

ECOLOGICAL DIVERSITY, VARIETY IN THE HEAVENS, AND HIGHER EDUCATION

Sherri L. Cooper

I. INTRODUCTION

In this essay, I explore correspondences between the natural and spiritual worlds in relation to concepts and measures of ecological science, especially those of species diversity and community structure in nature. This includes perspectives on variety and communities in the spiritual world as described in Swedenborg's Writings for the New Church. First I will define diversity and variety as general terms, then as they compare to Swedenborg's use of the terms, and finally in terms of ecological science. The discipline of correspondences is reviewed and dealt with, using diatoms (my favorite research organism), and paleoecology (the study of past ecosystems), as examples. Included is a survey of the specific uses of the study of correspondences as described in Swedenborg's publications and the applicability of that study for philosophy and science courses. The theological Writings of Emanuel Swedenborg (1688–1772) contain a new revelation for understanding God and our relationship with God; these teachings have been important in the establishment of the New Church (also known as the Swedenborgian Church). Swedenborg writes that there is an internal sense or spiritual meaning to Scripture that is not generally known.

* Sherri L. Cooper is currently an assistant professor and director of the biology major at Bryn Athyn College in Bryn Athyn, Pennsylvania. She received her Ph.D. in geography at Johns Hopkins University (1993) working with palynologist Grace Brush, her M.S. degree in Marine Sciences at the University of Delaware (1982) with John L. Gallagher, and a B.S. degree in Botany (1978) at Duke University. She was a research professor at the Duke University Wetland Center from 1995-1999, and Assistant Director of the Mid-Atlantic Regional Marine Research Program from 1993-1995.

Dr. Cooper is internationally recognized in the field of estuarine paleoecological diatom analysis. She has authored or coauthored 10 journal articles and 20 technical reports and book chapters that involve wetland, estuarine or coastal marine ecology and paleoecology, especially in relation to human impacts on the environment.

Sherri and her husband David and their two children live in Bryn Athyn. Mailing address: Bryn Athyn College of the New Church, P.O. Box 717, Bryn Athyn, PA 19009. E-mail: Sherri.Cooper@brynathyn.edu.

II. DEFINITION OF TERMS

The first definition of diversity in *Webster's* unabridged dictionary (Wyld and Partridge 1962) is a "state of being different, unlikeness; variety, difference; **a.** in outward form, appearance, structure; **b.** in mental and moral character, thoughts, opinions etc." Variety, on the other hand, is defined as the "quality of being various; reverse of monotony; absence of sameness; diversity of external objects or conditions, or of qualities etc." Diversity is here defined as a "state," while variety is a "quality." Similar definitions are given in *The American Heritage Dictionary* (2000). Diversity is defined as "**1a.** The fact or quality of being diverse; difference. **b.** A point or respect in which things differ. **2.** Variety or multiformity." Whereas variety is defined as "**1.** The quality or condition of being various or varied; diversity. **2.** A number or collection of varied things, especially of a particular group; an assortment: *brought home a variety of snacks.* **3.** A group that is distinguished from other groups by a specific characteristic or set of characteristics." In both of these dictionaries, diversity and variety are obviously related, as they turn up in the definitions of each other.

In *Conjugal Love*¹ (§ 324), and other works, Swedenborg often separates the meaning of these two words as concepts in relation to the spiritual world. Swedenborg writes:

All things display infinite variety and also infinite diversity. By variety we mean differences between the members of a single genus or a single species, as well as between different genera and species. By diversity we mean here differences between opposites. The following example will illustrate our concept of the distinction between variety and diversity. The heaven of angels, which holds together as a unit, displays infinite variety. There is not a single angel there who is entirely like another, not in soul and mind, nor in affections, perceptions and the thoughts they induce, nor in inclinations and the intentions they produce, nor in tone of voice, face, body, gestures, manner of walking and many other things.

¹ *Conjugal Love* is primarily about the subject of married love and the spiritual nature of men and women. Swedenborgian faiths generally accept these written works of Swedenborg as divinely inspired.

Yet, although there are hundreds of millions of them, they have been and are being arranged by the Lord so as to make a single form, displaying total unanimity and concord. This would be impossible, were not all the angels with all their variety guided universally and individually by the One. This is what we mean by variety. By diversity, however, we mean the opposites of these varieties, which exist in hell. For there all without exception are diametrically opposed to the inhabitants of heaven; and hell composed of them is held together as a unit by varieties which are relatively the utter contraries of the varieties in heaven, that is, by perpetual diversity. These remarks will establish what is to be perceived by the words "infinite variety" and "infinite diversity."

Swedenborg clearly separates diversity from variety. Variety is a term that is used most often in conjunction with heaven, or for all that is good and true. Diversity, on the other hand, more often refers to the state or quality of hell, or of all that is evil and false. Perhaps the use of two separate terms was simply a way to explain the similar complexity (infiniteness) of each (heaven and hell) while keeping them different (opposite) from each other. We have seen already that in the English language, at least, these two terms are nearly interchangeable.

In ecology, which is the study of the relationships between and among organisms and their environment on earth, species diversity is defined as "a numerical measure combining the number of [different] species (richness) and the distribution of the total number of individuals among the species (evenness)" (Nybakken 2001). It is expressed through various diversity indices, the most common of which is Shannon's H' , with the use

of information theory (Shannon & Weaver 1949):
$$H' = - \sum_{i=1}^s \frac{n_i}{n} \ln \frac{n_i}{n},$$

where H' is the assemblage diversity, n is the total number of individuals counted per sample, n_i is the number of individuals of the i -th taxon and s is the total number of taxa in the sample. Diversity, under this definition, is an index of assemblage structure in which it is possible for diversity to increase while species number decreases, if evenness increases. This is the most widely used diversity index in aquatic systems (Washington 1984). It is interesting to note that species richness, which is simply "the number of

[different] species in a given area" (Nybakken 2001) may be considered to be a common definition of diversity, but in ecology it is only part of the story. A simple example of how Shannon's H' works is outlined here. If given two adjacent "forests" of ten trees, one forest (A) with all the same species of tree, the other forest (B) with ten different species, then forest B has the greatest diversity, because it has the most species. However, if both forests contained the same number of species (with the example of two species each), but forest A has five trees each of species 1 and 2, while forest B has nine trees of species 1 and one tree of species 2, then forest A has a higher diversity due to its "evenness" of species abundance.

Species can also be found in "varieties" that are not considered to be separate species (or states of being), but rather different forms of the same species. This is a later dictionary definition for variety. Diversity indices can be used to take this variety into account with the same weight as with species. Also, "community diversity" can be determined for a single class of organisms, composed of its own genera and species, in which case it may be viewed as more of a "variety" index. More will be said on this later in the paleoecology discussion.

Diversity indices are often used to describe attributes of community structure in ecology. A community is defined as "an association of interacting species living in a particular area" (Molles 1999). The environment, including climate, geology, topography, and soil, play a large role in determining the available resources and composition of these communities. This environment with which they interact is external to the living organisms. The community, therefore, can be considered to make a "one" or whole "ecosystem" with its environment. Indices of community diversity allow discernment of "quality" (uses and functions) and variety of these, within the environment, and/or within an ecosystem. Greater diversity is seen as an important, good, and healthy state for an ecosystem. High diversity allows sustainability of an ecosystem, making it less subject to change by stressors. This diversity defines "one" ecosystem. In this way, diversity in terms of the science of ecology is more similar to Swedenborg's definition of variety in the heavens, as all parts are needed to make a more perfect whole.

In Swedenborg's description of the spiritual world, community is defined not so much by "space" or environmental area (as it is in ecology), but by common affections or loves. In *Heaven and Hell*² (§ 41), Swedenborg writes that in heaven, "angels . . . are separated into larger and smaller communities depending on differences in the good effects of the love and faith they are engaged in." Further, in *Arcana Coelestia*³ (§ 8469), Swedenborg writes that:

. . . heaven is made up of countless communities that are distinct and separate from one another. . . all in each community share a common good, which is distinct from the good of other communities. Also each member of a community possesses a particular kind of good, distinct from the good any other in the community possesses.

