Chemical Education in a New Church College

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One question I face whenever I analyze my chemistry curriculum is, "How can I emphasize things of lasting value in this course?" No teacher wants his or her students cramming for a test just to forget the material within days, hours or minutes after taking it. Yet *Arcana Coelestia*[1] makes clear that this is exactly what must happen with the trivial bits of information we must accumulate in the process of our education (cf. §1487). We must contact and memorize thousands of facts before we can begin assembling these facts into concepts, integrating this information into higher order knowledge that we hold in our brains, and putting our knowledge to use. We then discard useless trivia. Education in chemistry can have lasting value as a component of Bryn Athyn College of the New Church's offerings in a religious, liberal arts setting. Here, I explore how this can be true.

An obvious reason to teach chemistry in college is to give students the skills they will need if they pursue vocations in the chemical sciences. Several of our students go on to do this, and our chemistry curriculum supports them. But the majority of students taking a first-year course in chemistry go into other fields. In this work I am concerned with the role of chemical education for the majority group.

A course in first-year chemistry as an important contributor to a liberal arts education—a form of education dedicated to supporting human freedom. In this context, studying chemistry should help liberate people. The mission of a liberal arts curriculum finds motivation in the Bible, which calls us all to free ourselves and help free others from limitations due to blind adherence to tradition—traditions that either confine existence to belief in the absence of rationality and evidence, or confine us to evidentiary matters without allowing operation of spiritual rationality and faith. One biblical story that illustrates human progress through education is Abram's call, journey to the Promised Land, and sojourn in Egypt (Gen 12-13). *Arcana Coelestia* interprets the Abram story in this way, stating, for example, that "all instruction is simply an opening of the way" (§1495.2)—a way connecting more internal with more external parts of our minds. According to the *Arcana Caelestia* our minds open through the use of "knowledges and cognitions" (cf. §1555). What the text here means is that facts learned through sensory experience, together with ideas resulting from analyzing that experience, are the exercises necessary for our mental development.[2]

When Abram first journeyed into the land of Canaan, he pitched his tent between Bethel and Ai until a famine forced him southward (Gen 12:8-10). Upon returning to Canaan after the sojourn in Egypt, Abram again camped there with Bethel on the one side and Ai on the other (Gen 13:3-4). *Arcana Caelestia* states that camping between Bethel and Ai before and after this process represents changes of state resulting from education in both things of the world (Ai) and the Word (Bethel) (*AC* chapters 12 and 13). The Hebrew meanings of the names Bethel and Ai shed light on their symbolism. "Bethel" means "house of God," and "Ai," "ruin." Bethel is sometimes called "Beth Aven," which means "house of evil," indicating a potential danger associated with belief in the absence of evidence. Ai as a ruin illustrates the emptiness of trivia building nothing. I imagine liberal arts education as taking place in the psychological space between Bethel and Ai, which seems to represent, along with a balance of the Word and world, the juxtaposition of "cognitions" and "knowledges," concept and fact, and belief and evidence.

If liberal arts education relies on the Word and the world, then how can chemical education fit in this scheme? Does chemistry belong to the world alone? I assume not. All parts of a truly liberating education camp between Bethel and Ai, and so it is not appropriate to think of chemistry as a "worldly" course to be balanced in the curriculum with a course in religion. Rather, each subject achieves more for the students' education when they each balance Bethel and Ai. The chemistry curriculum specializes in studying the world, but even in doing so, we find ourselves exercising two parts of our minds—the sensual part, which takes measurements, and the rational, cognitive and imaginative part which builds theories and concepts based upon and explaining those measurements. In addition, the skills we build while studying chemistry and exercising these two levels can help us balance these two parts of our thinking in other areas, too. And further, since creation reflects the will of the Creator, a Creator who made heaven and earth, we can sometimes see connections between natural and spiritual being.

Lasting value in education comes when a course teaches us to think. A first-year course in chemistry should get into the higher reaches of our mental activity, yet in order to do so we must cover much trivia. The challenge is not to stop on the foothills of facts but push on to the heights of rational understanding, evaluation and application. An equal challenge is to give the foothills their due while panting after the mountains. The first inclination of many high-scoring students is to assemble facts, often neatly into bundles, memorize them, work them through some algorithms to make sure they function properly, and be perfectly happy with that. This strikes me as entirely unsatisfactory since these students have already ordered their minds to function like this—like fact ingestors and regurgitators.

