Toward a biblical basis for ecology, with applications in mycorrhizal symbioses in orchids

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'*God was our original habitat and our hearts cannot but feel at home when they enter again that ancient and beautiful abode.*'[1]

Ecology is the study of the intricate relationships between organisms and their environment. In order to develop a creation model of ecology, the foundation must be based on sound biblical presuppositions, beginning with the assumption that there is a Creator who desires to be known in word and deed. The framework upon this foundation is forged from current creation research that has shed light on ecological principles. The study of orchid mycorrhizal symbioses is consistent with the creationist idea that microbes are an organosubstrate and are critical in bridging the gap from the environment to the orchid so it can germinate, develop and persist in the biosphere. This suggests that the orchid baramin was created as a biological system with fungi. As scientific research continues to unveil the elaborate and interdependent relationships in ecosystems, the observations suggest that they are products of masterful engineering. Fascinating and challenging questions remain and it is hoped that building a creation model of ecology is encouraged and that all who would marvel at such complexity would long to enter that ancient and beautiful abode.

The neo-Darwinian model, with its random naturalistic presuppositions, has dominated the science arena for a century and a half. In contrast, the recently developed modern creation model is in its relative infancy (although belief in creation is ancient) and only certain aspects are now being rigorously researched. Examples include the research in creationist geology and paleontology, showing evidence of a world wide catastrophic flood[2] and its implications for the reinterpretation of both time scales and mechanisms that produce various geologic features. Creation physicists are making great strides in predicting mechanisms and strengths of planetary and cosmic magnetic fields[3] while exploring radiometric dating techniques consistent with young-earth predictions.[4] Creation biologists have not only falsified the neo-Darwinian contention that mutations plus natural selection can generate the world's biodiversity from random events,[5] but also have shown that evolutionary genetic theory is fatally flawed and effectively falsified by numerical simulation.[6]

In 1866, the term ecology was first coined by Ernst Haeckel, from the Greek *oikos*, meaning 'house' or place-to-live[7] and *ology*, study of. The study of ecology concerns the relationship of organisms which include both, interactions with each other and with the abiotic environment. The field is an integration of many sciences including geology, physics, chemistry and biology. These complex biotic and abiotic interactions comprise the 'ecological system' or 'ecosystem'. The ecosystem concept was developed in the 1930s by English ecologist, George Tansley,[8] and ecosystems can range in size from a drop of water to the biosphere, depending on where researchers want to draw their study boundaries. Trying to unravel the mysterious and infinitely complex relationships within these systems can be both invigorating and perplexing.

This paper lays the biblical foundation for an ecological model, summarizes creationist research directly related to ecology, and incorporates an analysis of orchid mychorrizal symbioses. It is hoped that further investigation into the beautiful complexities of this world will instil an attitude of profound love for the Creator and encourage research that will develop a more viable, and uniquely biblical, creation model of ecology. The call for a 'great synthesis', whereby the Bible is central to our beliefs and foundational to the scientific models we construct, is critical.[9]

Worldview in scientific interpretation

As with all scientific disciplines, interpretations of ecosystem dynamics are dependent on presuppositions of the researchers, which are ultimately affected by their worldviews. Unfortunately, public school and university educators do a poor job emphasizing this because many are unaware of their own assumptions, and thus produce a blend of scientific facts with worldview interpretations. For many, the confused result is a belief that the creation/evolution issue is a war between science (evolution) and religion (creation). All observations are interpreted through the lens of a worldview, and in this paper the issues surrounding ecosystem origins are not issues of science verses religion, but worldviews of materialistic naturalism verses biblical theism (supernaturalism).

In recent decades neo-Darwinist James Lovelock, noting the biosphere's ability to physiologically self-regulate, developed a materialistic explanation for this phenomenon known as the *Gaia Hypothesis*, named for the Greek goddess Gaia or 'mother earth'. Lovelock contends that life has affected the planetary environment and maintains itself by manipulating the current environment for its own benefit.[10] Though he believes random processes produced life, and that the earth is not making conscience decisions, it still smells of teleology to many materialists and is, therefore, controversial. New Age followers, many of whom are ecologists and environmental educators, distort Lovelock's original ideas and view earth as a conscious entity, worshiping 'her' accordingly. This worldview is often injected into public high school and university curricula. Materialistic naturalism, as a worldview, is vacuous because it discounts the Creator and has clearly been shown to be a dead end.[6] Random mutation and natural selection are recognized processes by creation ecologists, but careful study has shown that these processes cannot explain the origin of complex organisms and their interdependent relationships within ecosystems. It is well documented that even the most 'simple' biochemical systems in bacteria are more complex, by orders of magnitude, than anything humans have designed. Yet the naturalist paradigm is left trying to explain how complex 'seemingly designed' systems could be products of random, non-intelligent processes.