According to Swedenborg, there is no space or time in the spiritual world. We read that communities are not separated by space, but by distinct goods or loves (states). In the same way, hell is also divided into communities of people with love of distinct evils or falsities.

In *True Christian Religion* (§ 477), Swedenborg writes that:

Hell . . . is similarly divided in keeping with all the varieties of affections belonging to the love for evil. After death a person, being then a spirit, is at once allotted to a community in keeping with his life in the world, and this is where his dominant love is. It is a heavenly community if love to God and towards the neighbour were chief among his loves, a community in hell if self-love and love of the world were his chief loves.

This concept of spiritual communities is comprehensible, but not in the context of space and time. In the natural world, communities are bound by

² *Heaven and Hell* is a work about the secrets of heaven and hell, and the equilibrium between them that allows spiritual freedom to humans on earth.

³ The *Arcana Coelestia* is a multi-volume work that explains the inner spiritual meaning of the books of Genesis and Exodus in the Bible.

both space and time, and are studied in this framework. In addition, as we will see below, the natural world is affected by both heaven and hell.

III. CORRESPONDENCE BETWEEN NATURE AND THE SPIRITUAL WORLD

A. The science of correspondences

Before continuing with this paper, it is important to establish the relationship between nature (on earth) and the reality of the spiritual world. In *Heaven and Hell* (§ 87), Swedenborg begins his description of correspondence between the natural and spiritual worlds by saying that “People today do not know what ‘correspondence’ is.” The primary reason for this, according to Swedenborg, is that people have moved away from heaven because of their love for themselves and the world. They do not attend to spiritual matters but to earthly matters. Swedenborg says that “knowledge about correspondences is in fact angelic knowledge.” Without an acknowledgment of the spiritual world there is no possibility of any knowledge of correspondences.

In *Heaven and Hell* (89), we learn that “correspondence” means that the whole natural world is responsive to the spiritual world. In other words, “the natural world arises from and is sustained in being by the spiritual world, exactly the way an effect relates to its efficient cause.” Cause and effect are easily understood in terms of natural laws, such as: gravity as the cause, and weight being an effect; and later (*HH* § 106), we read that “absolutely everything in nature, from the smallest to the greatest, is a correspondence.” The reason for this, again, is that everything in the natural world comes from, and is sustained by the Lord through the spiritual world, as stated in *Arcana Coelestia* (§ 5131):

there is a correspondence of sensuous with natural things, a correspondence of natural with spiritual things, a correspondence of spiritual with celestial things, and finally a correspondence of celestial things with the Divine of the Lord; thus there is a succession of correspondences from the Divine down to the ultimate natural.

In Dole (1984), we learn more about the nature of correspondence and representation. Correspondences are said to be a responsiveness to heavenly things. Correspondences can only be acknowledged and recognized if we know and accept that there is a spiritual world. Everything that is in harmony with heaven is corresponding or "is responsive." In *Arcana Coelestia* (§ 2991) Swedenborg writes that ". . . all natural phenomena portray aspects of the spiritual things to which they are responsive, and these spiritual things too portray elements of the heavenly things they come from." Further, in the same work (§ 2993) we read that ". . . everything in the natural world finds its cause in something true that is spiritual and its fundamental in something good that is heavenly . . . So they come from the Lord Himself, who is the source of everything good and true." In his revelation, Swedenborg writes that without a link to the spiritual world, everything would cease to exist: ". . . the correspondence of natural phenomena with spiritual ones, or of the world with heaven, takes place through functions, and that the functions are what unite them . . . the forms that clothe the functions are correspondences and unions to the extent that they are forms of the functions" (*HH* § 112). The correspondences of the natural and spiritual planes are most related to function (use) and therefore also to the form that determines function.

What correspondences can be found between the natural and spiritual in relation to the subject(s) of this paper? Following is an example exploration of possible correspondences for the living (and fossil) organisms known as diatoms, based on Swedenborg's Writings for the New Church.

B. Classification of diatoms

Diatoms are single-celled autotrophic organisms that live primarily in aquatic systems and have a silica frustule consisting of two valves that are preserved as fossils in sediments after the diatom dies. Diatoms are currently classified within the Kingdom Chromista (Gould & Keeton 1996): Subkingdom Chrysophyta, Phylum Ochrista, Class Bacillariophyceae (or Diatomeae). The Chromista are a kingdom of separately evolved, primarily photosynthetic organisms, that contain their chloroplasts *inside* the endoplasmic reticulum and possess a unique form of chlorophyll (chloro-

phyll c). Some textbooks classify diatoms as algae in a division within the Kingdom Protista (Campbell et al. 2003). The Kingdom Protista is a “catch-all” kingdom for eukaryotic⁴ organisms that don’t seem to fit anywhere else in the basic five kingdom system.⁵ Some older textbooks still classify this special class of algae as lower plants (e.g., Round 1970). The phylogeny⁶ of this group of organisms is obviously still being worked out. Whatever kingdom they are classified within, there are more known species of diatom than in any other class of organisms outside of the animal kingdom. Even within the animal kingdom, only certain classes of insects may contain more species than the diatoms. Current estimates are that the diatoms consist of about 200,000 species (Mann & Droop 1996), but there are other estimates as high as one million! Diatoms are also estimated to produce approximately 25–30% of the world’s oxygen supply—which is more than all the rainforests combined. They are an excellent food source at the base of the food web in almost all aquatic systems; freshwater, brackish, and marine. Their food storage is lipid (fat)-based, rather than starch, as in plants. They are a very diverse group in terms of tolerance for variable environmental conditions, but each species has its own limits and optima. This is one of many reasons that their communities are useful for study in relation to water quality issues, past and present.

C. Correspondences of diatom form and function

Swedenborg names three “kingdoms” on earth in *Heaven and Hell* (§§ 103–115: the animal kingdom (living organisms), the vegetable kingdom (growing organisms) and the mineral kingdom (neither living nor growing). This classification system doesn’t explicitly include microorganisms and many other living things that we now categorize into at least 5–8 kingdoms. In fact, biologists have recently named three “domains” of

⁴ Eukaryotic organisms are made up of cells that have a membrane-enclosed nucleus and other membrane-enclosed organelles. All organisms except bacteria and archaea are composed of eukaryotic cells.

⁵ The basic 5 kingdom system is composed of the following kingdoms: Bacteria, Protista, Fungi, Plantae and Animalia.

⁶ Phylogeny is the evolutionary history of a group of organisms. Biologists traditionally represent the genealogies of organisms as phylogenetic trees.

living things: two prokaryote⁷ domains and eukaryotes. Swedenborg probably would have known about microscopic organisms. Microscopes and microorganisms were being discovered just before and during the time of Swedenborg's life (Campbell et al. 2003). Perhaps as others did at that time, Swedenborg may have categorized microorganisms as either small animals or plants, although most autotrophic microorganisms do not become larger (grow), but they do multiply! Many autotrophic microorganisms can (or appear to) move on their own, and during the time of Swedenborg's life were often classified as small "beasties." This may be an important distinction, since Swedenborg's two groupings of organisms into animal and plant kingdoms have particular correspondence to spiritual realities, as discussed below. I wonder what special correspondences there might be for prokaryotes (cells with no nucleus or other organelles).

Regarding the correspondence of animals, Swedenborg writes that: "The animals of the earth correspond in general to affection, mild and useful animals to good affections, fierce and useless ones to evil affections" (*HH* § 110); and "The reason animals are affections, according to their genera and species, is that they are alive, and the only source of life of any creature is from affection and is in proportion to it" (*ibid.*). Then in the same work (§ 111) he writes in more detail about specific correspondences of plants:

There is a like correspondence with things in the vegetable kingdom. In general, a garden corresponds to the intelligence and wisdom of heaven; and for this reason heaven is called the Garden of God, and Paradise; and men call it the heavenly paradise. Trees, according to their species, correspond to the perceptions and knowledges of good and truth which are the source of intelligence and wisdom. For this reason the ancient people, who were acquainted with correspondences, held their sacred worship in groves; and for the same reason trees are so often mentioned in the Word, and heaven, the church, and man are compared to them; as the vine, the

⁷ Prokaryotes are all single-celled organisms that do not contain a nucleus or other cell organelles (including bacteria and archaea), and were the earliest known life-forms on the earth.

olive, the cedar, and others, and the good works done by men are compared to fruits. Also the food derived from trees, and more especially from the grain harvests of the field, corresponds to affections for good and truth, because these affections feed the spiritual life, as the food of the earth does the natural life; and bread from grain, in a general sense, because it is the food that specially sustains life, and because it stands for all food, corresponds to an affection for all good. It is on account of this correspondence that the Lord calls Himself the bread of life; and that loaves of bread had a holy use in the Israelitish Church, being placed on the table in the tabernacle. . . .