If the point of a liberal arts education is to free the human being, then how can reusing a successful "learning" formula time and again in different subject fields accomplish this? It seems more like an enslavement to me. My hope is to take these already successful students on an exploration of their own uncharted mental territories, introducing them to more of the many wonders of the mind. I want them leaving the class knowing themselves and their own capabilities significantly better than when they entered. All subject fields have the power to do this. My field happens to be chemistry. And in that field I see a number of applications that can serve to draw us closer to our goal of human freedom. But I cannot do this when the foothills seem satisfying enough and the mountains far too complex, or boring or, even worse, not to the point.

Not to the point? How can reaching beyond rote algorithms into the human sphere of careful consideration not be to the point? What point are we looking at? Many of the better students seem to see the point of education as:

a) To get good grades and impress my parents, my friends, and/or myself.

b) To get good grades and use these to move on to a job I hope to enjoy.

These are fine goals and have served their owners well through most, if not all of their educational process. But many teachers, myself included, are not satisfied with these ambitions. What haunts me about an approach to education along these lines is the fact that algorithmic learning simply duplicates machine learning. Any process we can reduce to an algorithm we can teach a machine. I do not want to be in the business of turning out flesh-and-blood algorithm processors. I am not afraid that computers or robots might someday become so human-like that we will lose the distinction between the two. Rather, I am afraid humans might more and more begin to resemble these machines.[3] I hold that education built upon trivia is, like Ai, a ruin.

Why a ruin? If we think of an ancient ruin—take the Incan city Machu Picchu for example—what sort of message do we perceive from it? What questions does it bring to mind? This old city was once a lively place full of dreams and accomplishments. Incas loved, hated, gave birth, and murdered there. But today it is a ruin—a shell of what it once was. As a shell, a ruin implies that it once contained something. When that something was present, along with the now ruined walls, that city was a containant of human life and eternal significance. A ruin is such because its walls now contain nothing.

In the same way the world is a ruin. It is not a ruin in the sense that it is entirely worthless but in the sense that without what it contains it has no value. "Meaningless, meaningless," writes the Teacher of Ecclesiastes (1:2). But when this earthly shell is not empty it has great value. In John we read, "For God so loved the world that He gave His one and only Son, that whoever believes in Him shall not perish but have eternal life" (Jn 3:16 *NIV*), and in Luke, "Are not five sparrows sold for two pennies? Yet not one of them is forgotten by God. Indeed, the very hairs of your head are all numbered" (12:6-7 *NIV*). So the world is both a ruin and at the same time of great value since it is a shell, but a shell containing life. If we focus on the shell itself we gain little, and we come to know something that has fleeting existence; but if we focus on the shell together with the life in the shell we gain much, and this is of lasting value. Thus even though the world is, in a sense, a ruin it contains much and teaches much.

Educational trivia are just this sort of ruin. But just as I would not throw away the world simply because, of itself, it is meaningless, I also believe we cannot throw away learning trivial facts, even though, eventually, we must release those facts which are not useful. Life inside the shell requires the shell, and education of the higher reaches of the mind requires educating the factual brain, too. A worthwhile education, therefore, follows Abram's lead and pitches its tent between Bethel and Ai.

As a field of study, chemistry lends itself well to helping students exercise new areas of analysis and abstraction. The big push in chemical education is to understand the microscopic causes of macroscopic phenomena. This requires abstraction since we do not encounter matter as atomic but as continuous and macroscopic. Therefore, to "think chemically" is to think abstractly.[4] The following discussion gives a taste of the mental abstraction necessary to build the concept "atom" and suggests why this abstraction is useful.

If abstraction is one of the reasons students find chemistry difficult to master, we might ask: What is abstract about matter? What could be more concrete? We interact with matter every moment of our lives and have built a tremendous database in our brains regarding the way matter behaves, which materials we expect to be light and which heavy, which flexible and which brittle, and so on. We find nothing abstract, or beyond the immediate, in any of this.

The problem comes when we start investigating why a material is hard or soft, conductive or insulating, dull or shiny, reactive or inert. Current explanations of these phenomena depend on the microscopic world of atoms, and this is where the abstractions arise. When have we seen or investigated an atom? Atoms have diameters of less than 7×10^{-10} meters, which is smaller than a wavelength of visible light, making them impossible to "see." Atoms weigh less than 5×10^{-25} kg. That number is small enough to have no meaning for most people. If we compare the mass of the heaviest atom to the mass of a 160 lb (75 kg) human, we find the human weighs 1.6×10^{26} times more than the atom. That comparison still leaves us is a quandary. How do we compare this proportion to anything? If a human has a mass 1.6×10^{26} times greater than an atom, what has a mass 1.6×10^{26} times greater than a human? The mass of the entire earth is 5.98×10^{24} kg, which is just 8.0×10^{22} times more than a person. Hence we are more massive when compared to the mass of the earth than the heaviest atom is when compared to us. In fact, the mass of the heaviest atom is to us what our mass is to 2,000 earths! This can give us some comprehendible idea of the smallness of an atom.

