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Cambium

VOL. 4, NUMBER 1

INNOVATIVE K-8 CURRICULUM FROM THE ARBOR SCHOOL OF ARTS & SCIENCES

REAL WORK, REAL RISK, REAL REWARD

During its conception and crafting, this issue of Cambium has been known in-house as "The *Why* of the Crazy *How*." Whenever the conversation among Arbor School faculty turns to our most fundamental aims and the search for evidence that our students are absorbing the ideas and forming the habits we hope will be most enduring, we find ourselves talking about the projects and practices that may baffle the uninitiated onlooker. Why would any school choose to spend months preparing an outdoor Shakespeare production involving every student from the kindergarten on up? Why not let the grounds crew maintain the campus rather than sending children into the woods to pull invasive ivy during school hours? Why are we asking kids to write their papers longhand — and where's the computer lab?

We're aware that some of what we do at Arbor seems to defy convention and even common sense. But there is method — and, better yet, deep and oft-evaluated planfulness — in the madness. So we've decided to use this issue to reveal the considerations that underlay our sometimes inefficient, sometimes laborious, sometimes downright crazy ways of guiding children toward authentic and lasting mastery. Within these pages you'll find our students setting lead type upside down and backwards in a hundred-year-old printing press; painstakingly hand-sewing intricate designs of brightly colored felt and buttons to create Northwest Coast native-inspired costumes; learning about algebraic functions by telling some *very* silly stories; and constructing forts from old tires and sheets of plywood at Recess. Why? Read on.

In this issue

Adlai, Maxwell, and Miah play in a woods fort they built entirely of natural materials

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ARBOR SCHOOL
OF ARTS & SCIENCES

THE PEN & THE PRESS

INTERMEDIATES EXPERIENCE THE LITERARY REVOLUTION

by Eliza Nelson and Daniel Shaw, grade 4-5

rbor's Intermediate classroom may reveal some surprising scenes for visitors when the Inventions and Discoveries curriculum is in full swing every second year. Perhaps, in dim lighting, to the solemn sounds of Gregorian chant, our guests will spot fourth and fifth graders patiently scribing their own illuminated manuscripts with calligraphy pens. They may witness a small tribe of focused students scanning trays of type, selecting and setting letters in order to print their writing on our inky, clanking Chandler press. On another morning, they might watch a band of teachers, parent volunteers, and 45 children sewing and binding individual copies of a class-made book. Why do we spend great gobs of time on such elaborate and archaic endeavors, especially when shortcuts and modern efficiencies abound? This is a question we have asked and answered many times.

One of the crucial human inventions we explore with students on their journey from ancient times through the Renaissance is the development of writing. From the cuneiform used to depict the world's first recorded story in Sumer to Egyptian hieroglyphs to the breakthrough of the alphabet as a way to indicate individual sounds rather than whole words; from Homer's *Odyssey* to Shakespeare's sonnets; from gilded, hand-copied Bibles to Martin Luther's printed pamphlets, we want the Intermediates to gain appreciation for the power and beauty of writing through deep instruction on the revolution that was the alphabet, the pen, the press. We can and do immerse them in research and stories about the history of writing, but we also want them to strengthen their knowledge through the romance and precise efforts of authentic experience. In fact, so memorable do these experiences prove to be that, since the early days of Arbor, all Intermediates have taken part in scribing medieval stories and producing a class book on a printing press. These have become well-loved traditions, rites of passage in every student's Arbor career.

During the fall term we trace the development of the alphabet in Egypt, Sinai, Phoenicia, Greece, and the Roman Empire. We read *Gilgamesh*, the earliest great work of literature, considering its timeless themes of power and friendship and comparing its destructive flood with that of the familiar Old Testament tale. But the crown jewel of the Intermediates' study of writing comes when we turn to the medieval scriptorium in mid-winter — always our chosen time to explore the Dark Ages. While studying medieval times, we aim to give the students a sense for daily life all those centuries ago in Europe and the East. Through shared non-fiction readings, medieval book groups (see Sidebar), and independent research on medieval tradesmen, churchmen, peasants, and nobility, we help the kids build understanding of the priorities, realities, and challenges of life in medieval society. With this background the Intermediates ready themselves for writing their own medieval stories. Each child thoughtfully completes a planning sheet, deciding on the main problem and solution of her story, as well as particulars of character, setting, and historical reality.

When at last we have a class set of story drafts to read and comment upon, we invariably encounter tales of hope and change, with characters who rise up to better their lives. It is a subtle art to help kids revise their stories for historical accuracy — reflecting the static, hierarchical structure of life in the Middle Ages — without squashing their youthful optimism and compassion. Once we have made teacherly attempts to walk that tricky line, our Intermediates are ready for the fun of finalizing their fiction.

Some of our favorite medieval fiction:

The Young Merlin Trilogy,
Jane Yolen

Catherine, Called Birdy &
The Midwife's Apprentice,
Karen Cushman

A Proud Taste for Scarlet and Miniver,
E.L. Konigsburg

Leif the Unlucky,
Erik Christian Haugaard

Adam of the Road,
Elizabeth Janet Gray

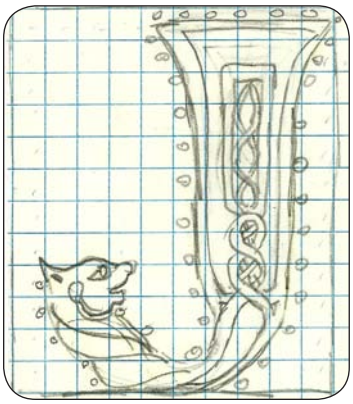
The Adventures of Robinhood,
Roger Lancelyn Green