Diatoms are most likely “vegetable” according to Swedenborg’s categories, primarily because they are autotrophic (produce their own food from the sun’s energy). Light and light energy correspond to truth. Diatoms are not true plants, however. Although they contain chloroplasts and photosynthesize, they are single-celled. Phylogenetically, the diatoms evolved separately from the plant kingdom.

Since Swedenborg writes that the vegetable kingdom corresponds to intelligence and wisdom, the different species of diatoms perhaps correspond to various small, simple, or very basic truths or knowledges of the spiritual world. Diatoms are quite beautiful in outward form; the silica (glass) frustule of each species of diatom has its own unique ornamentation consisting of pores, striations, processes and furrows (see Figure 1). Although we might think of them as small and simple in many ways, they also contain incredible variation in the details of their individual species structure.

Diatoms can also be considered the “bread” of the aquatic world. They are at the base of the food chain and are one of the richest or most nutritious forms of food for most organisms that eat such things (which in turn are eaten by other organisms!). In other words, they provide food for almost all of life in the food web of aquatic systems on earth. As “bread,” diatoms correspond to affections for what is good and true. Diatoms also function to produce oxygen, which is essential for aerobic respiration, a process that is basic to energy and metabolism in all higher plants and animals on earth. Since correspondence takes place through function, and

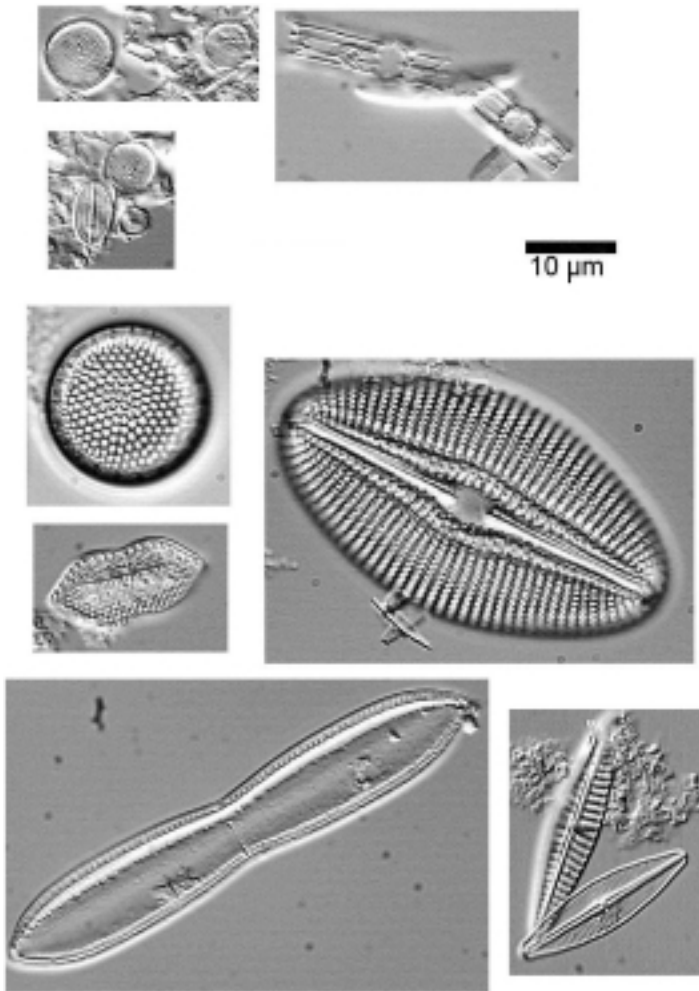


Figure 1. Light microscope images of different species of diatom subfossils found in the Pamlico and Neuse River sediments (Cooper 2000). The scale bar is 10 micrometers (10×10^{-6} meters).

diatoms provide these extremely basic and important functions for sustaining all of life on earth, diatoms may be thought to correspond to simple, very basic, spiritual truths, and affections for good. Diatoms also have the form that clothes these functions on earth. They not only have

their intricately beautiful silica shell, their color in life is called “golden-brown” by scientists and taxonomists because of the unique chlorophyll that they contain. This color could arguably be considered “bronze,” which corresponds to natural goodness. According to Swedenborg, natural goodness represents the base (ultimates or effects) of the spiritual world, and constitutes the outermost (natural) heaven. In *Arcana Coelestia* (§ 425), Swedenborg writes:

Up to now the world has not known that “bronze” means natural good, nor indeed that every metal mentioned in the Word has some definite meaning in the internal sense. For example “gold” means celestial good, “silver” spiritual truth, “bronze” natural good, “iron” natural truth, and so on with all the rest.

IV. THE STRUCTURE OF COMMUNITIES

A. The form and uses of communities and diversity in nature

Our planet earth contains many diverse (different) ecosystems. Remember that an ecosystem is a group of organisms that live together and function together as one unit along with their environment. In an ecosystem, each organism has a specific purpose or role to fill within its habitat, known as its *niche* (Enger & Smith 2004). If part of an ecosystem is altered or destroyed, then the entire ecosystem could fail. Within each ecosystem are communities of organisms that interact with each other. These communities are usually composed of different species, and the more diverse a community is, the healthier it is considered to be. Very diverse communities are usually more resilient to stresses imposed on them by nature, climate, or humans.

1. Ecology: the scientific study of ecosystems

Succession is an ecological concept that describes the gradual change in plant and animal communities in an area following disturbance, or after the creation of a new substrate, such as after a volcanic eruption or the

retreat of glaciers (Molles 1999). As succession progresses, diversity of species and number of interactions between species generally increase to an optimum that is possible within the environment. Succession proceeds through various stages (known as *seres*) to a climax community. The climax community is relatively stable, long-lasting, fairly complex, and exhibits relatively high species diversity. There are all trophic⁸ levels (including decomposers) represented, and many interactions between species and the environment. Specific types of terrestrial climax communities depend on climate and soil type as well as resource availability within the environment, while aquatic communities depend more on salinity, depth, and nutrient availability.

Succession can also be viewed in terms of similarity with evolution of life on earth. As stated by a student for a written exercise in my class this spring; "In the evolutionary process, very simple organisms [may] evolve into more complex things . . . Just as a bacteria can't suddenly sprout arms and legs and start walking, trees can't sprout out of rocks. In this way, evolution and ecological succession are both slow processes which start simply and progress into a complex system." Starting with prokaryotes, processes such as evolution (natural selection) and mutualism allowed for the development of larger and more complex organisms, such as humans. This process happened slowly, with many intermediate steps, adding diversity of tissues, organs, and intricate societies. In the same way, ecological succession often begins with lichens, which prepare the basis of soil for larger plants, that prepare for shrubs, and so on. After this class exercise, it was pointed out to the students that spiritual regeneration of the human mind might be viewed as a similar process.

Where are communities with the greatest species diversity found on earth? The most diverse communities on earth are found in areas that have the most favorable parameters necessary for life, including: constant amenable temperature, constant water availability, plentiful but not overbearing nutrient resources, and minimum perturbations. In terrestrial habitats,

⁸ Trophic levels are "feeding" levels within an ecosystem. At the base of the food chain are commonly found the photoautotrophs, organisms that can make their own food with light energy and carbon dioxide. This level is referred to as the "primary producers." Other examples of trophic levels include consumers (herbivores and carnivores), and decomposers (detritivores).

the most diverse biome (ecosystem found around the globe) is the tropical rainforest. A terrestrial biome is a particular type of “climax community” that is largely determined by climate and substrate availability. As a climax community develops, it must contain representatives of all the levels of the food chain (trophic levels) in order to be self-sustaining. Different kingdoms of living organisms often fulfill these different roles. In aquatic habitats, the most diverse ecosystems are the coral reefs of tropical waters.