One of the amazing characteristics of an atom is that even though it has little mass, it concentrates that mass into the very highly dense nucleus. The density of the nucleus is much greater than that of any material we contact in the macroscopic world. If the mass of the earth were compressed until its density matched that of the nucleus of an atom, the diameter of the compressed earth's sphere would be about 200 meters. The reason the materials we handle are much less dense than a nucleus of an atom is because the great majority of an atom's volume is just empty space. This inventory of atomic characteristics can leave our atomic vision wholly disconnected from our everyday vision.

An entity as small as an atom requires abstraction, and abstraction causes difficulties. I tell my students that matter is mostly empty space, but that is contrary to their own experience. They know they cannot walk through walls. How can my telling them that atoms are mostly empty space help them? Why should students bother with an abstraction when the physical realities of macroscopic matter have sufficed thus far?

The answer is we cannot explain properties of materials without a microscopic understanding of those materials. Even so, people may ask, What's the use of *explaining* a property when all we really need is *knowing* the property? After all, the important thing about copper in a wire is that copper conducts electricity, and equally important, that the plastic around the copper does not. Why should we care why the copper conducts and the plastic insulates?

One answer to that question is that understanding why materials have properties enables us to predict properties of new materials: new either because we have synthesized them or new because we have not yet discovered them. Several synthetic polymers make good examples of this. The chemical industry is producing polymers with a vast array of different properties these days. The clothing market is one beneficiary of these new materials. Chemists have designed some polymers to stretch for a close fit with the skin, repelling water, and ventilating. Other polymers have very strong fibers that resist sheer. These have been used in lightweight body armor. Recently dentistry has switched from using metal amalgams for fillings to polymers. These dental polymers have specific requirements. They must not shrink or enlarge upon setting, they must set at or near body temperature, and they must not release toxic reagents. Chemists designing the dental polymers were unlikely to strike upon the proper materials satisfying these requirements had they not understood the way the microscopic properties of matter would affect their macroscopic properties.

The particular beauty of synthetic polymers—as an example of the power of understanding the role atoms have in determining physical and chemical properties of matter—is the fact that these materials are entirely artificial. They are not somewhere waiting to be discovered. They actually do not exist until the chemist brings them into existence. And chemists do not usually make thousands of polymers and then test each one to discover its properties. Chemists actually design polymers to have certain properties. Of course they do not always find that the polymers have the expected properties, but they arrive at the intended materials much more quickly than by completely random construction and sampling.

Understanding atomic behavior has helped our understanding of biochemistry as well. In this area pharmaceutical research is the most obvious beneficiary of detailed chemical knowledge, but other areas benefit as well. Studying the chemical foundations of biological activity helps us discover new chemical and physical functions. A good example is the "chemiosmotic pump," which is the driving force that creates a chemical and electrostatic charge across the membranes of biological cells. Nature designed her own batteries long before humans did. How many more currently hidden phenomena await our discovery and application in new functions? One intriguing area is the study of cellular communication and its potential to help us find new methods of management and leadership.

The utility of chemical abstraction in understanding the world of atoms and molecules rests in the fact that by engaging in this type of thinking we become more capable of modifying our environment to suit our needs. If, for example, we understand why bronze is stronger than copper, perhaps we can design other alloys with properties we desire. In addition to helping our technology advance, I believe that thinking simultaneously in both abstractions and physical-sense reality helps us develop into more complete and freer human beings. I say this because the simultaneous use of physical, abstract and synthetic reasoning serves other human endeavors too. In the fields of chemistry, literature,[5] and in the Word we find this cycling between sense experience, analysis and abstraction from that experience, and application resulting from abstraction.

Returning to the imagery of being between Ai and Bethel we find a creative tension from being outside the definition of either camp. In a similar way the Promised Land itself is in tension since it is geographically located between the powers of the north and those of the south—Assyria, Babylon, and Persia on the one side and Egypt on the other—a situation well-exploited in Daniel's vision of the conquests of the kings of the north and south (Da 11:1-35). Far from being a land of peace, Canaan, time and again during its history, is tugged one way and then the other. Why would God send his chosen people into a land of disputes such as this? Jesus' saying, "I am the gate" (Jn 10:7) and "I am the way the truth and the life" (Jn 14:6) shows that He, the Lord, is with us in that tension—that He stands in the middle with us and *is* our conduit from one state to the next. Perhaps the epitome of this imagery is when Jesus stands at the threshold between life and death and raises Lazarus from the tomb (Jn 11:43). In contrast, the false gods do not stand at the threshold but live confined within the walls of their various temples. In one case Ezekiel finds a pagan temple literally in the wall (Ez 8:7-10). Perhaps in subconscious recognition of their inability to lead into a new state, the priests to Dagon do not step on the threshold of his temple (I Sa 5:5). Not being at the threshold, at the conduit between, indicates a deadly lack in the false gods. Zephaniah's prophecy singles out false prophets who will not stand at the doorway.[6]