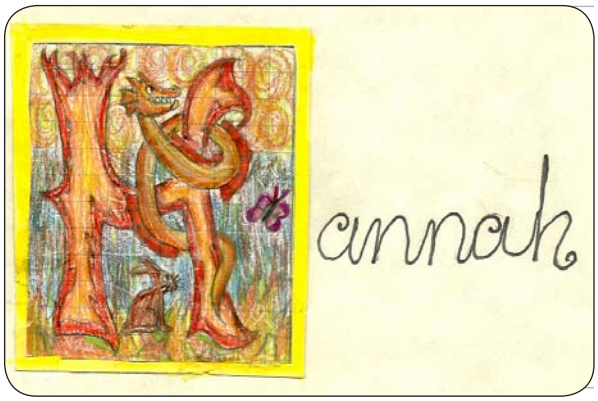
The Sword and the Stone,
T.H. White

A Parcel of Patterns
Jill Paton Walsh

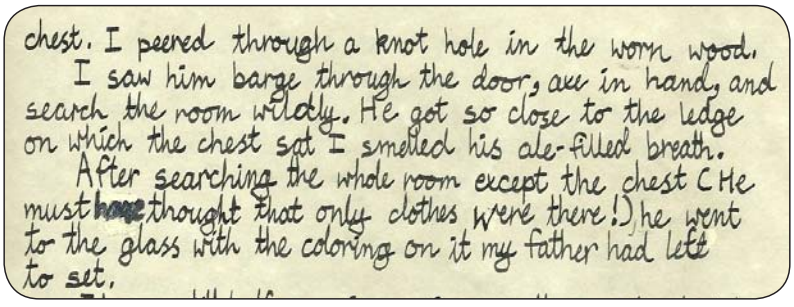
Quest for a Maid
Frances Mary Hendry

We begin the process by conducting workshops on medieval illumination. Students learn the history of the art, view examples (real ones, in lucky years when we can arrange a visit to the rare books collection at nearby Reed College), and design their first letters on graph paper. We usually have them begin with their own initials, and we emphasize the creation of substantial letterforms that fill out the framed space. After this initial practice, each child creates a detailed illumination for the first letter of his story. Designs around the letter itself reflect characters or scenes from the tale. Colored pencil shading and gilded gel pen bring each child's intricate art alive on a small card that can later be glued onto the correct story page.





We begin the actual story recopying with great ceremony, celebrating the skill and dedication of monastic scribes, considering the astonishing time it would take to produce one hand-calligraphed Bible, and noting the high value of each volume. We show examples of what scribes do to correct their rare mistakes — namely, crossing out each error with a thin line of black ink and not relying on yet-to-be-invented, gummy white-out products. We bring out fine, parchment-style paper (bought by the ream at a local art store), fresh paper clips to fasten a sheet of dark-lined paper as a guide behind each plain parchment sheet, and new ink cartridges for the students' fountain pens. We extol the virtues of margins, posture, attention, and the italic handwriting practice the students have completed over the course of the fall. (We use Barbara Getty's and Inga Dubay's Italic Handwriting Series workbooks from Continuing Education Press at Portland State University, particularly Book G's great sidebars on the history of writing.)


chest. I peered through a knot hole in the worn wood.
I saw him barge through the door, axe in hand, and search the room wildly. He got so close to the ledge on which the chest sat I smelled his ale-filled breath.
After searching the whole room except the chest (He must have thought that only clothes were there!) he went to the glass with the coloring on it my father had left to set.

An excerpt from Hannah K.'s medieval story

At last our medieval scriptorium begins in earnest. We enforce strict silence and concentration, often enhanced by lighting candles at tables and playing CDs of Gregorian chant. The students complete their gorgeous manuscripts, hand-sew their bindings, and prepare for a costumed medieval feast, followed by a celebration with parents to share the finished stories. The children are immensely proud, proving every time how hands-on, difficult, unwieldy, but real work brings lasting learning and true satisfaction.

illuminated letters by Patrick, Hannah K., and former Intermediate Design teacher Kathy Albert

Amelia writes of the last moments of Mary, Queen of Scots: "It was a cold day, I felt weak and feeble. As I approached the doors, my knees started to shake, and the man with the black clothes wasn't making anything better. As I walked down the stone stairs, I could feel the eyes of the Pope, Elizabeth, and many more. They led me to a block of wood, which was smooth in one place for my neck. Before the axe came down I said a prayer for England and its queen." After discussing the Renaissance as a time of rebirth, inventions, discoveries, and war, Amelia concludes: "The Renaissance will always be remembered for its beauty but if you look again you will see more."

Our study of the Renaissance takes place, appropriately, in the spring when the changes outdoors mimic the immense cultural shifts of the period. Students study scientists, artists, explorers, and political figures (see Sidebar). We often find ourselves asking, "What about that person is renaissance-y?" In other words, what makes them emblematic of the Renaissance? We spend time looking at the vast differences between the Middle Ages and the Renaissance. Students research the changes and challenges within the Church during the period. And of course, we investigate the impact that scientific inquiry had on academics and culture. In particular, we focus on writing and the printing press.

The Intermediates at Arbor School are blessed to possess a nearly 100-year-old Chandler printing press. Work with a printing press can be tedious. The letters are tiny, oft covered in ink, and easily confused: a *u* looks exactly like an upside-down *n*, a *p* like an upside-down *d* and like a backwards *q*. Students learn that the best way to check their work is in a mirror, as they set type backwards and upside down. The old press is noisy and often prints too lightly or too dark, leaving us with a sheaf of inadequate pages to recycle or even to throw out if they are too inky. Students realize that printing pages from a computer would be faster and easier and could yield a more precise result, but they rarely point out this fact and, in the end, would never trade their hard-won books for something that came from a computer.

The creation of a hand-bound book involves many steps. The first centers upon content. In past years our book has focused on people of the Renaissance or across history, on scientific discoveries and inventions, or upon mathematical realizations. At this point in the spring our students deftly read, research, and summarize their gained knowledge. We provide and assign a range of topics. Students usually work in pairs, researching on their own and then coming together to write a polished piece.

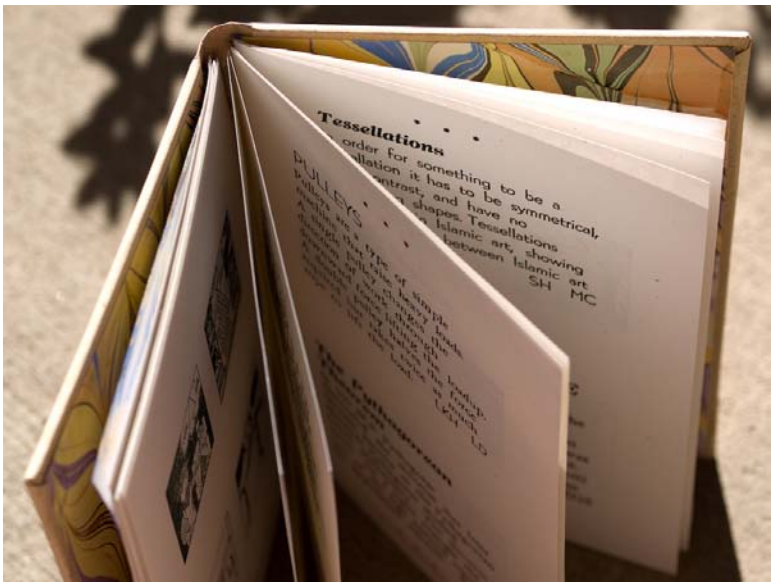
The writing often provides the greatest challenge in this project for our students. On most projects we find ourselves encouraging students to add more detail or add precise descriptive language during the revision process. The space constraints on the pages of our book, the time required to print and set each one, and the limited amount of type we have force us to write paragraphs as concise and simple as possible. We set a word limit, typically around 40 or 50, and students are shocked when they start with 80 or 100 words and have to cut their paragraphs in half. They choose each word with exacting precision, ensuring that every letter they set conveys information and no space is wasted. The exercise provides a great revision opportunity and our Intermediates often spend an hour or more making small changes to their 60-word paragraphs. They revel when a teacher finally signs off on a beautiful, concise, and clear 45-worder.

