Have students write on subjects such as the science of cooking (both at home and in the laboratory); how guns work; what ballpoints are; how jets go; what languages are; how color TV works; how a flash bulb works; why a ship floats; what glass is; how gas and water meters work; how an automatic transmission works; what a quartz clock is; what the difference is between a compression refrigerator and an absorption refrigerator; what plexiglass, enamel, rubber, and porcelain are; why and how toilets and door locks work and don't work; and what a differential gear is. Good references for such subjects are *The Way Things Work* (no author credited) and *Extraordinary Origins of Everyday Things* by Charles Panati.

Everyone can present subjects in the form of questions, answers or suggestions, then research and write about them in the form of essays or poems that are both ruminative and factual.

Experiments with sound

Echo was a nymph in Greek mythology. Because of her unrequited love for Narcissus, who had fallen in love with his own image, Echo pined away until only her voice remained. Another version of the myth says that Hera, Zeus's wife, deprived Echo of her power of speech unless she was spoken to first, and then she was compelled to reply with the same last word that had been spoken. Hera did this because Echo was trying to distract her, by incessant talking, from Zeus' dalliances with the other nymphs.

Echoes, sonar, and radar are forms of reflection and repetition, ranging from bats to whales to poetry to mountain yodelling. *Echo ranging* is the generic term for obtaining data about distant objects by the transmission of energy and the reception of its reflection.

SONAR means SO(ound) N(avigation) A(nd) R(anging). RADAR is an acronym of RA(dio) D(etecting) A(nd) R(anging).

Excellent and mysterious poems have been made by humans (and maybe whales and dolphins!) using echoes. Here are some examples by humans.

If I address the Echo yonder,
What will its answer be I wonder?
(Echo) I wonder.

O, wondrous Echo, tell me, bless,
Am I for marriage or celibacy?
Silly Bessy.

If then to win a maid I try,
Shall I find her a property?
A proper tie.

If neither being grave nor funny
Will win the maid to matrimony?
Try money.

If I should try to gain her heart,
Shall I go plain, or rather smart?
Smart.

She mayn't love dress, and I, again, then
May come too smart, and she'll complain then?
Come plain then.

—Excerpt from anonymous 17th-century poem

From "An Echo"

Ah, will no soul give eare unto my mone? one.
Who answers thus so kindly when I crie? I.
What fostered thee that pities my despair? aire.
Thou babbling guest, what know'st thou of my fall? all.
What did I when I first my faire disclos'd. los'd.
Where was my reason, that it would not doubt? out.
What can'st thou tell me of my ladies will? ill.

—Lord Stirling (1604)

Heaven

O who will show me those delights on high?
Echo. I.
Thou Echo, thou art mortall, all men know.
Echo. No.
Wert thou not born among the trees and leaves?
Echo. Leaves.
And are there any leaves, that still abide?
Echo. Bide.
What leaves are they? impart the matter wholly.
Echo. Holy.
Are holy leaves the Echo then of blisse?
Echo. Yes.
Then tell me, what is that supreme delight?
Echo. Light.
Light to the minde: what shall the will enjoy:
Echo. Joy.
But are there cares and businesse with the pleasure?
Echo. Leisure.
Light, joy, and leisure; but shall they persever?
Echo. Ever.

—George Herbert (1593-1633)

Here's a contemporary and deliriously whimsical example:

From "The Echo"

Violets! No flower can compare
Pair

With your frail beauty
Yooty
As I bend down to sniff you
If you
I must declare
Air
That such frail power
Hour
Resides in your frail beauty
Ooty
That like a frail bunny
Unny
I must beware
Where
Lest by some chance
Ants
I too beguiled
I'ld
Should rest, should stay
A
Here by your fragrant bosom
Uzzim.

—*Kenneth Koch*

Some classroom experiments could include:

- Write an echo poem from the point of view of any combination of the following: an average person, a nymph deprived of all but echoic speech, an alien, a scientist, a whale, etc.
- Write a brief essay on what is sound and how does it return to us? Also, what is noise?
- Write about the noises you hear right now.
- Listen to them and imitate them vocally and on paper. (Echo them.)
- In an essay, attempt to communicate with other species.
- Visit an aquarium (or buy a record) and listen to eels, whales, and dolphins. Translate their speech. What time is it for them? Do they know you? Who is visiting whom? Can whales' language be heard by us more clearly than ours by them? Do we interpret emotionally or scientifically? (P.S. Let's make ourselves the subjects of ranging. Let's let the experts—the other mammals who can speak—study us.)

Permutations in writing

What we hear is often random, and in terms of astrophysics the universe is quite unpredictable, even chaotic.

Have everyone reorganize or reorder science or mathematics material at random, as an attempt at the total transformation or complete (chance) rearrangement of any given, based on the idea of interchanging. This is an experiment in discovering whether permutations create new ideas. If 1, 2, and 3 taken two at a time can be 12, 21, 13, 31, 23 and 32 (six combinations), then words, lines, phrases, and sentences put together in random combinations might do something different too.