The prophets have an important place in calling us into creative tension. Idolatry is a common topic for most of the prophets, and the contrasts they draw between false, human-made gods and the one true God often hinge on the idea of volition or freedom. For example, Jeremiah distinguishes between false gods and the true God by describing idols as being nailed to a pedestal, immobile and mute (10:4-5). Habakkuk makes similar statements (2:18). While the idol does nothing, is just a "scarecrow in a melon patch" (Jer 10:5 *NIV*), the people who worship the idols move around and make noise (Hab 2:19). Worship of the Lord is in sharp contrast. Habakkuk writes:

> But the Lord is in His holy temple;
> Let all the earth be silent before Him.
> (2:20 *NIV*)

To Habakkuk a false and a true deity are distinguished by who is silent and who makes sound. False gods are a trap that keeps us confined in small rooms. In these small rooms we hear only ourselves. The true God comes to the doorway and opens it for us and calls us to a new life. Is there any example in the Bible of a false god doing that for anyone?[7]

Our natural tendency is to seclude ourselves in Ai or Bethel and resist going to the door. Swedenborg reports seeing a spiritual replica of Stockholm while he was in the spiritual world (SE §5711). The houses had no windows, representing the locked and lightless state of mind trapping many of his countrymen and women. Another example of our tendency to stay put is the many trials Moses must endure because of his reluctant followers in the wilderness. On many occasions they accost him, whining about how he has led them out into the desert to die and how they want to return to Egypt. After settling in the land the people, at the risk of losing what is possible, seek traditions and forms that will help them remain confined to what they know. They clamor for a king instead of a heavenly ruler, and in return they receive a dynasty that abuses them and keeps them in submission. Near the end of the Jewish kingdom Jeremiah narrowly keeps his life as he tells his people they must throw off their pride and confidence of peace and protection within the walls of Jerusalem, abandon their city, put on the yoke of the Babylonians, and go captive into that foreign land (6:1, 27:12). The leaders say "Peace, peace" when there is no peace (6:14). Jeremiah tells the people that they cannot rely on Jerusalem or blind and senseless faith in Jehovah to save them. They have no security there. They need to change their state, and that is what they most resist.

Why is Jeremiah's message relevant to us today? Where are we in this story? Through imaginative abstraction from the text we may find the story calling us to leave our “Jerusalems,” our safe walls, and stop relying on our mistaken or incomplete picture of our God. We are not to settle in Bethel or Ai alone—relying solely on faith or on sense experience. We are to occupy the land between. In studying chemistry we are forced to keep our thinking balanced between immediate, sense experience (Ai) and imaginative, abstract rationalizations of that experience (Bethel). If I can strengthen this type of balanced thinking in chemistry students and connect this to the usefulness of linking experience and imagination in other human endeavors, then I am teaching chemistry in a liberal arts tradition which seeks to free human beings from provincialism and ignorance.[8] This is one way chemical education can have lasting value.

Study of chemistry contributes to our balance between Ai and Bethel in another way, too. While Ai’s focus on the natural readily appears as an error to those whose orientation is to think of life as a spiritual entity, Bethel’s error is less obvious to this group even though it is equally or more dangerous. Bethel errs when it adheres to ideology at the expense of experience. As soon as a person utters or thinks “I believe,” that person becomes less observant of contradictory evidence. This error is not the exclusive property of religious believers but infects all who cling to theories. One historical, chemical example is the idea of phlogiston—a philosophical quality of energy possessed by materials. Adherents to this idea, like Joseph Priestly (1733-1804, the discoverer of oxygen), had either to ignore observations or impart strange properties to this thing they called phlogiston. Some adherents to the phlogiston theory even claimed the material had negative mass (Salzberg 1991, 177). Like any science, chemistry teaches us to test our beliefs with sense experience. I find this testing essential in order to come to know the strengths and weaknesses of my own beliefs.