However, there are ecosystems with less species diversity, but not less productivity (in terms of biomass generated), in other habitats of the world. Some examples would include kelp forests in temperate shallow marine habitats, estuarine ecosystems, and salt marsh ecosystems. Why? These habitats are unable to sustain the large numbers of species because of limited “microhabitats” or variety of niches. Although these productive ecosystems may not show large fluctuations in temperature or water availability (and may therefore be considered relatively stable), they do not have the optimum temperatures of the most diverse communities found in the tropics. All ecosystems on earth have limited physical resources that place boundaries on their diversity.

How is ecosystem health determined? An ecosystem is considered to be healthy when it can sustain itself. The definition of a climax community describes a healthy state for organisms within their environment. Unless these ecosystems are disturbed by either natural (e.g. storms, earthquake, etc.) or human influences (see below), they will exist for long periods of time with relatively little change.

2. *Paleoecology and diatoms*

Ecosystems are in constant flux. Environments inevitably change due to any number of factors, including human impacts (a major source of change in recent years). Paleoecology is the study of relationships between past organisms and the environment in which they lived. Paleoecologists are concerned with the reconstruction of past ecosystems by using all available evidence, including biological, chemical, and geological contributions (Birks & Birks 1980). A paleoecological approach makes it possible

to define the “naturally occurring state” of an ecosystem against which human influences can be measured (e. g., Bradbury & Waddington 1973, Dixit et al. 1992, Håkansson & Regnéll 1993; Cooper 1995a, 1999; Cooper et al. 2004; Cooper and Goman 2005; Kauppila et al. 2005). This science has direct bearing on the debate concerning the primary factors contributing to declining water quality in lakes and estuaries in recent times, and on hindcasting of models from which predictions about the effects of future environmental change on these ecosystems can be made. For example, this approach has played an integral part in providing scientific background for Chesapeake Bay watershed management plans (Brush & Davis 1984, Brush 1986, Cooper & Brush 1991, Harding et al. 1992, Cooper 1995).

There are several important indicators commonly used in paleoecological studies, such as plant and animal fossils, sediment characteristics, and sediment composition (including sediment chemistry). Fossil indicators used for assessing eutrophication, nutrient availability, light availability, and sedimentation rates include diatoms and pollen (e. g., Dixit et al. 1992, Birks & Birks 1980, Brush 1984, 1989). Eutrophic is a term that applies to lakes or estuaries (or other bodies of water) with high nutrient content and high biological production (Molles, 1999). Eutrophication often means excessive nutrient inputs that can lead to loss of dissolved oxygen through decomposition, and a consequent degradation of the ecosystem.

Diatoms are unique forms of algae, particularly useful for paleoecological research because of their silica exoskeleton (frustules), the morphology of which is species specific. Modern diatom taxonomy is based on frustule characteristics, and therefore a fossil diatom of good preservation can be identified as accurately as a living one. Diatoms are abundant in aquatic environments, generally cosmopolitan in distribution, and have a fairly well studied taxonomy and ecology (Reid et al. 1995, Stoermer & Smol 1999).

The abundance and composition of diatom assemblages are determined by the interaction of many environmental factors, including light availability, temperature, salinity, nutrient availability, pH, and pollution (e.g., Patrick 1965, 1973, Birks et al. 1990, Juggins 1992, Anderson et al. 1993, Nelson & Kashima 1993, Bennion et al. 1996, Stoermer & Smol 1999, Cooper & Goman 2005, Kauppila et al. 2005). Presence or absence of

individual species and diatom assemblages can therefore be interpreted as indicators of eutrophication, climate changes (sea level and precipitation), land clearance (turbidity), pH, and salinity changes (e.g. Cooper 1999). Diatom assemblages can also be used to assess changes in benthic (bottom or sediment types) vs. pelagic (open water) environments, since different species indicate specific habitats. Responses of diatom communities to different land use patterns can show which historical periods or events have shaped human-induced changes to aquatic ecosystems.

Diatom counts for a sample are generally converted to relative abundances of each species present. Most studies using diatoms as indicators will be based on counts of at least 400–500 diatoms per sample. The average counting error is small relative to the overall diatom analysis, which focuses on diversity indices of the entire assemblage and comparisons between samples. Diatom assemblage diversity is generally calculated for each sample using Shannon's H' (Shannon & Weaver 1949) as defined earlier, and has been used specifically to study the effects of stresses on algal communities in coastal systems (Patten 1962, Hendeny 1976). This is not an index of the entire ecosystem diversity, but of the variety of genera and species of diatoms within that community. It is often specified as "diatom community diversity."

Centric diatoms (diatoms with radial symmetry) are generally planktonic (floating) forms in estuarine waters, and pennate diatoms (diatoms with bilateral symmetry) are generally benthic, littoral, or epiphytic forms that grow on or attached to a substrate. It is some of the pennate diatoms that are able to move within or on sediments. Centric diatoms are more prevalent in eutrophic waters than pennate diatoms in certain areas (Andrén et al. 1999, 2000; Cooper, 1995, 1999; Cooper et al. 2004). The centric to pennate ratio (c:p) is useful in determining changes from predominantly benthic to predominantly planktonic communities (and vice versa), as well as being a possible indicator of eutrophication (Andrén et al. 1999, 2000; Cooper 1993, 1999; Cooper et al. 2004). Additional cluster analyses and statistical analyses of diatom assemblage data (such as principal components analysis and canonical correspondence analysis) can provide more insight into the causes of change in diatom community structure.

3. *Anthropogenic influences on communities*

What are the relationships between natural communities on earth with humans; how do humans affect community diversity? Studies in many areas, including paleoecology, document the decline in diversity of communities with increasing human impacts. Paleoecological studies using diatoms have been accomplished in freshwater lakes, wetlands, streams, and rivers, as well as estuarine and marine habitats (see previous section). Along the east coast of the United States, areas with the most history of land clearance and high populations (urbanization and industrialization) often show the most dramatic changes to water quality as measured by diatom community composition. These changes usually begin with initial land clearance for agriculture, and accelerate with urbanization and industrialization. Recently, with much stricter environmental laws and more public awareness, some improvement (or decline in degradation), can be seen. Figures 2 and 3 below show measured declines in diversity of diatom communities through time in simple graphs of time vs. diatom community diversity, along with the attendant increase in centric to pennate ratios of the diatom communities.

It is important to note that the declines in diversity seen in these (and other) estuaries along the east coast of the U. S. are due to both a decline in overall richness (species numbers) and in evenness of species. In all cases, a few small nutrient-loving centric taxa become dominant in these systems with increasing human impacts, while many benthic species disappear. There are various reasons for these changes, including nutrient inputs (e. g., agricultural fertilizers, human and animal sewage discharges), increased sedimentation from development and deforestation, increased turbidity of the water column and increased runoff of freshwater from land.

B. The form and uses of communities and variety in the spiritual world

1. *Communities and variety in heaven*

What constitutes a community in heaven, how are they organized, and how are they affected by their environment? In *Arcana Coelestia* (§ 4067), Swedenborg writes that:

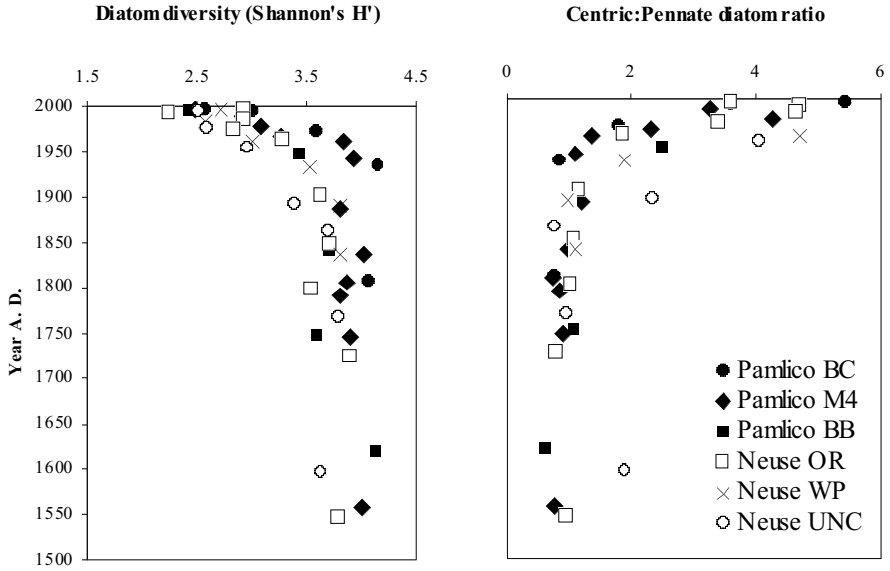


Figure 2. Diatom diversity and centric:pennate diatom ratio changes through time in six sediment cores collected from the Neuse and Pamlico estuaries of North Carolina.