In music, John Cage and other composers have made use of random methods that include computers; the throwing of dice; the methods of the ancient Chinese text, the *I Ching*; incorporating everyday sounds in composition; and chance techniques to determine, on stage, in what order and way a work is to be performed. Painters such as Jackson Pollack also used randomness by splattering canvases with accidental dots, splashes, and patterns of color reminiscent of the visual data of electronics and of astronomy. The poet Jackson MacLow incorporates chance into both the reading and writing of his poetry, through the random introduction of words and phrases from outside sources, as well as different reading methods, rendering the work different every time it is seen or heard. Of course, at the moment of the creation of a work through aleatory methods, its new meaning may not be apparent.

Writing techniques that can be used in the classroom include: making the last sentence be the first, the penultimate the second, etc.; numbering a poem or essay's sections from 1 to 6 (or 12) and throwing the die (or dice) to determine a new order; combining the first word and the last words of each typed or written line to discover what new combinations of thoughts eventuate; cutting pages in quarters and replacing one quadrant with another; finding clues from numbers that appear at random, such as the temperature; taking all the words and phrases that "stand out" in a given piece of writing and making a list of them to discover why they seem important; repeating things that "stand out"; combining two or more people's writings on the same subject by interspersing paragraphs, phrases, or ideas; reading a text backwards; and inventing new chance methods of one's own.

When dealing with the operations of chance, simple methods create results as magical as complex ones. And what about 11, 22, and 33? Repetition can be explored mathematically and verbally.

Here is an excerpt from a verbal example of repetition called "If I Told Him, a Completed Portrait of Picasso," by the early 20th-century experimental writer, Gertrude Stein:

If I told him would he like it. Would he like
it if I told him.
Would he like it would Napoleon would
Napoleon would that he like it.
If Napoleon if I told him if I
told him if Napoleon. Would he like it if
I told him if I told him if Napoleon.
Would he like it if Napoleon if Napoleon
if I told him. If I told him if Napoleon
if Napoleon if I told him. If I told
him would he like it would he like
it if I told him...

Presently.
Exactly do they do.
First exactly.
Exactly do they do too.
First exactly.
And first exactly.
Exactly do they do.
And first exactly and exactly.
And do they do.
At first exactly and first exactly
and do they do.
The first exactly.
And do they do.
The first exactly.
At first exactly.
First as exactly.
At first as exactly.
Presently.
As presently.
As as presently.
He he he he and he and he and
and he and he and he and and as and
as he and as he and he. He is and as
he is, and as he is and he is, he

is and as he and he and as he is
and he and he and and he and
he.

Repetition jogs us into thinking of words and ideas in new ways.

A history of one's own ideas

When Albert Einstein was asked to write his autobiography, he wrote little about his personal life and mainly about the history of the development of the ideas that led to the general and special theories of relativity and to his other conceptions in physics.

Students and teachers can set aside a day or a week or a year to attempt to write a history of the development of the scientific ideas that have influenced them most, how and why, and what might happen in the future. Such histories or autobiographies of ideas most often will be written in the form of discursive prose, which may be interspersed with diagrams, equations, illustrations, and other visual data. Occasionally a history of an individual's ideas has been written in poetic form, for example Wordsworth's *The Prelude* and R. Buckminster Fuller's *How Little I Know,* two long poems. The work need not be long, however.

When Einstein wrote his history, he spoke abstractly about the concepts of thinking and wonder, and about the feelings of awe experienced in childhood. In writing such a history, it's vital to recognize that the way we think, learn to think, reach conclusions, and create questions are as much the stuff for analysis as what we know (and what we do not know).

A good way to begin this project is to discuss childhood memories, especially those that relate to wonder and awe.

Mutual aid

This involves writing and thinking about the evolutionary concept of the sociability, mutual protection, and shared struggle for existence of ants, bees, bird, and humans in primitive tribes and in cities.

It's fun to begin this experiment by bringing an ant colony to class and then asking "Why do we live in cities?" The writing exercise can be based on direct observation or on memories of mutual aid among human beings. Here is an example:

> Organisms help each other so that they may survive and evolve faster. Yesterday I had to babysit in Manhattan. I had to take care of two kids, one is four years old, the other twice her age. I had a problem getting them to go to sleep because they both refused to go to bed on time. Both of them fell asleep at about ten thirty and I went to bed an hour after that.

This is a good experiment to use after discussing Darwin, since, in high school today, the concept of mutual aid creates as spirited a set of disagreements about human nature as what I've come to think of as the general and special theories of evolution create about the relationship between religious and scientific belief.

Peripatetic scientists

The word "peripatetic" comes from the Greek *peripatein*, to walk around, and from the Indo-European base *pent*, "to step" or "to go" (related to the words "find" and "bridge"). It refers to the followers of Aristotle, called peripatetics, who walked about in the Lyceum while he was teaching.

Have students take a walk together, discussing scientific matters, observing, and making notes about everything. The scope of discussion can be limited to the sizes of things, the colors of things, types of trees, questions concerning the construction of cities, kinds of materials and stone observed, the weather, and so on. Written records can be gathered and compared in the classroom. The ambience of this experiment can be either intently serious or lighthearted and hilarious. It seems to work either way. Stress the importance of detailed observation.