In a course like first-year chemistry I make a point of exposing reasons for many of our current theories. The kinetic molecular theory of a gas is a good example. This theory states, among other things, that all gas particles are in constant, random motion, and that the average kinetic energies (KE, energy due to motion) of two gases at the same temperature are identical. We speak of *average* kinetic energies because gas particles at the same temperature do not have a single velocity but are smoothly distributed over a wide range of speeds. The kinetic molecular theory predicts that the average speed of a gas particle is related to its mass since KE = $(½)mv^2$, where m = mass of a particle and v = its velocity. This theory has been tested in a number of ways.

One test I show the class is the agreement between the kinetic molecular theory and Graham's law of effusion. Graham's law, named after Thomas Graham (1805-1869) who discovered it in the 1830s, states that gases effuse (escape) through a tiny hole in a pressurized container at rates relative to the square root of the reciprocal of their molecular weights. Effusion rate is a measure of molecular speed because the faster a gas particle travels the quicker it "searches" the interior of the container and finds the hole.

The following proportionality expresses Graham's Law:

$$r \propto \sqrt{\frac{1}{m}}$$

where r is rate of effusion of the gas and m is the mass of the gas particles. Graham also compared the rate of effusion of one gas to another by dividing one rate by the other. The resulting equation is:

$$\frac{r_A}{r_B} = \sqrt{\frac{m_B}{m_A}}$$

where A and B refer to gases A and B.

After introducing effusion and these two equations, I ask the class to consider how Graham might have arrived at these expressions and what the expressions mean. The first equation is a little easier to understand. It indicates that the smaller the mass of a particle the faster its velocity. But velocity increases as a square root instead of proportionally. This is odd and surely not the kind of mathematical function Graham thought he would obtain. Graham arrived at these expressions through analysis of experimental observations—by fitting a mathematical model to his data. He had no idea why effusion followed this model.

The kinetic molecular theory, developed in the 1860s, explains Graham's observation, and the observation serves as a confirmation of the theory. If gases are composed of particles which are in constant, random motion, and the average kinetic energies of these particles are the same at the same temperature, then the average velocity of the lighter particles must be faster than that of the heavier ones, as the following lines of mathematical reasoning demonstrate.

$$\text{If } KE = \frac{1}{2}mv^2, \quad \text{and} \quad \overline{KE}_A = \overline{KE}_B, \quad \text{then} \quad m_A\bar{v}_A^2 = m_B\bar{v}_B^2\ ;$$

$$\text{therefore, if} \quad m_A < m_B \quad \text{then} \quad \bar{v}_A^2 > \bar{v}_B^2.$$

We can combine these expressions into a form similar to the one Graham used. When we do this we obtain:

$$\frac{\bar{v}_A^2}{\bar{v}_B^2} = \frac{m_B}{m_A}$$

We arrive at Graham's empirical expression after taking square roots.

$$\frac{\bar{v}_A}{\bar{v}_B} = \sqrt{\frac{m_B}{m_A}}$$

The proportional rate expression derived from the kinetic molecular theory exactly matches the empirical expression Graham discovered. I make a strong point in class that when we find agreement between two independent methods of describing the way materials behave, one from empirical observation and the other from theory, we can be reasonably confident the theory is correct. This is how we ground imagination with physical analysis.

Chemistry (or any science) provides a good training ground for developing this type of analytical thinking. Once students learn to examine assumptions in science they may transfer that skill to other areas, leaving behind what Socrates called the "unexamined life." Testing theories in science is relatively easy because the whole field is based on sense experience, and theories in science must be testable in some manner. However, sometimes scientific theories or hypotheses remain untested for many years until someone figures out how to design an appropriate experimental test for it. Bose-Einstein condensation is one example.[9] All scientific theories, in order to be "scientific," must have the possibility of being tested, and in many cases the test is stated as part of the theory. This is not usually the case in other areas of learning. In the New Church we hold that the promised second coming of the Lord occurred in 1757 A.D. and was an event taking place in the spiritual world. The very nature of this doctrine or belief denies the possibility of testing it through sense experience. The event took place outside the physical realm and therefore no test in the physical world can confirm or deny it.[10] We need either to bring non-physical tests to bear on this theory, or to examine it through a kind of correspondential testing. Although analysis of scientific theories is simpler than analysis of theological ones, we ought not wall off our theological ideas, secluding them from testing. This is the error the Bethel-alone mind set makes.

I believe the physical world provides us with a means of analyzing how well we understand the nature of the spiritual world, God, and even salvation. We can do this through a kind of abstraction from realities in the physical plane to see how well they fit with our ideas about the spiritual plane. This stems from the assumption that order in the physical world reflects a causative order in the spiritual one (AC §5711, Woofenden 1970, 109).