Students truly enjoy handling the type: the satisfying click as a letter settles in the correct spot, the noticeable weight of the lead in their hands, and eventually the immensely rewarding experience of seeing their words boldly printed on fine paper.

As always with our projects, craftsmanship plays a central role. We want students to have a finished product that not only reflects hard work but that they also truly love. To that end, students create their own marbled endpapers. With high-quality paper and a palette of complementary colors, each student crafts a pair of unique sheets to glue to the inside covers of her book. Even though each book contains the same information, the marbled endpapers fill each student with a sense of ownership of her particular book. In fact, an alumnus of Arbor who now teaches there still treasures his own book from 15 years ago.

Eventually we have all requisite pieces — covers, pages, and endpapers — and we are ready to build books. With an adult at each table, students sew together signatures of two or more folded pages. After spending hours upon hours painstakingly writing their medieval story by hand, students marvel at the speed with which a 16-page printed book comes together. We carefully glue endpapers to covers and the signatures to the endpapers. We make 55 books, enough for each student and teacher and a few to save for our records.

Students remember the time-consuming but rewarding process of setting type. They recall the magic of turning a plain piece of paper into a kaleidoscope of color. And they cannot forget the whole class sewing books together as a group. Most importantly, they appreciate the revolutionary power of the printing press to magnify the number of books they could create. It is our fervent hope that through these unwieldy, extended, and hands-on encounters with past methods of producing literature, students gain and retain true admiration for humanity's historic efforts to record its own thoughts and words.



How to Make Marbled Paper

1. Prepare a solution of the alum in 1 c. warm water. Spray or sponge it onto the paper to be marbled, coating the paper thoroughly, then let the paper dry and press or iron it flat. The alum will bind the color to the paper.

2. Process the carageenan in a blender full of water, then let it rest for at least 8 hours to get rid of bubbles and foam. This viscous liquid is called the *size*.

3. Pour the size into a shallow baking tray large enough to accept the paper to be marbled. Skim off any bubbles or debris with a scrap of newspaper.

4. Sprinkle several colors of ink or paint onto the tray, where they will float atop the size.

5. Stir the floating paint with a stick, comb, etc. to swirl the colors and form designs.

6. Gently lay the alum-coated paper in the tray, starting from the center. The paper will draw up all the color; only one print can be made.

7. Lift the paper from the tray and transfer it to a rinsing tray or board. Wash off the excess paint and hang the paper to dry. Later, iron it flat.

8. Skim the size with more newspaper and apply new paint for the next paper to be marbled.

Materials:

1 Tbsp alum
(aluminum sulphate)

2 Tbsp carageenan
(a seaweed-derived gelatin)

large shallow baking tray

tempera or other paint

stirring devices of choice

Complete marbling kits are available at art supply stores or online from Galen Berry at marbleart.us. An internet or library search will turn up many useful tutorials. Diane Maurer-Mathison's *The Ultimate Marbling Handbook* is a particularly good resource.

ROBES OF POWER
TRANSFORMATION & CELEBRATION IN SENIOR HUMANITIES

by Ben Malbin and Anne Moloney, grade 6-8

A quavering, surging melody — the Tlingit Paddling Song — floods Arbor's Arena with a soundscape evocative of rolling waves. The 1940s recording of native voices rising together in the Paddling Song is arresting to ears unaccustomed to this particular quality of sound. Equally transfixing is the sight of six sixth graders striding solemnly into the center of the room, each wielding a painted wooden oar. They step up onto the black boxes that represent a canoe. As the music continues, the Sixes are still, their focus dignified and unwavering before a sea of friendly faces. No one waves to a young sibling or grins for a video camera; they are immersed in the performance. In unison, they raise their oars and begin a steady paddling motion. The music streams on, the singing voices full of passion. For the peoples of the Pacific Northwest Coast, music does not occur merely for enjoyment, but to achieve a purpose. Songs are used to make children sleep, to win a lover, to mourn the dead, to gain power over game animals, or to bring victory in war. A sense of purpose is fiercely present this night as these six students gaze ahead, their precisely synchronized oars stroking first on one side of the canoe, then the other.

When the song ends, the paddlers process back to the door and raise their oars on either side to form an arch. As a low-toned drum beats a steady, insistent pulse, the rest of their classmates file slowly and purposefully into the Arena beneath the oars. They stop in a line, turn to face the back wall, and hold their arms out so the Robes of Power that cascade from their shoulders to their feet can be admired. One girl has a sky blue robe with a long, slender otter meandering down her back. Another has a beautifully detailed black raven starkly contrasted against white fabric. A boy's robe boasts an original design of a mosquito with a smaller mosquito inside of it. Each student radiates with pride at the creative vision and hard work embodied in his robe's adornment. The younger students in the audience are rapt, imagining which animals they will choose for their own Robes of Power.

an illustration of Raven from "Whale Tooth," by Cole W.

Even in a society less accustomed than ours to mass production and instant gratification, the notion of asking middle-grade children to spend weeks on a sewing project might raise a few eyebrows. That the project occurs under the auspices of a Humanities study of Northwest Coast native cultures is probably even more surprising. But every third winter at Arbor School, 60 middle-grade Seniors wield scissors and thread needles to hand-sew robes inspired by the button blankets made 150 years ago along the rocky shores of the Pacific Northwest. The display of the resulting Robes of Power at Potlatch is one of the high points of their school careers.

Our Potlatch celebration involves every student in the sixth through eighth grades in music, storytelling, dancing, and the recitation of poetry. It is the culmination of our

study of the indigenous peoples of the Pacific Northwest Coast, part of the Americas year of the Senior curriculum cycle at Arbor.