Science acrostics

The acrostic is a poem in which the first letters of each line, read downwards, form a word, phrase, or sentence. The subject of each poem can relate to its "spine-word," or not. In the first three acrostics below, the vertical word is "science":

> Science seems to
> Come into every
> Introduction to
> Every last
> Notion at the Manhattan
> Center of
> Entropy

> Science places
> Calm clams
> In
> Every Ocean
> Nothing is
> Critical but
> $E = MC^2$

> Science is
> Corrupt yet maybe
> It is not.
> Everything
> New
> Contains
> Everything
>
> —*Anonymous*

Here are some examples for "atoms," "math," "philosophy," "absolute value," and "factorization."

> All
> Tiny
> Objects
> Make
> Sense
> —*Rodney Pink*

> Maybe the most
> Astonishing subject,
> Terrorizes and
> Hard.
> —*Yesenia Ramos*

People
Have
Incredible
Love
Of
Space
Other
People
Have
Yaks
—*Eurik Perez*

Absolutely un
Believable the way
Some people understand the value
Of math just
Like adding of integers it's really
Unbelievable
The way you know what you're saying
Even if you don't

Valuable math
And
Like addition of integers
Understanding a person's language
Even in English
—*James E. Rivera*

Fast
And
Complicated
The
Others say
Really not hard but not easy either
I think the way they think
Zooming around around
And
Thinking
It
Over and over again
Nagging about the things they know
—*James Rivera*

Acrostics can also have the vertical word at the end of the line or in the middle. This is an especially useful form for developing verbal inventiveness. In science classes, it is marvelous to see metaphor lead to new ideas and speculation about scientific subjects through the use of the acrostic.

The use of etymologies

In class, make frequent use of the origins of science words such as "atom," "decimal," and "epiphysis." Students and teachers should rapidly get out their dictionaries to find the unique clues to understanding that etymologies often provide.

Here are some examples:

- muscle: from the Latin *musculus*, meaning "little mouse."
- science: from the Latin *scire*, "to know, to cut, to divide, to separate" (related to "skill" from the Swedish *skäl*, meaning "reason," and the Icelandic *skilja*, meaning "it differs"; also related to "sex" from the Latin *secare*, "to cut or separate"), and from the Indo-European root *skei*, related to "scissors."
- mathematics: related to the Greek *manthanein* ("to learn, to be alert"), the Indo-European *meudh* ("to pay attention"), the Persian *mazda* ("memory"), and the German *munter* ("cheerful").

No wonder mathematicians have such good memories, while being cheerful, alert, and attentive. No wonder scientists are always dividing things with their reasoning scissors!

- technology: from the Greek *technologia*, "a systematic treatment," which in turn derives from *techne*, "art or artifice" (from Indo-European *tekth*, "to weave, build, join," whence the Greek *tekton*, "carpenter") and *logos*, meaning "word or science."

An "engineer" (a producer) means much the same as "poet" (a maker), but, etymologically speaking, the engineer has the better of it, being derived from the Latin *ingenium*, related to "genius."

Basic etymologies can be found in most editions of *Webster's Collegiate Dictionary*, in Eric Partridge's *Origins*, in *Skeat's Etymological Dictionary*, and many other etymological dictionaries.

Epistemology

Epistemology comes from the Greek words *episteme*, meaning "knowledge" and *logos*, meaning "word or science." Though it seems formidable to experiment with the origins, nature, method, and limits of knowledge, this becomes the simplest of writing exercises, and works equally well for people of all ages.

Invite students to write a series of ten questions on any or all subjects, and then to write a second series of ten questions about the subject of the class. Then, in a third exercise, have them write about how to find the answers. For instance, what book or library would contain the information I need? If I don't know, whom could I ask? Where is the nearest bird sanctuary? What means of transportation do I use to get there? Can I call the public library or the natural history museum to find the answers to questions? Can I call a professor at a college or university? Can I call someone who works in a private business? Can I call or write the author of an article or book to get answers? Or even, how do I obtain the money to buy an expensive book I need? Finding answers often leads to further questions.

Though the questions need not be answered, a further experiment could be to exchange questions and attempt to answer each other's, then to return them to the questioner for comment.

If there's time, a good summary writing could involve the idea of the questions themselves: How do we know what we know? Can we know everything? Do we know everything just by the fact of existing? Is it important to know the names of all things—rocks, minerals, fish, birds, mammals, stars, flowers, elements, trees, etc.?

A brief example comes from a ninth-grade student:

I know everything I know
Such as
Education
My religion
The danger around us.
—*Herman Zarate*

Complexity of thought

Here's an attempt to create writing that reflects—yet does not speak "about"—the complex nature of thought. Invite everyone to write about the most complex scientific or personal topic they know of, one they feel cannot be understood. Give a variety of possible forms in which the writing could take place: freewriting; discursive writing;

poetic forms; a visual image, as if one were drawing a dream; a design of words on a page singly or in phrases or sentences that seem best to reflect thought. Encourage both the visual and verbal creation of transitions between aspects of a thing or things, an idea or ideas.