I have already discussed how we can make abstractions in chemistry that help us understand why materials have their properties. We might call this kind of abstraction "horizontal" because we are explaining physical phenomena using physical means such as intermolecular forces of attraction to explain boiling point differences of different materials. If, on the other hand, an abstraction refers to the spiritual realm we might call it "vertical" abstraction. We can employ vertical abstraction when we mentally connect concepts of spiritual properties with natural ones. In the New Church this kind of connection is said to be "correspondential" and Swedenborg's theological works state that a pre-Hebrew, and wide-ranging "Ancient Church," represented by Noah and his descendants, specialized in this kind of thinking (cf. ML §76). In more recent times the

Jewish Cabala and esoteric alchemy espoused similar ideas. The esoteric alchemists attempted to explain properties of heaven by investigating the nature of the physical world—a kind of reverse astrology (Salzberg 1991, 37). Cabalistic, or correspondential, or esoteric—call them what you will—opportunities arise in the chemistry classroom, and these kinds of vertical abstractions can have strong effects on beliefs.

One illustration of this kind of thinking relates the laws of thermodynamics to an important difference between created and uncreated beings. The first law of thermodynamics states that the total amount of matter and energy in the universe remains constant and is nowhere created or destroyed. The second law states that all spontaneous processes (anything that happens) increases the dispersion of energy in the universe. This implies that no matter what we do with our lives we increase randomness or entropy. Whatever energy exists in the entire universe is more concentrated at this moment in time than at the next, and there is nothing we can do to stop this degradation.

One example of this is the energy transformations taking place in our sun. At every instant the sun loses huge magnitudes of energy, radiating it out into space. A tiny fraction of that radiant energy strikes the earth and drives the vast majority of processes taking place here. The energy leaving the sun is not destroyed but becomes more and more dilute as it radiates outward in a sphere. As the radiant energy becomes more dilute its disorder increases. On earth the sun's energy allows increasing atomic or molecular order, such as charging a solar voltaic cell or driving photo synthetic reactions. But this increase in order comes at the expense of tremendous loss of order in the sun itself. The loss in order overwhelms the increase in order we see here. This decay in order agrees well with Swedenborg's statements in theological works such are *Divine Love and Wisdom* that the natural world did not and does not create itself, but was created by God (cf. DLW §55). Our current understanding of the cosmos and the laws of thermodynamics accords well with this since we know of no means by which we can reverse the decay of order in the universe, and yet somehow the universe came into being. We as created entities in this created world cannot cause a net gain in concentrated energy. But God, an uncreated being, can.

In the realm of human events we can spot tremendous ordering events that seem to contradict the second law. New York City is a good example. Three hundred years ago Manhattan was a wild island and today it contains awe-inspiring structures above and below ground. Buildings and infrastructure, composed of purified materials, clearly represent a gain in molecular order. But to create this increase in order we had to pay a high price. Tremendous amounts of energy were dissipated (diluted) in the refining, transportation and construction processes.

We can relate loss of order in the universe (second law of thermodynamics) to our personal states. Nothing we do in our lives creates a net gain in concentrated energy but only a loss. As I tell my class, even if we attempted to end our own contributions to increasing entropy by killing ourselves, our decaying bodies would disorder the universe. The second law is inescapable.

Another way to look at this is to think of our spiritual progression as a microscopic ordering process. The spiritual processes of repentance, reformation and regeneration cause a purification of our beings. Assuming a spiritual corollary to the physical laws of thermodynamics, this purification in our spiritual lives is either impossible, or comes at the price of creating greater disorder. If we were to attempt purifying own spiritual lives on our own we might succeed in creating a local area of order but only as we alloy some other part of ourselves. If this is the case, our regenerating ourselves would probably harm rather than help others. But if we accept the Lord of creation as the force that, like a refiner's fire, purifies our lives, perhaps similarly to the way the sun energizes plants enabling them to make complex sugars from air, or even more similarly to God's creating wholly new universes from spirit, then our regeneration may come at no cost to order, but represent a net gain. We, created entities, cannot do this, but God, who created all order and matter and energy, can. Jesus tells his disciples, "With man this is impossible, but with God all things are possible" (Mt 19.26 *NIV*).

Thinking further on salvation, I believe we can develop physical metaphors for spiritual processes that may help us visualize how we can work with the Lord and let him save us. People have struggled for centuries trying to figure out their role in the process of what Jesus calls being "born again." Nicodemus was perhaps the first to wonder about this. He exclaimed to Jesus, "Surely [a person] cannot enter a second time into his mother's womb to be born!" (Jn 3:4). The doctrine of salvation by faith alone is an attempt to understand our role and God's role in this process. Most Christians accept that they cannot merit salvation and that only faith in the Lord saves us. And yet many also believe that they must do certain things in their lives in order to be saved. This is a paradox. If we cannot merit salvation why must we do anything for it? Nothing we do can obtain it and God gives it to us as a free gift; then why struggle through repentance at all?