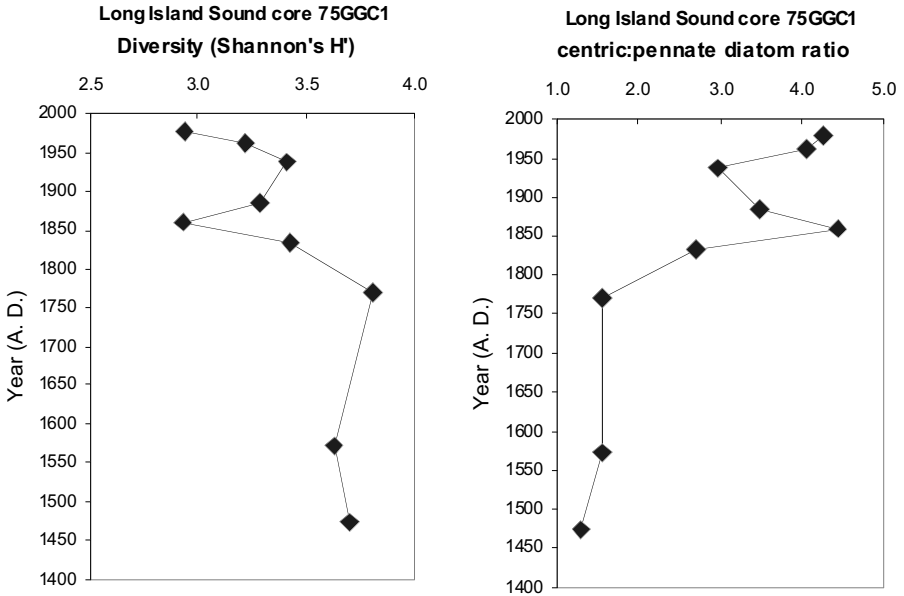


Figure 3. Diatom diversity and centric:pennate diatom ratio changes through time in one sediment core collected in Long Island Sound, from 1400 to 1995 A. D.

Countless communities exist in the next life, and these are arranged and set in order by the Lord according to all the genera of good and truth; also communities that are the complete opposite, according to all the genera of evil and falsity. They are so arranged and set in order that no genus of good or truth exists, nor any species of that genus, nor even any specific difference, which does not have [a link with] such angelic communities, that is, to which angelic communities do not correspond. Nor on the other hand does any genus of evil or falsity exist, or any species of that genus, or even any specific difference, to which communities of devils do not correspond.

Communities in heaven correspond to specific goods or truths, and those in hell to specific evils or falsities. This is in contrast to the delineation of communities on earth by space, time, climate, and resources. However, in both the natural and spiritual worlds each “genera and species” contributes to its community as well as the whole “system.”

To better appreciate Swedenborg’s understanding of heavenly communities, we read the following: “[N]o angel or spirit can possibly have any life unless he lives in some community, and in so doing in a harmonious relationship of many people” (*AC* § 687): “In heaven all who perform uses from an affection for use draw from the life which they share in common, a state of wisdom and happiness exceeding that of others . . . The parts there are angels, and the community is a society of them” (*DLW* § 431); and

For as soon as angels or spirits assemble they instantly become arranged . . . into a state of order, . . . a heavenly community that is an image of heaven. This would never happen if the universal influence emanating from the Lord did not cover the most specific things of all, and if all these were not in an utterly perfect state of order. (*AC* § 6338)

It is evident that heavenly communities are essential to the existence of heaven.

In relation to communities, what constitutes variety in heaven? The following passage uses an example from “the learned world” (as Swedenborg put it) which would today include the scientific community,

and speaks to me directly of ecosystem community diversity as I have described it above. In *Heaven and Hell*, Swedenborg writes that:

It can scarcely be made clear to the comprehension that the perfection of heaven is the result of variety, without employing terms in common use in the learned world and by them showing how unity, to be perfect, is formed from various parts. Every unity has its existence from diversity, for a unity that is not the result of diversity is not anything; it has no form and therefore no quality. When, on the other hand, a unity comes into existence from various parts, and these various parts are in a perfect form in which each attaches itself in series, like a congenial friend to another, then the quality is perfect. So heaven is a unity resulting from the arrangements of various parts in the most perfect form, for the heavenly form is the most perfect of all forms. (§ 56)

So it is with communities and ecosystems on earth. Without each species, trophic level, and interaction, each community could not sustain itself or its members.

2. Communities and variety in the world of spirits and in hell

In relation to the world of spirits and to hell, what is the form and use of communities and variety? In *Arcana Coelestia* (§ 4067 above), we read that there is no genus of evil or falsity that is not represented in hell. Every community in the world of spirits, as well as hell, are composed of people with a similar love, whether it be of good or evil. As in the spiritual world, there are organisms and communities that develop on earth that are considered to be detrimental to healthy ecosystems. This includes many exotic or introduced species that disrupt the natural variety of an ecosystem. Another example related to my own research would be harmful algal blooms, or specific diatoms that produce toxins. There is not always a clear purpose evident in the presence of these species. In relation to *Pseudonitzschia* (one genera of diatoms that produce toxins), the blooms generally occur in response to human waste or other organic nutrient inputs to aquatic systems. They are a “response” to human impact, rather than part of the undisturbed natural order. In the spiritual world, we are

told, “good” and “evil” communities are both arranged in order. In *True Christian Religion* Swedenborg writes that:

After a few days they [people who have died] see that they are in a world where there are various communities established. This is called the world of spirits, and it lies midway between heaven and hell. All the communities there, though countless in number, are arranged in wonderful order, according to whether their natural affections are good or evil. Those communities which are arranged in accordance with good natural affections are in touch with heaven; those arranged in accordance with evil affections are in touch with hell. (§ 281)

We are also taught that we on the earth are associated with communities in the world of spirits by our thoughts and affections, as in *Arcana Coelestia*, where Swedenborg informs us that:

I have been shown quite plainly that a person’s thought, also that of spirits, and of angels too, radiates into numerous communities in the spiritual world, but that the thought of one person does so in a different manner from that of another. So that I might have sure knowledge of this I have been allowed to talk to some of the communities to which my own thought has penetrated. And from this I have been able to know what was flowing into my thought and which community it came from as well as the location and the essential nature of that community, and to know all this in such a way that I could not be mistaken. The extension of the thoughts and affections of man, spirit, or angel into different communities is what determines how much ability he has to understand and perceive. (§ 6600)

Also:

There are very many communities of this kind in the world of spirits, which is half-way between heaven and hell. There are as many communities as there are genera and species of affections of love for good or evil. In the meantime, before being raised to heaven or cast down to hell, they are spiritually linked to people in the world, because they too are half-way between heaven and hell. (*TCR* § 818)

These passages tell us that the natural world is “half-way” between heaven and hell. Here on earth we have order and correspondence related to both heaven (good and truth) and hell (evil and falsity), not simply one or the other.

3. *Equilibrium*

The fact that the people in the world are half-way between heaven and hell leads to the issue of equilibrium. What is it and what does it mean for the spiritual world and for the natural world? Equilibrium between heaven and hell allows for spiritual freedom, as pointed out in *Conjugal Love*.