Because we believe that such celebrations draw their value from the students' sinking deep roots into curricular ideas, our Seniors first read in Humanities about the groups of people who first settled the northern Pacific coast. We explore the geography of the area, reading about the rivers, oceans, and mountains of our own home region. Students come to appreciate the surplus of natural resources and food that exists here. Living with such abundance, the first Northwest Coast inhabitants were fortunate in needing to spend less time searching for food than did their inland counterparts. With the luxury of leisure time, they carved enormous totems, painted their longhouses, and gathered to tell and hear stories. Potlatches were often the climax of their arts, as people came from near and far to enjoy bountiful feasts, performances, fine hospitality, and grand displays of wealth.

The button blanket was once an iconic Potlatch gift. Originally made from dark blue duffle acquired from Hudson's Bay Company traders in the mid-19th century, the blankets were decorated with a central crest of red flannel appliqué and buttons made from abalone or dentalium shells. Hand-sewing robes inspired by those blankets for our Potlatch becomes Arbor students' most significant Design project of the year.

Students begin the process by studying the basic elements of formline design — the ovoids, U-forms, and S-forms that are used in creating traditional Northwest Coast art. After plenty of practice drawing and combining the forms in different ways, students begin to create their own designs, usually representative of an animal. Rather than copy an existing motif of the totem animal they have chosen, they are encouraged to incorporate elements of several designs into a drawing that is uniquely their own.

After they are satisfied with a small drawing, students make several photocopies of their design and begin a color study, experimenting with the bold colors traditionally used by Northwest Coast natives. They then overlay their drawing with a grid, create a larger grid on a big sheet of paper, and recreate the drawing so that it will fill the space on the back of their robe. The next steps are to trace each block of color, cut out each neatly labeled piece of tracing paper and pin it to the correct color of felt as a pattern, and then cut the felt shapes that will be applied to the robe. What follows is hour upon hour of sewing by hand, a process that hones students' patience, precision, and dexterity. They practice focusing on each stitch and simultaneously considering the shape of the whole design. Their stamina is admirable; more than one Arbor graduate remembers arranging special permission to stay after school in order to complete an ambitious design.

"Owl" by Aly

"Loon" by Anna

Why is the Robe of Power such a compelling Design assignment? When we survey students as to whether the robes should be an Arbor tradition, the answer is almost unanimously affirmative. Their reasons are thoughtful and enthusiastic. Emerson values the assignment because it teaches students how "to plan." He continues, "We have to think the whole process through to make sure everything works out. Also it feels amazing when you finish the project." Alice and Claire believe in the power of tradition, both here at Arbor and within Northwest Coast native culture. Alice writes that she

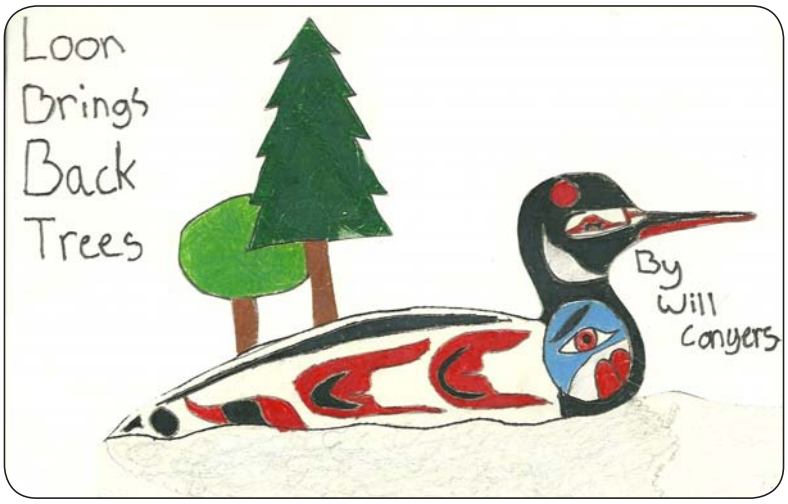
"Hawk," by Charlie M.

learned a lot about Native American art, "while at the same time everyone got to create something unique." Claire remembers being a kindergarten student and watching the Seniors perform in their Robes of Power at Potlatch. Now she feels the satisfaction of having grown old enough to make her own robe and perform in her own Potlatch ceremony. In class, when we begin the assignment, students love to look at images of button blankets that were made not only by native craftsmen but also by older students — buddies, siblings, and even former students who are now teachers at Arbor.

It is no easy task for a student who has very little experience with sewing to take on a project of this magnitude. But the lure of the finished product is powerful. The Northwest Coast designs have an enduring strength that appeals to both males and females. Adorning themselves with a garment that they have independently and painstakingly created is highly appealing to students in each of the middle grades. And the camaraderie forged as they labor together in the felt-strewn studio, listening to recordings of Northwest Coast native music and narrative, is lasting.

As they sew, the Seniors are immersed in story. While they trade spools of thread, trim frayed edges, teach each other the proper methods of tying off loose ends, hold pieces of felt in place while another pins them, and walk around to admire their friends' designs, teachers read aloud the collections of Northwest Coast stories we have in our library. We play recordings of Chief Lelooska, a famed sculptor, storyteller, and historian with ties to several Northwest tribes, telling traditional tales.

The stories augment our students' appreciation for the values, beliefs, and lore of the people we are studying and also serve as inspiration for the writing they will do on their own. Each student crafts a story that demonstrates his growing understanding of the culture, mythology, and environment that we have been discussing, reading, writing, and hearing about. Our Seniors' main characters are chiefs, eagles, boys getting ready to hunt, a girl who transforms into a seal, wolves and, of course, Raven, the protagonist of many Pacific Northwest Coast tales. The stories teach lessons and morals, entertain, and explain how different elements of the natural world — the stars, the seasons, a whale's blowhole — came to be. They are ultimately presented on fine paper, bound, and abundantly illustrated with drawings and borders.



A few students recite selections of their work from memory at Potlatch. “Many moons ago, when men were new to the earth and the first longhouses were being built, there was a hunting party,” Cole began his tale, “Whale Tooth.” “This hunting party was going out into the lush Northwest Coast forest for meats and skins. At the head of this party was Chief Oktuga and his son Kiki. The night before the hunt, the chief was bathing in a pond when he saw a face in the clouds. It looked almost exactly like Raven. He did not know what it meant.” The audience was spellbound as Cole described Kiki’s accidental killing of Raven’s brother and Raven’s demand for the largest tooth of a whale as recompense.

“Killer Whale,” by Hannah P.