Energy transfer processes in the natural world may provide us with a representation of the Lord's redeeming us and help clarify our roles and God's role in accomplishing salvation, which is, according to the New Church, necessary to accomplish the Lord's very purpose of creation which is to provide "a heaven from the human race" (DLW §330).

Human beings have found various energy resources in the world and have figured out how to make good use of them. A relatively simple example is a windmill to take advantage of wind power. An even simpler example is a sail. In each case humans are harnessing a natural energy source to do work for them. Wind power is available for us to use, and has existed as long as the earth has had an atmosphere. But that power does not do much work directly for us until we assemble some mechanism for it. The power itself is available to us as a free gift, but the means by which we take advantage of the power is our responsibility. We assemble the mechanical works and supporting structures of a windmill from materials distributed in the world. The mechanics then move under the force of the wind, which helps us with some task. We may look at the windmill and think "I made that," and at the ground corn and say "I milled that corn," congratulating ourselves on our fine brains and accomplishments. But we did not grind the corn—the wind did. And we did not create the wind nor do we know much about it. Jesus said, "The wind blows wherever it pleases. You hear its sound, but you cannot tell where it comes from or where it is going" (Jn 3:8). The power we use comes as a free gift—a gift we may not even recognize for years. Even power from our own body—running, lifting, pulling—comes not from us but from the biology and chemistry of our bodies. We did not design it and we hardly understand it, but from what we can see of what is going on inside our bodies, our energy comes from a set of reactions developed in bacteria over one billion years ago.

I think this image reflects the process of our salvation. The power that saves comes from God, not from ourselves, but God does not save us with ourselves standing idly by. We must orient ourselves—build the windmill or trim the sails—so that God's wind turns our wheels, separating flour from waste, or pushes us gently on our way. We do not need to generate the spiritual wind, but we do need to recognize it and let it do its work on us. Even though this requires action on our parts, our action is not what saves us, and so we can take no merit in it.

The Bible uses several images showing what we need to do to accept the Lord's free gifts. Here are a few examples quoted from the New International Version:

> Turn from evil and do good;
> seek peace and pursue it. (Ps 34:14)
>
> Administer justice every morning;
> rescue from the hand of his oppressor
> the one who has been robbed. (Jer 21:12)
>
> For I desire mercy, not sacrifice,
> and acknowledgment of God rather than burnt offerings. (Hos 6:6)
>
> Sow for yourselves righteousness,
> reap the fruit of unfailing love,
> and break up your unplowed ground;
> for it is time to seek the Lord,
> until He comes
> and showers righteousness on you. (Hos 10:12)

As the Bible makes clear, we cannot stand by idly and wait for God to make everything blessed for us. Just as we must recognize natural resources available to us and use our ingenuity to make use of them, we must also "prepare a way for the Lord" (Isa 40:3). Vertical abstractions of chemical concepts can help us clarify our spiritual beliefs and, in turn, these spiritual beliefs can inspire a holy sense into our applications in the physical world.

The abstract thinking encouraged in studying chemistry empowers our ability to use thinking to discover something new, whether this be realization of a physical law hiding in laboratory results or theological concept reflected in the workings of the natural world. The key to seeing connections between sense experience and concept is our willingness to accept the tension that exists between the two. Maintaining responsiveness to both is reflected in Abram's returning from Egypt, "to the place where his tent had been at the start, between Bethel and Ai" (Gen 13:3). When we accept this tension for the creative benefit it brings we allow ourselves to develop into new states. In this way education reflects spiritual journey, along with its eternal value.

Notes

1 Chapters 12 and 13 of *Arcana Coelestia* explain the meaning of Abram's first travels through Canaan and his sojourn in Egypt. In my faculty development study *Chemical Education Between Bethel and Ai* I analyzed this biblical story as an allegory of education. This study is available in the Swedenborg Library, Bryn Athyn, PA. A related work using this imagery will be published elsewhere.

2 The exact meaning of the terms "knowledges" and "cognitions" has been debated by New Church thinkers. In my study, I review previous interpretations and offer my own, which is reflected here.