Everyone is brought up in this state of equilibrium; and since this is between good and evil, or what is the same thing, between heaven and hell, it is a spiritual equilibrium, and this confers freedom on those who enjoy it. As the result of this equilibrium the Lord draws all to Himself; and if a person freely follows Him, He leads him out of evil into good, and so to heaven. (§ 44)

This equilibrium (or freedom) does not only apply to the human race, but to the entire natural world. In *Heaven and Hell* Swedenborg writes that:

There is also an equilibrium in all the subjects of its three kingdoms, the mineral, the vegetable, and the animal; for without equilibrium in them nothing can come forth and have permanent existence. Everywhere there is a sort of effort acting on the one side and reacting on the other . . . (§ 589)

The natural world must therefore maintain a correspondential equilibrium between good and evil, truth and falsity.

Within ecosystems on earth, various plant, animal, and other kingdom organisms could correspond to “good” or “evil” in a very general sense, but even those that we may consider “evil” contribute to the whole ecosystem. For example, vicious predators are often necessary to keep prey populations in a healthy state. Upon study, it is usually evident that there is equilibrium in nature, although in certain cases it can seem to be

out of balance. Many scientists today believe that human influences have altered ecosystems in a negative way, as was shown with coastal ecosystems in this paper. Most of this negative influence is due to ignorance of effect and a lack of "environmental ethic." Many human-altered ecosystems have lower diversity of organisms, and are not as resilient to continued stress or change. Humans have also introduced or allowed the proliferation of "exotic species" into "native" or natural ecosystems. These exotic organisms often take advantage of niches opened up by human influences, and become dominant by aggressively limiting the native organisms. These "exotics" can cause a profound change in the entire ecosystem.

An example of the problem with exotic species is evident in the Pennypack Ecological Restoration Trust (PERT) adjacent to the Bryn Athyn College campus in Bryn Athyn, Pennsylvania, U.S.A. Non-native vegetation such as Japanese knotweed, multiflora rose, and aggressive vine species such as porcelainberry, have choked out the re-growth of the native climax community. Without the native forest community, and warm season grass meadows, much of the wildlife of the area has also been affected. The Trust is attempting to restore native habitat by controlling the exotic species and nurturing the growth of native species. They do this with a variety of restoration ecology methods, and the results affect all of us, whether we are aware of it or not. Bryn Athyn College students have been involved in many of these projects. This leads well into the next section of the paper on the application and use of this study. The use of this study will be discussed in terms of the application of the science of correspondences in education, and the specific examples given in relation to diversity.

V. APPLICATION AND USE OF THE STUDY

A. Education

In terms of correspondence, it is important to understand the relationship between the natural world and the spiritual world. Science and religion are often viewed as rivals or simply as completely separate spheres

of engagement (Cooper 2004). However, we can research (and begin to understand) how the two foundations of truth on natural and spiritual planes correspond, from the revelations of Emanuel Swedenborg. In *Spiritual Experiences*, Swedenborg writes that:

. . . Since sciences have shut up the understanding, therefore, sciences may also open it; and it is opened so far as men are in good. And it was also proved that all things of heaven constantly have their foundation in the laws of the order of nature, in the world and in man, so that the foundation remains permanently fixed . . . (§ 5709)

Bishop Pendleton (1985) wrote in *Education for Use*, “We hold, therefore, that there is no real discrepancy between science and faith, but that when rightly interpreted the sciences support and perfect man’s understanding of an all-wise creator . . .” All things spiritual and divine “rest” in nature, and nature is in the human form when interiorly considered. If we view the world with some knowledge and appreciation of the spiritual world, it is impossible not to see the incredible order and balance all around us as divinely designed. Studying nature and science are essential in developing the mind of man. It can be argued that belief in God is engendered and enhanced by learning about the order and complexity of life and the universe. On this, Swedenborg writes that:

Indeed nobody is forbidden to acquire knowledge, since it is useful for life and gives delight. And the person in whom faith resides is in no way forbidden to think and to talk as learned people in the world do. But he does so from the premise of belief in the Lord’s Word and of confirming spiritual and celestial truths by means of natural truths, using as far as is possible the terminology of the learned world. Consequently his premise must be the Lord, not self; the former is life, while the latter is death. (AC 129)

Although the spiritual and natural planes of life are discrete, they are in correspondence. Goods and truths are only received in thought and delight when they have been clothed by ultimates (on the natural plane). In *Arcana Coelestia* we read that “. . . good seeks to live in truths, and truths

seek to live in knowledges, and knowledges in things of sense, and things of sense in the world" (§ 6077). This thought is confirmed by Schnarr (1973, 321) when he writes in *New Church Life* that "in the hands of a man who looks to the Lord for guidance and enlightenment, knowledges of nature and science are said to be . . . a means of increased wisdom."

The responsibility of higher education is to provide natural knowledge in an ordered structure. The curriculum of most colleges and universities would follow this tenet. While it is important to learn and practice the natural sciences for use in the world, there can also be a study of correspondences, promoting spiritual growth in students. Education may strive to elevate the thought and affection of its students and faculty out of and above natural things to the spiritual correspondence and use that is present in a separate degree. On this we read the following:

. . . With regard to facts, these are acquired in childhood with no other end in view than that of knowing. In the Lord's case they were acquired out of delights in and affection for truth. The facts that are acquired in childhood are very many indeed, but the Lord arranges them into order, so that they may serve a use—first to enable the person to think; then so that through his thinking those facts may be of use; and at length so that the following may be accomplished, namely, that his very life may consist in use and be a life of uses. (AC § 1487)

A spiritual person acknowledges the Divine in all things, and has elevated his or her mind to the use of the goods and truths from the Lord. Rather than acquiring knowledge for the sake of knowledge, the spiritual person looks to the good in use of that knowledge.

Undergraduate students in college are generally at an age when the rational degree of their minds are being opened and developed. They are at a critical stage in their lives between youth and adulthood when knowledge and faith are being brought together for the first time. It is possible to explore with students why they should search for truth, and to establish that natural truths correspond to Divine truths. By studying science, for example, students can gain a deeper understanding of the Divine, and have the possibility of gaining more wisdom. Swedenborg wrote about this transition of the human mind in *Arcana Coelestia*:

... it should be recognized that the rational cannot possibly be conceived and born, that is, formed, without facts and cognitions. But facts and cognitions must have use as their end in view, and when they do, they have life as their end in view, for all life looks to uses because it looks to ends. ... With people who learn cognitions so as to become more perfect in faith grounded in love—for true and real faith consists in love to the Lord and charity towards the neighbour—the supreme use of all is present and they are acquiring spiritual and celestial life from the Lord. And when that life exists with them they possess the ability to perceive everything that belongs to the Lord's kingdom. This life exists with all angels, and because that life exists with them, so do intelligence and wisdom themselves. (AC § 1964)

Later in the same work (AC § 9755) we read that: "So it is that truths with a person in childhood are truths present in knowledge; but in adult life, if the person allows himself to be regenerated, they come to be truths present in faith. For the internal man is being opened gradually as the person advances into adult life." This regeneration can occur on earth or in the spiritual world after death.

Examples of how truths are taught in heaven and the spiritual world can also be learned from the Writings of Emanuel Swedenborg. These examples can help us to develop our own methods of teaching, and give us insight into the learning process. Goodenough (1977) has written an article entitled "Angelic Methods of Instruction" in *New Church Life*. In this article, Goodenough surveys memorabilia and methods of angelic instruction as presented in the Writings of Swedenborg. Goodenough discovered descriptions stating that general truths are taught first in heaven and the spiritual world, followed by particulars (specific truths). Angels often teach by giving examples, but also by asking questions. Students in heaven must think and learn for themselves. According to Goodenough, "The angels use no one method, but an enormous variety . . . Even the different methods have variations within them, so that no two sessions of instruction ever seem to be the same." The Lord is the true "teacher," and imparts all knowledge and wisdom through these different mediums only as students are willing to receive them.

B. How can this knowledge be used in the college science classroom and lab?

The world values science and technology as never before in history. This has been the trend ever since the life and time of Swedenborg who was led to science as preparation for his role as revelator. This scientific understanding is crucial to our current spiritual nature in relation to our understanding of the earth and of the spiritual world. Far from being able to relate to the Lord and the heavens as the Most Ancient Church did (with a complete innate knowledge of correspondences of nature), we rely on our rational ability to comprehend truth and remain in freedom to choose good. We are allowed the freedom to develop wisdom as if from ourselves.