Subjects for this experiment have included death, disorder, advanced algebra, nucleic acid, cute guys, philosophy, calculus, the news, and white dwarfs. Here are two examples:

> The square root of 2 to the decimal comma by E = mc^2 to the supposed interest of man to space if a dehydration to the skin and to mind biology and biochemistry mix/do not mix with each other has me to the waterplow to a toilet bowl to a field of gumdrops up and down all around jump hop skip don't matter where you land fall up throw down dog meow and a cat barks he can they do because of me to he of me you see. The dreams of an unknown turtle to me to be again you see if we dream of monsters, creatures and things that'll go bump in the night a mouse dreams about a cat a cat dreams about a dog what does a dog dream about it's come to Christmas time for humbug and time for taking do you think I'm going to jump low, walk low, that's the way to do it. Pretend in a dream just jump into someone's hair and be in a forest.
>
> *—Eurik Perez*

> Dis ain't da way I should rite
> I should bee more intelligent
> Maybe I Should learn more to make da world better
> Or should I stay da same and cauze more
> DisoRder
> I Did not mean to hurt u, i didn't know
> Excuse me if i cry.
> Remember mee cauze i'm not
> important but two me I'm
> quite brite.
>
> *—Hank Bueno*

An attitude of silence to the stars

This poem by Walt Whitman expresses the simultaneous doubt and wonder of the student (and teacher) of any science:

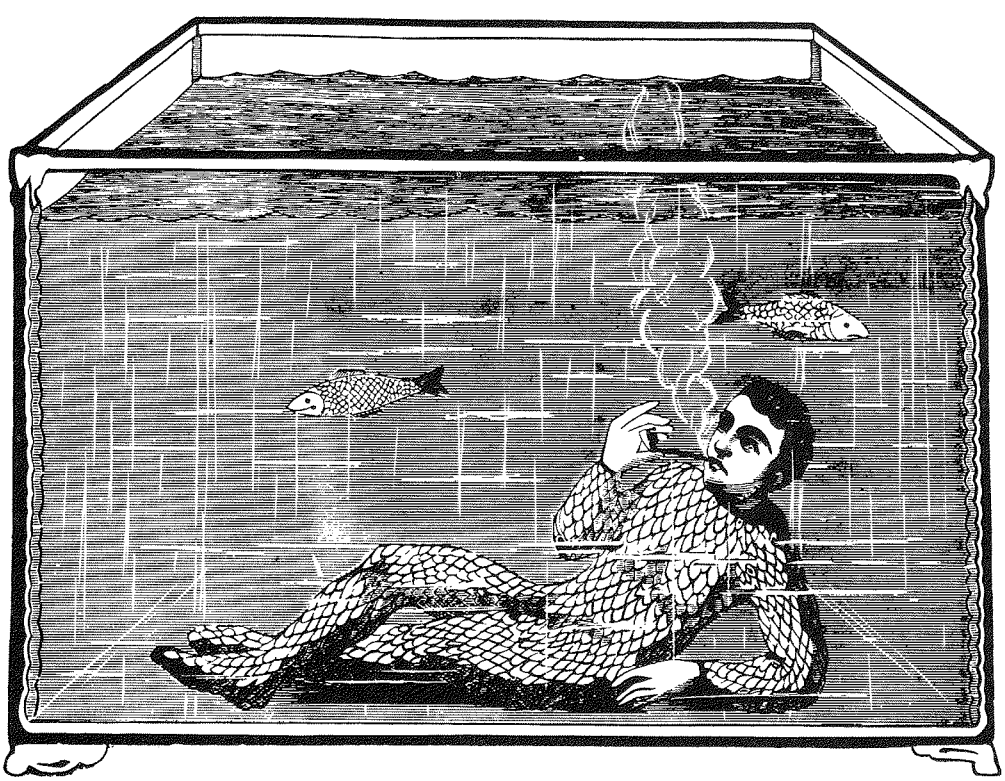
> **When I Heard the Learn'd Astronomer**
> When I heard the learn'd astronomer,
> When the proofs, the figures, were ranged in columns before me,
> When I was shown the charts and diagrams, to add, divide, and measure them,
> When I sitting heard the astronomer where he lectured with much applause in the lecture-room,
> How soon unaccountable I became tired and sick,
> Till rising and gliding out I wander'd off by myself,
> In the mystical moist night-air, and from time to time,
> Look'd up in perfect silence at the stars.

Study the poem, thinking of the beauty of natural events and of the gorgeousness of scientific ideas, then imitate the poem by writing a piece that begins, as the poem does, with four "when's," followed by "how..." and "till...."

When preparing to write, think of the idea of silence in combination with studying and teaching and writing. Think of why we choose to express some things and not others. How much do we know? What have we seen?

Should we then not investigate, put things into words or formulae? Is science dull and unrelated to the stars, the clouds, the weather, the fruits and vegetables we eat, to sex and love, to evolution, to the complex matters of death and wealth, to the daily matters of where our water and electricity come from?

The piece could end with a sentence about silence—how it can be "perfect." ●



Science & Poetry Writing
In the Elementary School

by Carol F. Peck

As writer-in-residence at an elementary school, I have enjoyed designing writing projects that plug into other curricular areas, especially science. Children have no problem linking poetry and science. Scientific facts can turn into exciting images, and the whole idea of metaphor can enhance all scientific study—everything can be viewed with "new eyes." Furthermore, children do not worry about blending fantasy and fact into a unified work of art, as several of the example poems below will show.