3 I share this fear with Erich Fromm, who, in his 1941 work *Escape From Freedom*, wrote of how human beings tend to avoid feelings of isolation through a process he called "automaton conformity" (208). A person escapes in this way by adopting a programed way of being (208-209). "The decisive point [between genuine being and automaton conformity]," Fromm writes, "is not *what* is thought but *how* it is thought" [Fromm's emphasis]. This question of what leads us to think a certain thing, is crucial to my educational motivations. Fromm continues, "The thought that is the result of active thinking is always new and original; original, not necessarily in the sense that others have not thought it before, but always in the sense that the person who thinks has used thinking as a tool to discover something new" (218-219). Developing an algorithm requires just this sort of thinking, but applying an algorithm does not.

4 Dudley Herron demonstrates this well in his analysis of the atom as a concept, and the information students require to construct that concept (1996, 267).

5 One fine example of this discussion dealing with literature and revelation is Kristin King's analysis of Robert Frost's poem, "Birches," in which the poet plays with the imagery of bending a birch tree to illustrate how abstractions must lead us back to the ground (King 1999, 52-55).

6 "On that day I will punish
all who avoid stepping on the threshold,
who fill the temple of their gods
with violence and deceit" (Ze 1:9 *NIV*).

7 A non-biblical example of a god calling a mortal into a new state is Athena's words of encouragement to Telemachus in Book I of Homer's *The Odyssey*.

8 Bryn Athyn College does not stand alone in its desire to teach science as a means of educating the whole person. The American Association for the Advancement of Science supports teaching science as a liberal arts course and part of a liberal arts education (AAAS Study Group 1990, 11-12). Farmer, writing on what has been done at King's College in Wilkes-Barre, PA, makes similar statements (1988, 134-135).

[9] Bose-Einstein condensation is a special phase of matter in which many individual atoms appear to coalesce. Einstein and Bose first predicted this condition in 1924, but it was not observed until 1995 (Anderson, *et al.*).

[10] An interested reader can find arguments for and against employing scientific tests to spiritual phenomena in a debate between Leon James and myself in the pages of *New Church Life.* See "works cited."

Works Cited

AAAS Study Group. 1990. *The Liberal Art of Science: Agenda for Action.* Washington, D.C.: American Association for the Advancement of Science.

Anderson, M. H., J. R. Ensher, M. R. Matthews, C. E. Weiman, E. A. Cornell. 1995. "Observation of Bose-Einstein Condensation in a Dilute Atomic Vapor." *Science* 269: 198-201.

Bedford, Allen J. 1994. "A Response to Dr. James' Request for a Paradigm Shift." *New Church Life* 114: 515-521.

———. 1995. "Dualist Science or Dual Enlightenment?" *New Church Life* 115 (1995): 366-370; 411-414.

———. 2002. *Chemical Education Between Bethel and Ai.* Bryn Athyn, Pennsylvania: Bryn Athyn College of the New Church. Monograph.

Farmer, D. W. 1988. *Enhancing Student Learning: Emphasizing Essential Competencies in Academic Programs*. Wilkes-Barre, PA: King's College.

Fromm, Erich. 1941. *Escape From Freedom*. New York: Avon Books.

Herron, J. Dudley. 1996. *The Chemistry Classroom: Formulas for Successful Teaching*. Washington, D.C.: The American Chemical Society.

James, Leon. 1994. "Two Perspectives on Swedenborg's Writings: Secular and Religious." *New Church Life* 114: 348-362; 394-399.

——— .1995. "Do the Writings Contain Scientific Revelation? *New Church Life* 115: 154-163; 228-235; 264-270; 325-330.

King, Kristin. 1999. "The Power and Limitations of Language in Swedenborg, Shakespeare, and Frost." *Studia Swedenborgiana* 11:1-63.

Merrill, M. and R. Tennyson. 1977. *Teaching concepts: An instructional design guide.* Englewood Cliffs, NJ: Educational Technology Publications.

Salzberg, Hugh. 1991. *From Caveman to Chemist: Circumstances and Achievements*. Washington, D.C.: The American Chemical Society.

Swedenborg, Emanuel. 1983-1999. *Arcana Caelestia.* 12 volumes. John Elliott, translator. London: The Swedenborg Society. [Published originally in London, 1749-1756, 8 quarto volumes.]

——— . 1986. *Divine Love and Wisdom.* George Dole, translator. New York: Swedenborg Foundation. [Published originally in Amsterdam, 1764.]

——— .1995. *Married Love*. N. Bruce Rogers, translator. Bryn Athyn, PA: General Church of the New Jerusalem. [Published originally in Amsterdam, 1768.]

———. 1902. *Spiritual Diary.* Vol. 5. J. Buss, translator. London: James Speirs. [Originally published posthumously, 1843-1847.]

Woofenden, William R. 1970. "Swedenborg's Philosophy of Causality." Ph.D. Dissertation. St. Louis University.