Science makes available a diversity of civil and social uses on earth, including such developments as the Internet and the Genome Project. Medical advances allow an increased life expectancy, from decreased infant mortality to increased quality of life in old age. Science allows the ability to automate tedious, damaging, or critical tasks and enhances effective communication around the world. It provides models for predicting future global climate change and allows us to quantify past human effects on ecosystems, as well as predict future changes.

Beyond civil and social uses, science itself provides many educational uses. Science involves the use of analysis, synthesis, quantification, creativity, imagination, and inference. Science promotes the ability to think abstractly, to hypothesize, to question, to observe, to investigate, and to derive conclusions. The study of science promotes the ability to present a logical argument that is based on observable facts. Scientific study requires that the student delve into finding truth on many levels of nature; from the universe, to the earth, to ecosystems, to individual species, to tissues and cells, and to the molecular components of life. The more we learn about the natural world through science, the more open is our ability to learn about and understand the spiritual world through correspondence. This acceptance of correspondence must be a personal choice, as we are constantly kept in equilibrium between good and evil, or truth and falsity. Concepts that have generally been beyond human comprehension can now begin to be imagined.

Natural concepts can take on new meaning. Darwin's theory of evolution and natural selection is one concept that generates debate and dissension between scientists and religious leaders (e.g. Kelley 2000). From the Writings of Swedenborg, we learn that the story of creation in the Old Testament has an internal spiritual meaning related to human (spiritual) regeneration, and is not a factual story of the creation of the natural world. We can view the evolution of life on earth as a process that has correspondence with regeneration of the human mind. This continual process has representation in many natural progressions such as physical growth and development, and ecosystem succession (discussed earlier). The process is critical to the development of diversity and variety as well as complexity, which are so important to the perfection of communities on earth and in the heavens.

Well-known theories become new and impressive with a deeper spiritual understanding of detailed correspondences. Students will have their own specific thoughts and affections regarding various knowledges that they learn in college. Examples of specific correspondences, such as those for diatoms that have been explored in this paper, can open their eyes to endless possibilities for their own interests. These insights can enhance their desire to research specific ideas, and therefore specific truths and goods from the Word.

VI. CONCLUSIONS

The very essence of heaven is the truth and good of the Divine. And the variety in the heavens is what makes them more perfect. Swedenborg reiterates this concept in *Heaven and Hell*:

It is worthy of mention that the more there are in one society of heaven, all acting as one, the more perfect is its human form, for variety arranged in a heavenly form is what makes perfection, ... Moreover, every society of heaven increases in number from day to day and as it increases, it becomes more perfect. Thus not only does the society become more perfect, but also heaven in general because it is made up of societies. As heaven gains in perfection by increase of numbers, it is evident how

mistaken are those who believe that heaven may be closed by becoming full. For the opposite is true, that it is never closed but is perfected by greater and greater fullness. Therefore, the angels wish for nothing more than to have new angel guests come to them. (§ 71)

These words can be comforting and inspirational.

In terms of natural ecosystems, we have explored the concept of diversity as an indicator of the health and stability of these systems. The two concepts of diversity in communities on earth, and variety in communities (and of communities) in heaven, do appear to correspond. Natural ecosystems, however, are not in heaven. They exist on earth, where there is an equilibrium maintained between good and evil, truth and falsity, just as there is in the world of spirits. This equilibrium is essential to the freedom of the human race. Therefore, the diversity of natural ecosystems contains elements that correspond to evil and falsity as well as to good and truth. Diversity of communities on earth corresponds more directly to the world of spirits, which is intermediate between heaven and hell. In the world of spirits, communities develop in which the primary loves of the individuals are more or less in accord, and they are arranged by the Lord. These communities are protected by the Lord, even though evil spirits may roam somewhat freely (before they cast themselves into hell). This freedom in the natural world has consequences for natural ecosystems. On earth, humans are able to have profound impacts on nature. Often, in either ignorance or greed, ecosystems are changed for the worse by human influences. But there is growing awareness of the necessity of stewardship and management for the preservation of life on earth. The sciences of ecology and restoration ecology provide knowledge for restoring balance to human altered ecosystems.

From the Writings of Swedenborg, we can have a much clearer understanding of the spiritual world. H. Lj. Odhner (1968) claims that the essential purpose of the new revelation of the spiritual world (specifically the work *Heaven and Hell*) is so that men might be able to think spiritually about the after-life. With this knowledge we are now able to explore the correspondence of natural existence in a new way. With the view of the spiritual world in mind, we can learn more about the Lord's kingdom by

studying our natural ecosystems in health, and in decline, due to human impacts. We can perhaps see evils more clearly for what they really are, and understand that natural diversity is indeed a healthy state. We can learn about the functions and niches of organisms, with a view of natural as well as eternal uses. The limited study of diatoms presented in this paper has made my own work more meaningful and exciting, and holds the same potential when used in higher education. □

VII. REFERENCES

- Anderson, N. J., B. Rippey, and C. E. Gibson. "A comparison of sedimentary and diatom-inferred phosphorus profiles: implications for defining pre-disturbance nutrient conditions." *Hydrobiologia* 253 (1993): 357–366.
- Andrén, E., G. Shimmielid, and T. Brand. "Environmental changes of the last three centuries indicated by siliceous microfossil records from the southwestern Baltic Sea." *Holocene* 9 (1999): 25–38.
- Andrén, E., T. Andrén, and H. Kunzendorf. "Holocene history of the Baltic Sea as a background for assessing records of human impact in the sediments of the Gotland Basin." *Holocene* 10 (2000): 687–702.
- Bennion, H., S. Juggins, and N. J. Anderson. "Predicting epilimnetic phosphorus concentrations using an improved diatom-based transfer function and its application to lake eutrophication management." *Environmental Science & Technology* 30 (1996): 2004–2007.
- Birks, H. J. B., and H. H. Birks. *Quaternary Palaeoecology*. Baltimore, MD: University Park Press, 1980.
- Birks, H. J. B., J. M. Line, S. Juggins, A. C. Stevenson, and C. J. F. ter Braak. "Diatoms and pH reconstruction." *Philosophical Transactions of the Royal Society of London B* 327 (1990): 263–78.
- Bradbury, J. P., and J. C. B. Waddington. "The impact of European settlement on Shagawa Lake, northeastern Minnesota, U. S. A." In *Quaternary Plant Ecology*, H. J. B. Birks & R. G. West (eds.). Oxford: Blackwell, 1973, pp. 289–307.
- Brush, G. S. "Rates and patterns of estuarine sediment accumulation." *Limnology and Oceanography* 34 (1989): 1235–1246.
- Brush, G. S. 1986. "Geology and paleoecology of Chesapeake Bay: a long-term monitoring tool for management." *Journal of the Washington Academy of Sciences* 76 (1986): 146–160.
- Brush, G. S. "Patterns of recent sediment accumulation in Chesapeake Bay (Virginia-Maryland, U.S.A.) tributaries." *Chemical Geology* 44 (1984): 227–242.
- Brush, G. S., E. A. Martin, R. S. DeFries, and C. A. Rice. "Comparisons of ²¹⁰Pb and pollen methods for determining rates of estuarine sediment accumulation." *Quaternary Research* 18 (1982): 196–217.
- Campbell, N. A., J. B. Reece, L. G. Mitchell, and M. R. Taylor. *Biology: Concepts and Connections*. New York: Benjamin Cummings, 2003, 781pp.