A biblical world view: the foundation for an ecological model

In contrast, the biblical world view recognizes both random and purposefully designed processes, allowing great freedom when testing hypotheses about ecosystem origins and mechanisms. This view recognizes that there is an all powerful Creator who has revealed Himself through the written Word.[11] He is the Self-Existent One, the omniscient, omnipotent God who is separate and above His creation.[12] Intimately involved with His creation, He holds it all together.[13] That ecosystems work because of complex interdependent relationships is consistent with His character. Therefore the biblical ecologist recognizes the majesty, power and wisdom of God in the beauty, complexity and mystery of His creation.[14]

In the beginning, God created everything very good and made humanity so that they would enjoy an intimate and dependent relationship with Him.[15] This means human life is precious and to be protected from conception to death, in the broadest possible terms that include protection for the unborn, child safety, not government welfare bureaucrats and provision for pure food, water and air.[16] Tragically, when Adam desired independence from the Creator, resulting in sin, human dependence upon God became marred and the Divine/human partnership broken.[17] The consequences of this spiritual independence are well illustrated in evolutionary, environmental philosophy which sees humans as only a higher functioning animal on the evolutionary continuum. They rank human population growth as the most serious environmental problem in the biosphere. Some even consider humanity a parasitic blight on Earth and have suggested that the planet would be better off if 90% of us were dead.[18] As a consequence of Adam's Fall, Earth is cursed. Death and suffering through disease, predation, parasitism and venom injection apparatus are a result of the curse and do not reflect God's character. Instead, they are consistent with broken, distorted and displaced relationships.

Fortunately, through Christ's atonement, God has restored this relationship for those who believe Him by faith.[19] How we respond to God's call for a renewed relationship will affect our connections with each other and with the created world. As Christians, our first love should be for Him followed by love for our fellow men.[20] Lives characterized by these qualities are only possible when they are rooted in Christ and guided by His Spirit.[21] Even with regard to animals, these godly characteristics are biblical precedence for taking care of them.[22] William Wilberforce expounded on these qualities which were the bases for his successful anti-slavery campaign in England and his founding of the Society for the Prevention of Cruelty to Animals.[23]

Illustration by Jennifer Hennigan

Figure 1. The terrestrial showy lady slipper (*Cypripedium reginae*), a member of the slipper orchid subfamily Cypripedioideae, depend on obligate fungal relationships for their existence. Taxonomically, the slipper orchids consist of five genera and roughly 150 to 170 species found everywhere but Africa and Australia. They have variable forms and are easily recognized because their flowers are uniquely modified with a slipper shaped, sac-like pouch. The flowers rely on complex pollination symbioses in which insects drawn to the flowers crawl into the opening of the 'slipper' and can only escape by passing the stigma and anther, allowing pollen masses to be deposited or removed and sexual reproduction to take place.[60]

The root of any ecological crisis is relational, particularly our broken relationship with the Creator. Historically, many Christians have fallen into spiritual delusion by embracing ungodly views. Bristow has challenged Christians to have the mind of Christ by avoiding the mindset of having more, in order to get more.[26] God is the basis for our significance and security while materialism is the root of greed and causes great detriment to the created order. Bristow's second challenge is that Christians need to avoid being so heavenly minded that they are of no earthly good. Scripture prophesies an eventual destruction of the current heavens and Earth because of the great evil that will manifest itself globally. Eventually there will be a wonderful and eternal replacement for both and they will become the true home for all believers.[24] However, that does not mean that we are to be apathetic now. God has given us the responsibility to represent Him and care for His creation now, and in preparation for the new creation, which we will also have responsibility to tend and keep.

The problems of materialism and apathy in Christendom have lead some to believe that a biblical worldview is responsible for the world's environmental problems. Lynn White not only blamed the biblical worldview for destroying pagan animism and paving the way for an unfeeling exploitation of nature, but he also felt that environmental issues will only be solved if we abandon the biblical paradigm all together.[25] White was evidently ignorant of the fact that it was the biblical worldview that was behind a seminal book that was arguably a catalyst behind the global conservation movement.[26] In 1864 George Perkins Marsh wrote *Man and Nature* that described the biblical perspective of stewardship. He believed that our talents, emotions, intellect, salvation and this world are gifts from God. God must be given credit for everything because He made and owns it all. Christians have tended to stay away from environmentalism due, in part, to the impact of Lovelock's ideas which fuelled the adoption of neopagan and New Age environmentalism and to the influence of Christian authors like Dave Hunt and Constance Cumbey.[27] As His representatives, Christians should be at the forefront of these issues because they have been given the task to be good stewards of the land. The word *steward* derives from the 10th-century English word *stigweard*, which literally means 'guard of the hall' implying one who is responsible to manage something for someone else.[8]

God's command to have dominion and subdue creation has been misunderstood.[28] People have used this verse as a justification for wonton environmental harm. In biblical theology, Christians are to manage and take care of that which is God's. The Hebrew for 'have dominion' is רדה (*radah)* and 'subdue it' כבש (*kabash),* and both carry the idea of being in charge.[29] Biblical stewardship that involves taking control of the land can be likened to a forester who uses an ecosystem approach in the management of a timber stand. He takes charge of the timber so that it is both ecologically and financially sustainable. Consequently, he exercises a benevolent dominion that balances the use of timber for market, maintains optimum wildlife habitat, and preserves the beneficial forest services for years to come. Foresters have a technical term that could be synonymous for this benevolent dominion called *silviculture*, or the art of producing and tending a forest with a particular goal.[30] Today, the term *conservation* is consistent with this view because it does not necessarily connote preservation, but recognizes the importance of biodiversity and emphasizes the wise use of land.[31]