No Potlatch celebration could conclude without a feast. Students prepare fresh bread, herbed salad, and salmon cooked in the traditional manner over an open fire. Those who are not cooking make gifts to be formally presented to honored guests, including Arbor faculty, former teachers, and other friends of the school. Guests and teachers borrow Robes of Power made in previous years to wear during the feast. In the traditions of the peoples of the Pacific Northwest Coast, largesse at Potlatch elevated the host’s status and served as the primary means of redistributing wealth. In our celebration, students practice the habits of generosity and hospitality. We all sit together, eating, laughing, and listening, the colors of the Robes of Power dominating the room, the Paddling Song still ringing in our ears.

Below: Greg Neps and students prepare the Potlatch salmon

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illustration from Reed's story, "Seagull"

FUNCTIONS AS STORIES
AN EXCERPT FROM *CROCODILES & COCONUTS*

by Linus Rollman, grade 6-8

Math is about numbers; Humanities and English are about words, right? So what are we doing asking kids to *write* in math class? Why are we asking students to look at pictures and to tell stories about candles, about circus performers, about dancing with bees in your pants? That doesn't sound very much like math!

In this particular instance, the purpose of writing in mathematics is twofold. In general, we ask our students to write in math class because human beings are narrative creatures — or perhaps *narrating* creatures. We tell stories not only to entertain ourselves, to add pleasure and richness to our lives, but because it is through storytelling that we understand. We tell stories to make sense of our own lives and of everything around us. What else is science but a series of interlocking — or, sometimes, contradictory — narratives based on observed and tested facts? What else but *stories* are our best collective approximations of the truths that explain our universe? And why should mathematics, nearly alone among disciplines, be so often regarded as devoid of the sort of narrative structure around which human understanding is built? That misperception causes all too many daunted students to turn away from the subject when they enter the realm of algebra. Math is not, in fact, a series of discrete skills to be memorized and mastered. It has its themes and motifs, a narrative structure, a series of stories. Those stories can and should form the core of a study of mathematics, and it is in part through the act of writing that those stories can best be accessed.

In the case of the excerpt from our Arbor Algebra textbook *Crocodiles & Coconuts: Equations in Two Variables* that follows, there is a second layer to the use of writing; this section serves as part of an introduction to the concept that many of the stories told in science are told in the *language* of mathematics. What the students are being asked to do is to translate between the ordinary English in which we describe our observations and the math in which those observations are recorded as part of a scientific description. In other words, if you're willing to look at it in a certain light, we ask students to write in math class because math and writing are really the same thing…

CHAPTER 2, LESSON 5: FUNCTIONS AS STORIES

In this lesson, you'll see very few equations. Instead, you'll look at graphs and, as the title of the lesson suggests, you'll tell stories. Even though you won't be using many equations, this work has everything to do with the sorts of two-variable equations that you've been studying. As you know, every two-variable equation has an infinite number of solutions, those solutions come in pairs, and those solutions can be represented as a graph.

I've claimed before that the shift from one-variable to two-variable equations is the most important shift in basic algebra, but so far I don't think that I've done much to convince you or explain why that is. So here's the reason:

The world changes.

All right. You had better be confused by that statement. Let me explain. One-variable equations are very useful if you want to figure out an unknown thing.

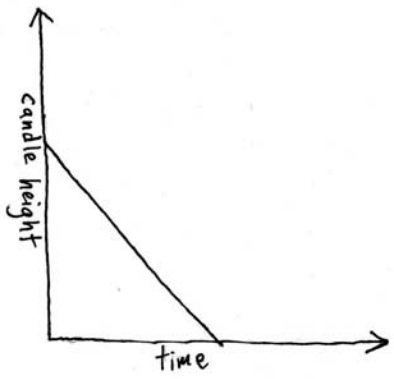
For instance, use a single variable to solve this problem:

1. **Giggles and Lucky are two juvenile meerkats. Right now, Giggles is six inches taller than Lucky. Once they've each grown two inches, Giggles will be twice as tall as Lucky. How tall is each meerkat?**

Excellent work. As I say, one-variable equations are quite useful. So what do you now know? You know how tall Giggles and Lucky are at this precise moment. But the thing is that Giggles and Lucky are growing, right? Their lengths are changing, the way that most things in our world change. And two-variable equations, unlike one-variable equations, give us a mathematical way to describe change. Or, to put it differently, two-variable equations can tell stories.

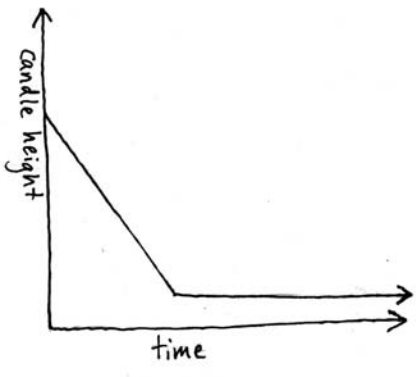
The first stories I'll ask you to think about and to tell have to do with candles. For centuries, candles were used as clocks, especially at night or on cloudy days. The earliest reference to candle clocks is from Japan around 1,500 years ago, but they were used in many other places and times. The most sophisticated candle clocks were used in the Middle East about 800 years ago: the candles rested in weighted dishes and as the candles burned away, the changing weights would turn dials.

Here is the story of a candle, told in graphical form:



Here's how I might choose to tell the story of that graph in English: "A candle starts off at a certain height. When it is lit, the candle shrinks steadily until it entirely disappears." Notice that, since there are no units on the graph, I can't specify exactly how tall the candle was to start with or how fast it burned, but I know it shrank steadily and disappeared. Also notice that the candle's line does not have arrows at the ends. This means that the candle does not keep shrinking into negative height (whatever that is!).

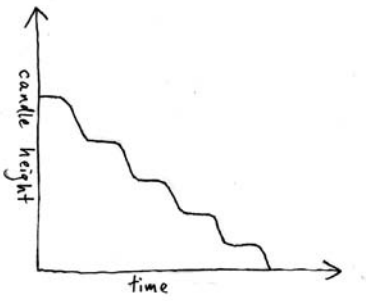
Here's another version of the story (one that I think is slightly more realistic):



2. **Tell this story. (Remember that the arrow at the end of the candle's graph means something like "continues on like that forever.")**

Tell the version of the candle's story that goes with each of the following graphs:

3.