In our school, second-graders study magnetism, for which I have devised "Poetic Magnetic Fields," which uses scientific terminology and concepts but applies them to people and their lives. First, I discuss the idea with the class, making sure that they understand the terms "attract" and "repel." Then we talk about various things that attract and repel us in daily life—foods, colors, people, animals, books, hobbies, music, etc. I point out how a collection of the things that attract and repel each of us really gives a thumbnail sketch of us. Then I give each student a prepared form, showing bar magnets in both "Attract" and "Repel" groupings to create a magnetic field, like the one below (but not filled in). I urge them to appeal to all five senses with a wide variety of specifics—not all food, or all animals because, as they tell me, "that would be boring!" (For second- and third-graders, filling in the diagram is usually enough; I have older students do this as a first step and then use the specifics to create a brief self-portrait poem. I thought "Magnetic Fields" was probably limited to grades 2 through 4 until I did a workshop during which a high school teacher exclaimed, "Magnetic Fields is perfect for some of my juniors!")

This project proved useful for a Parents' Night display: I had the children use the form to create verbal self-portraits, but they did not put their names on them. Instead, the teacher posted them around the room and had parents try to guess their child's identity from their "Attract" and "Repel" images.

Children often study spiders, insects, and whales, all of which lend themselves to writing projects. For example, once children know several facts about spiders, they are ready to become spiders imaginatively, weaving fact and fiction to suit their fancies. Usually I limit them to eight lines in developing If I Were a Spider so that the results may be written onto eight thin strips of colored paper that become the legs of a huge paper spider whose body carries the child's name and "If I Were a Spider..." and which looks great hung from the classroom ceiling.

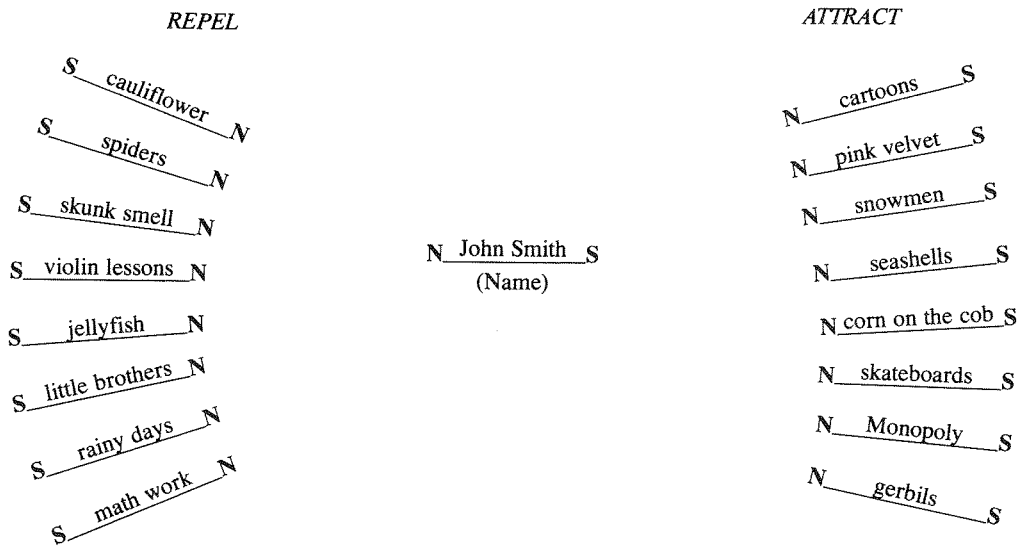
If I Were a Spider

I would spin a silky web and
All the little bugs I caught would take a long time to eat;
I would watch out for enemies;
I would be golden brown;
My web would be shining gold with dew drops;
And when I caught a bug I would jump back;
Then I would wrap it up;
And if a person looked at me I would hide under a leaf.

—Second-grader

Insect study leads to discussion of the compound eye. I cut plastic drinking straws in half, bind them with rubber

My Magnetic Field



bands into groupings of about 25, and ask the children to view the world through these "compound eyes." Describing a fragmented world is not easy, but they rise to the challenge.

The world looks like
Some beautiful bubbles
Floating down
And some ice cubes
And pieces of cut-up paper.

—Second-grader

The world looks like
It's coming here
Then popping out at you there—
It shatters the here and there.

—Second-grader

The world looks all sprinkly!

—Second-grader

Insect songs are varied, and a few years ago I made a back-porch tape of those heard on an evening late in August. I talk with the students briefly about insect music and then play the tape, asking them to sift out and identify the separate songs and then to transform themselves into one of the insects (this needs total silence except for the tape). Then each writes down the words of the song that particular insect is singing.

Katydid's Song

I am a katydid,
A lonely, lonely katydid;
I try to make friends,
But each time they go away—
So I guess I am a
Lonely katydid;
So I guess I am going
To have to live with it.

—Second-grader

Cicada's Song

Oh moon, you make me feel good,
You make me want to climb up
And see you;
I sing to the moon
Trying to make it come down
And pick me off the ground.