- Cooper, S.R. "A new biology program at Bryn Athyn College of the New Church." In D. A. Synnestvedt (ed.), *Faith and Learning at Bryn Athyn College of the New Church*, Bryn Athyn, PA: ANC Press, 2004.
- Cooper, S.R. "The History of Water Quality in North Carolina Estuarine Waters as Documented in the Stratigraphic Record." Water Resources Research Institute of the University of North Carolina Report No. 2000-327 (2000). 84pp.
- Cooper, S. R. "Estuarine paleoenvironmental reconstructions using diatoms." Pages 352-373 In E. Stoermer and J. Smol (eds.), *The Diatoms: Application for the Environmental and Earth Sciences*. Cambridge: Cambridge University Press, 1999, pp. 352-373.
- Cooper, S. R. "Chesapeake Bay watershed historical land use: impact on water quality and diatom communities." *Ecological Applications* 5 (1995a): 703-723.
- Cooper, S. R., and G. S. Brush. "A 2,500-year history of anoxia and eutrophication in Chesapeake Bay." *Estuaries* 16 (1993): 617-626.
- Cooper, S. R., and G. S. Brush. "Long-term history of Chesapeake Bay anoxia." *Science* 254 (1991): 992-996.
- Cooper, S. R., and M. Goman. "Historical changes in water quality and vegetation in WCA-2A as determined by paleoecological analyses." Chap 12 in: C. J. Richardson (ed.), *An Integrated Approach to Wetland Ecosystem Science: The Everglades Experiments*. New York: Springer-Verlag, 2005. *In press*.
- Cooper, S. R., J. Huvane, P. Vaithiyathan, and C.J. Richardson. "Calibration of diatoms along a nutrient gradient in the Florida Everglades Water Conservation Area 2A, USA." *Journal of Paleolimnology* 22 (1999): 413-437.
- Cooper, S. R., S. K. McGlothlin, M. Madritch and D. L. Jones. "Water Quality History of the Neuse and Pamlico estuaries of North Carolina using paleoecological methods." *Estuaries* 27(4) (2004): 619-635.
- Dixit, S. S., J. P. Smol, J. C. Kingston, and D. F. Charles. "Diatoms: Powerful indicators of environmental change." *Environmental Science and Technology* 26 (1992): 22-33.
- Dole, G. F. (ed.). *Emanuel Swedenborg: The Universal Human and Soul-Body Interaction*. New York: Paulist Press, 1984. 267pp.
- Goodenough, D. "Angelic Methods of Instruction." *New Church Life* (February 1977): 67-84.
- Gould, J. L. and W. T. Keeton. 1996. *Biological Science*. Vol. 2. New York: W. W. Norton and Co., 1996. 1205pp.
- Håkansson, H., and J. Regnéll. "Diatom succession related to land use during the last 6000 years: a study of a small eutrophic lake in southern Sweden." *Journal of Paleolimnology* 8 (1993): 49-69.
- Harding, L. W., M. Leffler, and G. E. Mackiernan. *A Workshop Report: Dissolved oxygen in the Chesapeake Bay: A scientific consensus*. Maryland Sea Grant Publication No.UM-SG-TS-92-03. 1992.
- Hendey, N. I. "The species diversity index of some in-shore diatom communities and its use in assessing the degree of pollution insult on parts of the north Coast of Cornwall." *Nova Hedwigia* 54 (1976): 355-378.
- Juggins, S. "Diatoms in the Thames Estuary, England: ecology, palaeoecology, and salinity transfer function." In *Bibliotheca Diatomologica* 25 (1992). H. Lange-Bertalot, (ed.). Berlin: J. Cramer, pp. 1-216.

- Kauppila, P., K. Weckström, S. Vaalgamaa, H. Pitkänen, A. Korhola, N. Reuss and S. Drew. "Tracing pollution and recovery using sediments in an urban estuary, the northern Baltic Sea: Are we far from ecological reference conditions?" *Marine Ecology Progress Series* 290 (2005): 35–53.
- Kelley, P. H. "Studying Evolution and Keeping the Faith." *Geotimes* 45(12) (2000): 22–23.
- Mann, D. G., and S. J. M. Droop. "Biodiversity, biogeography and conservation of diatoms." *Hydrobiologia*, 336 (1996): 19–32.
- Molles, M. C. Jr. *Ecology: Concepts and Applications*. New York: McGraw-Hill, 1999. 509pp.
- Nelson, A. R. and K. Kashima. "Diatom zonation in southern Oregon tidal marshes relative to vascular plants, foraminifera, and sea level." *Journal of Coastal Research* 9 (1993): 673–697.
- Nybakken, J. W. *Marine biology: an ecological approach*. 5th edition. San Francisco, CA: Benjamin Cummings, 2001. 516pp.
- Odhner, H. Lj. *The Spiritual World: Essays on the After-Life and on the Last Judgment*. Bryn Athyn, PA: Academy Publication Committee, 1968.
- Patrick, R. "Use of algae, especially diatoms, in the assessment of water quality." *Special Technical Publication* 528 (1973). Philadelphia: American Society for Testing and Materials.
- Patrick, R. "Algae as indicators of pollution." In *Biological Problems in Water Pollution*. USPHS Publication 999-WP-25 (1965): 225–231.
- Patten, B. C. "Species diversity in net plankton of Raritan Bay." *Journal of Marine Research* 20 (1962): 57–75.
- Pendleton, Willard D.. *Education for Use: Basic Concepts*. Bryn Athyn: Academy Publication Committee, 1985, p. 256.
- Reid, M. A., J. C. Tibby, D. Penny, and P. A. Gell. "The use of diatoms to assess past and present water quality." *Australian Journal of Ecology* 20 (1995): 57–64.
- Schnarr, Frederick L "The Use of Sensuals in the Formative Years: A Review of the Content and Uses of the Sensuous Degree of the Mind." *New Church Life* (May 1973): 198–208.
- Shannon, C. E., and W. Weaver. *The Mathematical Theory of Communication*. University of Illinois Press, 1949.
- Stoermer, E., and J. Smol (eds.). *The Diatoms: Application for the Environmental and Earth Sciences*. Cambridge: Cambridge University Press, 1999.
- Swedenborg, E. *Spiritual Experiences*. James F. Buss and George Bush, translators. New York: Swedenborg Foundation, 1889.
- _____. *Arcana Coelestia*. 12 volumes. John F. Potts, translators. New York: Swedenborg Foundation, 1905. [Published originally in London, 1749–1756, 8 quarto volumes in Latin.]
- _____. *Divine Love and Wisdom*. Clifford and Doris H. Harley, translators. London: The Swedenborg Society, 1969. [Published originally in Amsterdam, 1768 in Latin.]
- _____. *Arcana Coelestia*. 12 volumes. John Elliot, translator. London: The Swedenborg Society, 1983–1999. [Published originally in London, 1749–1756, 8 quarto volumes in Latin.]
- _____. *The True Christian Religion*. 2 volumes. John Chadwick, translator. London: The Swedenborg Society, 1988. [Published originally in Amsterdam, 1771 in Latin.]
- _____. *Conjugal Love*. John Chadwick, translator. London: The Swedenborg Society, 1996. [Published originally in Amsterdam, 1768 in Latin.]

ECOLOGICAL DIVERSITY

- _____. *Heaven and Hell*. George F. Dole, translator. West Chester, PA: Swedenborg Foundation, 2000. [Published originally in London, 1758 in Latin.]
- Washington, H. G. "Diversity, biotic and similarity indices: A review with special relevance to aquatic ecosystems." *Water Research* 18 (1984): 653–694.
- Wyld, H. C. and E. H. Partridge (eds.). *Complete and Unabridged Webster Dictionary*. New York: J. J. Little and Ives Co., Inc., 1962.

NOW AVAILABLE

On Tremulation

Trans. by C. Th. Odhner, 1899

Reprinted SSA, 1976, 2005

Emanuel Swedenborg's treatise, "On Tremulation," which now for the first time appears in the English tongue [1899], was originally written toward the close of the year 1719, as may appear from the following statement in a letter by the author, dated Nov. 3, 1719, and addressed to his brother-in-law, Dr. Eric Benzelius, then librarian of the University of Upsala:

I have also written a little anatomy of our vital forces, which, I maintain, consist of tremulations; for this purpose I have made myself thoroughly acquainted with the anatomy of the nerves and the membranes, and I have proved the harmony which exists between that and the interesting geometry of tremulations; together with many other ideas, where I have found that I agree with those of Baglivius. [Giorgio Baglivi, a disciple of Malpighi, and professor at Rome.] The day before yesterday I handed them in to the Royal Medical College. (See R. L. Tafel's *Documents Concerning Swedenborg*, Vol. I, p. 310.)

ISBN 0-915221-60-8; 65 pp. 5 1/2 x 8 1/2. Paper. \$9.95

Available by contacting the SSA at P.O. Box 757, Bryn Athyn, PA 19009; or ssa@comcast.net or online at www.swedenborg-philosophy.org where various payment options are available, including by credit card through PayPal.