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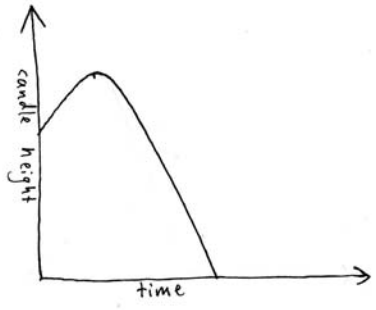

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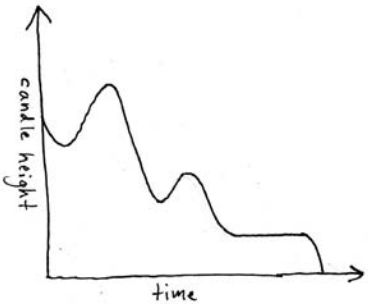


6. Sketch two candle graphs of your own and tell the stories that go with them.

Now I'd like to return to the idea of a function, which is what this chapter is all about, after all. In Lesson 1 of this chapter, I told you that a function is "a pairing of two sets of numbers so that to each number in the first set, there corresponds exactly one number in the second set." Then I told you this set of numbers was a function:

x	5	6	52	17	-13
y	7	10	-5	-4	10

... and that this set of numbers wasn't a function:

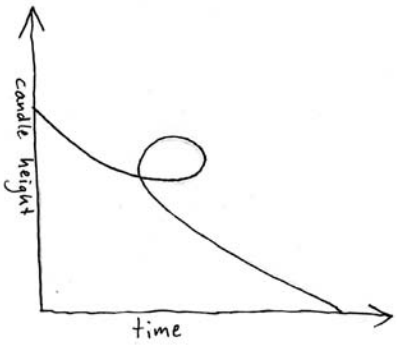
x	-2	3	3	5	-6
y	12	4	9	16	8

Well, another way to think about this is that, for something to be a function, *each x-value can have only one y-value that goes with it*.

7. Pause for a moment to answer this question: if a set of numbers had more than one y-value for a single x-value, how could you recognize that fact from the graph of that set? In order to answer this, it might help to graph that second set of numbers above, the set that isn't a function. Pay particular attention to the two points that both have an x-value of 3.

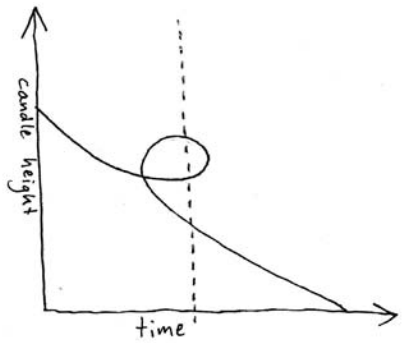
So why does this idea of not having more than one y-value per x-value matter? Why should that be the defining characteristic of a function? The answer to that question really has to do with stories.

8. **In order to try to understand why that definition of a function is important, try to tell the story of this candle graph:**



9. **I hope you had a hard time with that last one. In fact, you may have found it to be impossible. Copy a sketch of that graph into your notebook and mark the part of the graph that made the story hard to tell.**

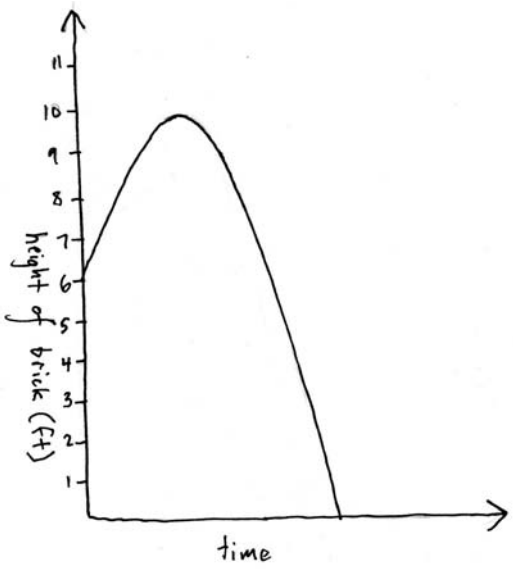
The graph from Problem 8 does not represent a function because there are certain spots where a single x-value (time) corresponds to more than a single y-value. Here, for example, I've marked one of those spots with a vertical line:



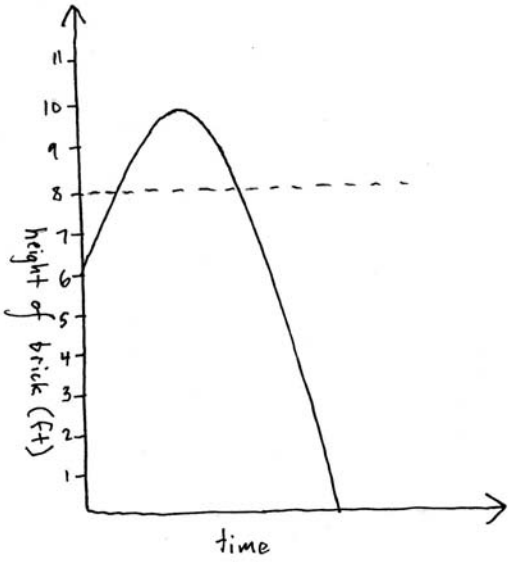
Now, some of the graphs that I asked you to tell stories for earlier were probably impossible. I'm thinking here of the graphs for Problems 4 and 5. Candles pretty rarely *grow* after you light them. You should be very surprised if you see that happen. (As some of my students have observed, it might be possible to *add* wax to a candle.) However, the story that goes with Problem 8 is impossible in a different way, precisely because it's not a function. The line that I put through that graph would have to mean that somehow *the candle was three different heights at the same time*.

That's why mathematicians bothered to come up with the concept of a function. Algebra is useful partly because it can represent aspects of the real world and can be used to make predictions about aspects of the real world. That prediction-making ability is more or less useless if it's possible to have more than one value of, say, candle height for a single value of time. In other words, you can't use an equation to make meaningful predictions unless the equation is a function.

Notice that it's absolutely fine for there to be two x-values that correspond to a single y-value. Here, for example, is a graph of the height of a brick that's been tossed in the air (this time I have used units on the y-axis):



Here's a story that might go with it: "Linus (who's about 6 feet tall), tossed a brick in the air. Then he got the heck out of the way as the brick fell all the way back to the ground." There are a bunch of points on that graph where there are two x-values that go with a single y-value. Here's one:



But that's absolutely fine. In fact, it makes perfect sense — there *should* be two different times where the height of the brick is the same: one on the way up and one on the way down. That doesn't ruin the story and it doesn't change the fact that this graph represents a function.

One of the best tests of whether or not a graph represents a function is to mentally run a bunch of vertical lines through it — if any one of them would pass through the line of the graph more than once, then the graph isn't a function.

All of the graphs that I've asked you to look at so far have had "time" plotted on their x-axis. Although that's true of many functions that you'll encounter, it doesn't have to be the case.