—First-grade (dictated)

Mantis Song

I sing about how bright
My wings are—
They look black and grayish
And different from the birds'.
I feel proud of my hands—
They can catch crickets!
I sing about my eyes—
They are large and wide—
They like to look at crickets
And other insects!

—Kindergartner (dictated)

Another "song" project involves whales. There are several good tapes and records of whale songs, often with good liner notes. I ask the class to listen to the songs, imagine themselves as whales, and—based on their knowledge as well as their imaginations—to write down the words of the song a whale might sing.

Whale Song

I sing a song of happiness;
I sing of diving in the stars;
I sing of owning the world;
The song I sing is of peace for all;
A whale sings of eating a squid;
My song is for being the king of the sea;
I sing of going over the ocean at top speed.

—Third-grader

Whale Song

I hear the sound of rain,
I swim the watery lane;
I sing of the stars,
I sing of my magical world, the sea;
I'm brutally hunted, murdered,
I sing of sapphires, rubies and jade,
Of pearls, gold and silver,
Of all jewels;
That is me,
The jewel of the sea.

—Third-grader

Rainbows are a popular elementary science study, and after students learn the technical reasons for a rainbow's various colors, we write fantasies about their origins.

Where Do Rainbows Come From?

A giant once wanted to paint a picture;
When he finished, he didn't like it;
He threw it out and it hit a cloud;
A cloud person found it
And thought it would be nice if he bent it;
So he bent it and laid it on two clouds.

—Second-grader

This works equally well for studies of leaves. Even the youngest children not only collect and classify them but also learn why and how they change color in the fall. After students learn those technical reasons, we write our fanciful explanations.

Fire Is...

Crackling!
Red, blue and yellow,
Rocketing into the air.
Fire is
Devastating!
It devours anything in its way
Except the evergreens
Which are somehow mysteriously
Protected.
Fire is racing!
From one tree to another,
Never stopping,
Until winter smothers it.

Fire is a golden treasure
Displayed on every tree,
The maple tree full of rubies
and topazes.
Fire is a thundering sound,
The blinding dazzle of the sun.
The
leaves
fall
down
off
the
trees—
hit
the
ground
and
die.

—Third-grader

How Leaves Change Color

A magic wind changes the roots
which have little bugs that go up
the tree and make the leaves
change color. The bugs put a
magic formula into the leaves.

—Kindergartner (dictated)

How Leaves Change Color

The trees turn colors from the
summer. All the different colors
come from different animals—
the red comes from a caterpillar's
dots, the yellow comes from a
butterfly, the orange comes from
a tiger, the green comes from a
grasshopper, purple from an owl,
magenta from a magic heart that
has feet, arms and head, and blue
from a blue monster!

—First-grader (dictated)

How Do Leaves Change Color?

Clouds turn colors
And shine down on the leaves.
They catch the reflections
And stay that way.

—Kindergartner (dictated)

Actually, any natural or scientific fact can become a source for a poem in which the poet becomes it, comments upon it, or invents an explanation for it.

Wind

I am a wind that blows the feathers on birds;
I talk cool to the sun!
Sometimes when I go to the playground with children
I make their hair fly up!
I live in the attic of heaven.

—Kindergartner (dictated)

Sun Song

If I were the sun
I would light the earth;
I would eat stars to make me brighter;
My friends would be Mercury and Earth;
I would go to Venus on vacation
And bounce up and down on the volcanos!

—Kindergartner (dictated)

Cloud

If I were a cloud
I would get a stomach ache when planes went through me;
I would be friends with the sun;
I would make hail;
I would go to the sea and get some steam;
I would make a mackerel cloud.

—Second-grader

Frogs

Frogs jump from a green lily
To a yellow lily because
They like the feeling of flying
From earth to sun and back
Without wings.

—Fourth-grader

Wine

Grapes
Fall
From
Vines
So they can
Construct
New
Lives,
But
Instead
They
End up
Being
Stomped on
By French
Men.

—Fourth-grader

In short, children make no false dichotomy between science and poetry; they seem to realize that accurate observation, imagination, and respect for truth are vital to both and that together the two disciplines can strengthen, enhance, and enrich each other. ●

A Brief Science/Writing Bibliography

by Bernadette Mayer & Dale Worsley

Abbott, Edwin A. *Flatland: a Romance of Many Dimensions* (Barnes & Noble, 1963). A first-person narrative about life in two dimensions and its expansion into the third. A classic fantasy about geometry.

Akimushkin, Igor. *Animal Travellers* (Moscow: Mir Publishers, 1970). About the method and reason in the migrations and wanderings of ancient and contemporary animals and insects. Excellent titles, beginnings and endings to individual essays. Contains astonishing information.

Amadon, Alfred M. *The Fold-Out Atlas of the Human Body* (Crown, 1984). Beautiful full-color replicas of the human body in the form of multi-layered, illustrated, movable fold-out plates. A reprint of the 1906 edition of the *Atlas of Physiology and Anatomy of the Human Body.*

Audubon, John James. *Selected Birds and Quadrupeds of North America* (Montreal, Quebec: Optimum Publishing Company Limited, 1978). One of many interesting collections of this great naturalist-artist's work. A good way to see how it was done when sciences such as ornithology were in their infancy. Also see other editions of his field work, as well as his *Journals.*

Bohren, Craig F. *Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics* (John Wiley, 1987). Answers to questions about natural phenomena.