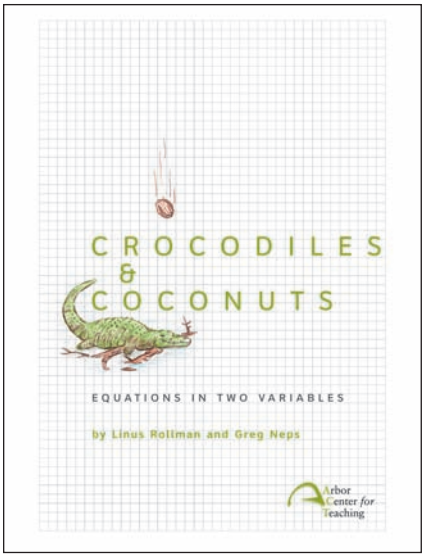
For each of the following scenarios, create a graph and write the story that goes with the graph. All of the graphs must be functions, but otherwise the stories can be as creative as you like. No one will be able to read your graphs, though, if you don't label the axes! (For each scenario, I've indicated which part should go on the vertical axis and which on the horizontal.)

10. **The distance a circus performer travels (vertical axis) changes depending on how much gunpowder is in the cannon (horizontal axis).**

11. **The size of a goldfish (vertical axis) changes depending on how much it eats (horizontal axis).**

12. **The length of time you spend in jail (vertical axis) changes depending on how much money you give the judge (horizontal axis).**

13. **How fast you dance (vertical axis) changes depending on how many bees are in your pants (horizontal axis).**



Crocodiles & Coconuts: Equations in Two Variables is available for purchase ($20 plus shipping) from the Arbor Center for Teaching. This second volume of the Arbor Algebra series introduces students to the Cartesian coordinate plane; graphing two-variable equations; functions and formulas; solving simultaneous equations; and graphing circles, ellipses, parabolas, and hyperbolas.

Volume 1, *Jousting Armadillos & Other Equations: An Introduction to Algebra* can be purchased for $15 plus shipping; Volume 3, *A Companionable Guide to Polynomials & Quadratics*, will be published later this fall. Each volume has an accompanying Answer Book & Tests for teacher use.

The Arbor Algebra series is designed to help students recognize the power and beauty of mathematics in a broad sense. As they build skills, students are asked to think about the essential questions that underlie their mathematical practice and to apply their emerging expertise to new and open-ended problems.

This type of thinking requires a high degree of independent exploration. Teachers and textbooks will always be vital resources, but we've seen that students naturally get the most out of the habits that they build and connections that they create for themselves.

To this end, we emphasize algebraic thinking as early as the fifth and sixth grades. Algebra gives students a language to universalize the principles that they uncover, helping them to understand new material more deeply and to draw sophisticated connections. Algebra also offers significant advantages in application. We believe that it helps students develop the critical thinking skills that they will need to solve complex problems and generate their own ideas. Throughout the Arbor Algebra series, students are asked to think, write, and speak explicitly about the core concepts they encounter. We want them to express mathematical ideas in their own words and on their own terms.

Email publications@arborschool.org to inquire about a free 30-day review of any of our Arbor Algebra books.

FORTS
PHYSICS, COLLABORATION, & DERRING-DO

by Peter ffitch, grade 2-3

As historian H. W. Brands tells the story in his book *The First American*, a young Benjamin Franklin and his friends liked to hunt small fish in Mill Pond. But the banks of the pond were soft and the boys' footsteps stirred up mud that clouded the water and obscured the fish. To solve the problem, the boys decided to build a jetty extending into the pond. But where would the materials come from? Ben noticed a pile of stones that had recently been delivered to a nearby building site and counseled his friends to wait for the end of the workday. Once the builders had departed, the boys began their own construction project, resourcefully using the materials at hand. When the workmen returned the next morning it was a simple matter to follow the trail of the missing stones, and though the boys argued the utility of their structure, they were appropriately reprimanded for their lack of honesty in acquiring its materials.

In Arbor's early days we experienced similar repurposing of materials by our young builders — materials that, from an adult perspective, were already being put to a fine purpose. Carefully placed landscape stones might disappear, only to turn up as the slabs on which mud pies were being prepared under a shady tree. Bamboo fence posts placed to protect gardens from errant soccer balls were cleverly converted to structural supports in forts and to imaginary weapons in the hands of children deep in fantasy play. Even a loose piece of siding from a garden shed could reappear as a perch in a tree from which the entire playground could be surveyed. And when queried about the provenance of their building materials, the children would reply, "We found them!" In the full exercise of their imagination and resourcefulness, our students had found a higher use for each object that they took. They were doing what children often do when given the time and space: creating a place of their own within an adult-designed world.

Wishing to protect Arbor's physical structures and to encourage the creativity and resourcefulness of our student builders, we began to designate certain materials as Fort Supplies. We collected scrap lumber, from 2" x 4"s to 4' x 4' sheets of plywood, as well as bricks, rope, old tires, and other treasures that would find new life in the imagination of our young architects (many families were happy to move such things out of their garages) and we made these materials available to the students during each Recess.

Nicholas climbs into the Primaries' favorite fort tree

A visitor to Arbor's playgrounds today will invariably find forts in all phases of construction and destruction tucked in and among the trees and shrubs that border our open fields. The constructions may vary in complexity, from the simple stores favored by the third and fourth graders as markets for their mud and clay creations in the pinecone economy, to the multi-level platforms that our younger students balance on the lower limbs of trees, from which they can see and imagine that they cannot be seen.

As a practical matter, our endorsement of fort building as a recess activity has necessitated time and attention from Arbor teachers. Heavy building materials can pose a danger to small fingers and toes; ill-designed structures can collapse. Fort play can be risky. We inspect materials and remove those that become unsafe due to wear and tear. We also keep an eye on structures to make sure that they are safe for the children

who will be in and on them. But new research supports our belief in the importance of taking physical risks in forming courage. The New York Times recently cited the studies of Ellen Sandseter, a Norwegian professor of psychology, to present the case that risk-averse parents and litigation-averse city and school officials are hindering children's development of confidence and a sense of mastery by making playgrounds too tame. ("Can a playground be too safe?" by John Tierney, July 18, 2011) Climbing, building with real tools, and playing without an adult hovering near are all among the experiences Sandseter identifies as being important in conquering fear.

Fort play is inconveniently messy, too. Last year, a gang of particularly industrious builders excavated a trench near the soccer field and covered it over to construct a subterranean lair. The children got gloriously filthy and the pit didn't add to the beauty of the campus grounds or the safety of unsuspecting passersby. Faculty meeting that week included a discussion of how much leeway to allow in fort building. In the end, we cheered the spirit of the underground fort, but asked the children to refill the hole after enjoying it for a few weeks. Others are routinely asked to take forts down as well, to ensure that fort supplies remain in circulation and available for all who wish to use them. We help the children with "fort clean-up" each Friday, a process that often involves loading garden carts full of boards and bricks to haul them back to the designated storage area.

Will C. removes a board during fort clean-up

That students must use recess time to dismantle a structure that was hard to build and around which an imaginary world has been created is sometimes met with some resistance, but we have learned that it is an important part of the process. The fresh start that is made possible each week provides an opportunity for new ideas to be tested and for new groupings of children to come together to do so. Those who choose to begin the week by rebuilding what they had the week before may find that they must do so with a different mix of materials, as other students may have dipped into the supplies; their resourcefulness and flexibility may be tested. And children who may have had only a secondary role in a fort one week may become the founders of one the following week. It has also been our pleasure to discover that each year there are students who love the clean-up as much as the construction and who are willing to pitch in and help put things away even when they had no hand in getting them out. These students model the sense of community and stewardship that we seek to foster in all of our students, and their happy energy in pulling carts and rolling old tires back to the fort supply depot often draws in those for whom cleaning up might not be a first choice. This is real work and its completion provides real satisfaction.

We have written in previous issues of this publication about the importance of recess as an opportunity for children to practice the character-oriented lessons that we teach directly and indirectly in the classroom, such as cooperation, collaboration, and inclusion. In group work and in problem-solving activities we teach for creativity, resourcefulness, and flexibility in thinking. Children engaged in fort play exercise these skills in much the same way that they would if engaged in many other recess games. Fort construction, however, serves to expand what can be practiced, from the realm of the social to the practical application of math and physics. From the process of finding a way to move large and heavy materials to the construction of walls, roofs, and platforms, students who are building are exploring the use of simple machines, they are discovering spatial relationships, and they are making important discoveries about three-dimensional geometry and about strength of materials. *Why is our fort more stable with a triangular structure rather than a rectangular one? Why does that board bend so easily when we stand on the wider side? What is it about this smaller board*

that makes it so much heavier than that larger one? These students are also engaged in design thinking and are forced to be resourceful and adaptable in trying to bring to life the vision with which they begin. They are also learning about how their own bodies move through space, about how to lift heavy things in cooperation with others, about how to haul themselves up into trees or to squeeze through small openings.

And all of this is happening without adult participation, perhaps the most significant factor in the productivity of this play for our students. It is well documented that children today are much more heavily scheduled than previous generations of youngsters and that time for unstructured, unscripted play has diminished in exchange for more time in adult-led sports and enrichment activities. Perhaps so many of our students value fort play so highly because it is theirs alone. It is their opportunity to create their own space, their own shelter, their own world. And while it may seem ironic that children are experiencing this independence at school, in the midst of a daily schedule that is entirely outside of their control, it should be instructive to us as teachers that they are so eager and so committed to take advantage of the opportunity when it is presented. We should also take note of the quality of the education provided by the kind of direct experience that fort play provides and so feel confident that it is worth the effort to make it a part of our school day.

Memorial Minute

John W. "Jack" McKittrick

December 13, 1927 – March 8, 2011

One late summer day in 2000, a grandfatherly visitor appeared at Arbor's door inquiring about our program. He and I had a memorable conversation about schools and resourcefulness, about grandchildren and legacies, and about quality and pioneering. (He was a pioneer himself. Armed with a degree in civil engineering from Stanford and an MBA from Harvard, he became President of Plantronics, where he led the company to engineering breakthroughs like the hands-free headset and voicemail through VMX.) Jack left that August afternoon with a promise that he would be in touch. With his wife, Amy, he honored that promise.

One of the topics we discussed in our first meeting was my desire to create a teaching apprenticeship program at Arbor, this to be both a source of renewal for the school and a way to reach beyond the confines of our small school to the wider educational community. Jack was intrigued with the idea and learned that one of the largest financial obstacles to such a plan was the initial cost of building an adequate professional library. Out of his understanding of that need, the McKittrick Family Resource Collection was established. His and Amy's generosity allowed us to purchase, catalog, and house a 2,000-volume collection within a year. This library remains the site of the Seminars on pedagogy and instruction that ACT apprentice teachers take as they work their way through two years in Arbor classrooms, and it is an essential resource to all the members of the faculty.

Jack's and Amy's devotion to the outreach efforts of Arbor and the Arbor Center for Teaching has been a constant. When the idea for Cambium was first proposed, Jack was quick to give his support to the project. His enthusiasm for the publications wing of ACT only grew when we set about writing our own math textbooks, and he introduced us to some of his Stanford colleagues in order to help us widen the scope of our ambitions. We continue to move forward vigorously with this work and think Jack would be pleased to know that his spirit infuses our ongoing efforts.

We are indebted to Jack for his support, ever grateful to him for his faith and foresight, and saddened by his passing.

–Kit Abel Hawkins

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Cambium

INNOVATIVE K-8 CURRICULUM FROM THE ARBOR SCHOOL OF ARTS & SCIENCES

THE ARBOR CENTER FOR TEACHING AT
ARBOR SCHOOL OF ARTS & SCIENCES

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Cambium: (n) the cellular growth tissue of trees and other woody plants, from medieval Latin "change; exchange."

What content would you like to see offered in Cambium? Do you have ideas about how we can improve it? Send us an email: cambium@arborschool.org

Masthead by Jake Grant, after an 1890 botanical illustration.

The Arbor School of Arts & Sciences *is a non-profit, independent elementary school serving grades K-8 on a 20-acre campus near Portland, OR. Low student-teacher ratios and mixed-age class groupings that keep children with the same teacher for two years support each child as an individual and foster a sense of belonging and community. An Arbor education means active engagement in learning, concrete experiences, and interdisciplinary work.* For more information on the Arbor philosophy, please visit www.arborschool.org.

The Arbor Center for Teaching *is a private, non-profit organization created to train teachers in the Arbor educational philosophy through a two-year apprenticeship while they earn MAT degrees and licenses, and to offer guidance to leaders of other independent schools. In 2007 its mission expanded to include the publication of material underpinning the Arbor School curriculum.*

"M for Miniver" by Reed G-S

Cambium is free! Please forward it to your friends and relations and don't hesitate to let us know if there's anyone we should add to our mailing list. For more information about publications from the Arbor Center for Teaching, contact Sarah Pope at publications@arborschool.org.

Cambium's production is made possible by a grant from the Bloomfield Family Foundation, which has also generously underwritten the development of the Arbor Algebra series. We are ever grateful for their support of our work.