Bronowski, J., & Selsam, M. *Biography of an Atom* (Harper & Row, 1987). Grades 4-7.

Brown, A.E., & Jeffcott, H.A., Jr. *Absolutely Mad Inventions* (Dover, 1970). Delightful.

Byrd, Richard E. *Alone* (Putnam's, 1938). A diary of the scientific experiments and personal experiences of Byrd's months spent manning the advance weather base in the Antarctic winter night of 1934. This text can be used to show the value of diaries in scientific studies, as well as the metaphorical and real risks involved in such exploration and experimentation.

Carson, Rachel, *The Sea Around Us* (Signet, 1961, and many other editions). Carson's classic science of the sea, beginning: "Beginnings are apt to be shadowy, and so it is with the beginnings of that great mother of life, the sea." Science, poetic language, perfect essay structure, illustration, and a useful appendix make this book a great example of popular science writing.

Darwin, Charles, and Huxley, T.H. *Autobiographies* (Oxford University Press, 1983). A beautiful contrast in writing styles.

Da Vinci, Leonardo. *The Notebooks of Leonardo Da Vinci.* Jean Paul Richter, ed. Trans. mainly by Mrs. R.C. Bell. Two vols. (Dover, 1970). In English and Italian, profusely illustrated by Leonardo. Includes sections on anatomy, zoology, physiology, astronomy, geography, naval warfare, flying machines, plus humorous writings, lies, and Leonardo's shopping lists. A useful example of the process of combining science writing with visual examples. Also a great example of the attempt at the perception of the whole by a single scientist.

De Bono, Edward. *New Think* (Basic Books, 1967). The uses of lateral thinking in generating new ideas and breaking out of restrictive and habitual thought patterns.

Dillard, Annie. *Pilgrim at Tinker Creek* (Harper & Row, 1974). Concrete observations and mystical insights by a poetic writer. Naturalism in the tradition of *Walden.*

———*Teaching a Stone to Talk: Expeditions and Encounters* (Harper & Row, 1982). The chapter "An Expedition to the Pole" can be useful in studying and teaching the structure of the essay.

Einstein, Albert. *Ideas and Opinions* (Dell, 1954). An anthology of Einstein's general writings: on minorities, scientific truth, atoms, space, freedom, education, pacifism, good and evil, and so on. Includes his 1939 World's Fair time capsule message. In this book, Einstein's writing style is a mixture of practicality and spirit.

Freud, Sigmund. *The Interpretation of Dreams* (Avon, 1965, and many other editions). The first systematic attempt to make a science of the analysis of dreams. Freud uses himself as the subject. A one-of-a-kind scientific text in which the poetry of dreaming is combined with first-rate science writing. Reading the table of contents alone is inspiring.

———*An Outline of Psychoanalysis* (Norton, 1949, and many other editions). Describes the beginnings of psychoanalysis and its practical and theoretical implications. Beautifully and intensely written.

Fuller, R. Buckminster. *And It Came to Pass—Not to Stay* (Macmillan, 1976). Six long science poems by Fuller, including "How Little I Know," "What I Am Trying to Do," and "A Definition of Evolution." This book provides an introduction to epistemology and science poetry.

Fuller, John G. *Tornado Watch #211* (William Morrow & Co., 1987). The scientific and journalistic recounting of a series of tornadoes on one day in 1985 in North America.

Fulwiler, Toby, ed. *The Journal Book* (Boynton/Cook-Heinemann, 1987). The uses of journals in all kinds of classrooms, with a section on "Journals and the Quantitative Disciplines." Many student examples.

Gardner, Martin, ed. *The Sacred Beetle and Other Great Essays in Science* (Prometheus Books, 1984). A revised edition of *Great Essays in Science* (Pocket Books, 1957). A feast of science writing, including some of the most perfect essays. This book alone could provide an entire year's curriculum in science writing. Includes work by Einstein, Lewis Thomas, Freud, Laura Fermi, Maeterlinck, H.G. Wells, Ortega y Gasset, Asimov, Oppenheimer, Whitehead, the Huxleys, Rachel Carson, William James, Stephen Jay Gould, Fabre, Krutch, Sagan, and others.

Gleick, James. *Chaos* (Viking Penguin, 1987). A study of wildness, disorder, and irregularity in the science of the everyday world in an attempt to lead to a unified theory or "theory of everything." Lucid writing with lots of good anecdotes and quotations.

Goodall, Jane. *In the Shadow of Man.* (Houghton Mifflin, 1971). A famous study of chimpanzees in Tanzania, characterized by courageous field work and close observation.

Gould, Stephen Jay. *An Urchin in the Storm* (Norton, 1987). A series of essays about books and science by this teacher of biology, geology, and history of science. The book includes portraits of four eminent biologists. Gould's other books include *Ever Since Darwin, The Panda's Thumb, The Mismeasure of Man,* and *Hen's Teeth and Horse's Toes.*

Heath-Stubbs, John, and Salman, Phillips, eds. *Poems of Science* (Penguin, 1984). An anthology of science poems, including Keats' "There was an awful rainbow once in heaven. . .," Edgar Allan Poe's "To Science," Whitman's "When I Heard the Learn'd Astronomer," Gerard Manley Hopkins' "I am like a slip of comet. . .," Marianne Moore's "Four Quartz Crystal Clocks," Auden's "Unpredictable but Providential," Chaucer's "Sound Waves" from *The House of Fame,* and so on.

Henn, T.R. *The Apple and the Spectroscope* (Norton, 1966). Lectures on poetry designed for students of science. Analyses of works by Donne, Marvell, Blake, Yeats, Shakespeare, Pope, and passages from the Bible. Some interesting equations and diagrams, one of which relates girls to anodes and roses to cathodes. Somebody should write a book like this about contemporary poems.

Herbert, Frank. *Dune* (Berkley Books, 1965). The original ecologically conscious classic science-fiction work.

Kohl, Herbert. *Mathematical Puzzlements: Play and Invention with Mathematics* (Schocken, 1987). More than 250 games, puzzles, paradoxes, and experiments divided into: Patterns on the Plane; Number Patterns; Knots, Maps and Connections; and Logic and Strategy. A book full of new ideas.

Kohl, Judith, and Kohl, Herbert. *The View from the Oak* (Sierra Club/Scribner's, 1977). Inspired by Jacob von Uexkull's essay "A Stroll through the World of Animals and Men: a Picture Book of Invisible Worlds," this book scientifically gives the view from the stance of the Other. Great illustrations. How to perceive time as animals might. A worldview free of the egocentric.

Lilly, John C. *The Scientist* (Bantam, 1978). An autobiography by the famous experimenter with dolphin communication, neurophysiology, consciousness-expanding drugs, isolation tanks, and communication with extraterrestrial beings. The chapters "Life Refuses Closure" and "Simulation of the Future of Man, Dolphin, and Whale" are examples of good writing.

Lucretius. *On the Nature of Things* (Norton, 1977, and many other editions). An ontological poem written in Rome c. 60 B.C. on the origin of the world, fear of death, the development of society, and the philosophy of Epicurus.

Manning, Kenneth R. *Black Apollo of Science: the Life of Ernest Everett Just* (Oxford University Press, 1983). An excellent biography of a prominent marine biologist who was forced to overcome nearly insuperable obstacles of racism.

McPhee, John. *Oranges* (Farrar, Straus and Giroux, 1966). The history of the botany and industry of oranges and orange juice. A good example of how to write about an ordinary subject with poetic spirit and memorable scientific implication.

Mead, Margaret. *Coming of Age in Samoa* (Morrow Quill Paperbacks, 1973, and many other editions). A groundbreaking anthropological work focusing on adolescent girls in Samoa. It poses the questions "Are the disturbances which vex adolescents due to the nature of adolescence itself or to the civilization? Under different conditions does adolescence present a different picture?"

Panti, Charles. *Extraordinary Origins of Everyday Things* (Harper & Row, 1987). Stories of the origins of customs, superstitions, kitchen and bathroom implements, central heating, seeds, cosmetics, marbles, buttons, top hats, graham crackers, and so on.

Rucker, Rudy, ed. *Mathenauts: Tales of Mathematical Wonder* (Arbor House, 1987). Twenty-three mind-blowing short stories written to torture and delight all mathematics students and those who love the pleasures of puzzles. Includes work by Isaac Asimov, Greg Bear, Ian Watson, Martin Gardner, Frederik Pohl, and others. Rucker is also the author of *Spacetime Donuts, The Sex Sphere, Master of Space and Time,* and ten other books.

Sagan, Carl. *Cosmos* (Ballantine Books, 1980). The best-seller based on the TV series. Chock-full of history, wonderments, speculations about everything mathematical and scientific.

Sauer, Carl O. *Man in Nature* (Turtle Island Foundation, 1975). An unusual geography textbook about North and Central America before the advent of the white man. Though intended for the middle grades, it's useful to everyone.

Stevenson, Robert Louis. *Dr. Jekyll and Mr. Hyde* (Bantam Books, 1985, and many other editions). The classic, originally published in 1886. Resonates nicely against current misapplications of science and the abuse of chemical substances.

Tart, Charles, ed. *Altered States of Consciousness* (John Wiley, 1969). An anthology of scientific essays on dream consciousness, meditation, waking and pre-sleep imagery, hypnosis, psychedelic drugs, and the physiology of trance states. Includes Kilton Stewart's famous essay on problem solving through dreaming among the Senoi tribe of Malaya.

Ternes, Alan, ed. *Ants, Indians, and Little Dinosaurs* (Scribner's, 1975). An anthology of writing from *Natural History* magazine, including delights by Margaret Mead, N. Scott Momaday, and Oliver La Farge. Divided into four parts: On Fauna and a Stone Age Friend; On Fossils, Famous and Obscure; On Natives and Naiveté; On Famine, Floods, and the Future.

Vare, Ethlie Ann, and Ptacek, Greg. *Mothers of Invention* (Wm. Morrow & Co., 1988). A history of women inventors.

Watson, James D. *The Double Helix* (Signet, 1968). A wonderfully gossipy account of the discovery of the structure of DNA by some wild young geniuses.