Ever since humanity was given the task of dominion, or using the land wisely, most cultures around the world have managed the land for their needs. Often it has been with devastating ignorance and sometimes with great knowledge and skill. The romanticized notion of early colonists coming to the untouched and pristine American wilderness is a myth. The indigenous peoples had been managing the land for hundreds of years, and through trial and error, many understood it well. They often recognized that a wisely managed and sustainable ecosystem was healthier and more productive than its wild counterpart.[8] Interestingly, there is increasing collaboration amongst practicing ecologists and native peoples as Western science seeks to understand Traditional Ecological Knowledge (TEK). Often, with TEK, the indigenous culture and language contain hints about ecological concepts and healthy ways to manage ecosystems that are unknown to formal science but have been practiced successfully for centuries.[32]

An initial synthesis of current creation research: scaffolding for an ecological model

When Noah stepped out of the ark 4,500 years ago, his world had changed drastically. God's judgment on the land and its creatures was devastating and complete. That judgment has implications for how we interpret the current mechanisms of geologic processes, organism diversification and distribution (biogeography), and complex biological interactions. Insights learned from understanding the land within a biblical creation model have biblical implications and applications in origin of life assumptions, godly stewardship, human relations, world hunger, sustainable agriculture, and energy use among many more. The following is a synthesis of creation research that contains many venues for future investigation.

Genetics/molecular biology/microbiology

Neo-Darwinists believe random beneficial mutations and natural selection provide the mechanisms that produced current biodiversity. Examples of these types of mutations include antibiotic resistance in bacteria and their ability to genetically adapt to environmental stresses. Upon further inspection of the bacterial genotypes, new insight has shown that when beneficial changes in nucleotide sequences occur, there is a loss of pre-existing activities in the original (wild-type) biochemical system. This knock out of existing biochemical machinery tends to change the enzymatic, regulatory or transport systems, and confers a temporary survival value to the bacterium in that new environment.[5] This trade-off of an existing biochemical system in order to survive a new environment, at the expense of systems used in other environments, is called antagonistic pleiotropy.[5] Anderson and Purdom note that many of these mutations look as if they produce adaptation as a result of design and give every indication of a designed mechanism. This process does not add complexity to the already existing system and, therefore, does not explain the origin of complex, interconnected systems. Further analysis of Hall's research of the *E. coli* ebg operon supports, to the idea that bacteria can adaptively mutate under numerous environmental conditions, but with a corresponding reduction in some aspect of the biochemical machinery.[33] Some have stated that this is evolution in action, but it is evolution in the wrong direction and is therefore untenable as an explanatory mechanism for life's origins.

Because of their crucial roles in ecosystems and the partially stochastic nature of environments, bacterial adaptive mutations would be expected within a creation model. The microbial world of bacteria, fungi and viruses must be understood in God's original creation. Microbes ('germs') are often looked upon negatively, but few realize that far less than one percent of these organisms are truly harmful, and the vast majority are crucial for all life.[34] Fascinating research has begun to explain how pathology arose after the Fall, but much work still needs to be done.[35] Potential areas of viable research should look for deleterious pathogens that have experienced a dangerous mutation and/or were displaced into organisms they were not designed to inhabit.

Francis has proposed that God created microbes as a link between macro-organisms and the chemical environment, calling them an organosubstrate or biomatrix.[34] He hypothesizes that if these are designed for this purpose they should be abundant, ubiquitous, involved in complex and crucial symbiotic relationships involving macro-organisms, able to form symbiotic microbial communities, mine and provide chemical elements from the lithosphere, and cycle elements in the biosphere. They fit all of these parameters and demonstrate that the biosphere, including humanity, could not survive without them. Some have proposed that the materialist endosymbiosis hypothesis can also explain these complex relationships.[36] However, all of the evidence discussed suggests that an engineered biomatrix is more consistent with the data.[34] Because humans, plants and animals could not function without microbes, it is hypothesized that they were created as biological systems with plants, animals and humans on multiple days of Creation Week.[37]

Viruses are biologically non-living and are looked upon as deleterious genetic machines. Current research suggests that their harmful qualities may be, by far, the exception than the rule because pathology is uncommon and there are many examples of beneficial viral symbionts.[34] Viruses have powerful mini-motors used to inject genetic materials into their hosts and their hosts are often bacteria.[38] Bacteria contain tremendous amounts of genetic potential and are constantly acquiring and exchanging genetic information. Because of this ability, they provide many ecological services such as bioremediation, recycling nutrients, cleansing water and regulating soil pH. This ability to exchange and gather genetic information may be facilitated and ameliorated by viruses. Instead of parasitic symbioses, viruses may be commensal with bacteria in genetic exchange, much like bees cross pollinating flowers.[39] Fascinating areas to investigate include the roles of viruses in genetic transfer as a function of microbe involvement in global homeostasis, and potential mechanisms for rapid intrabaraminic diversification.

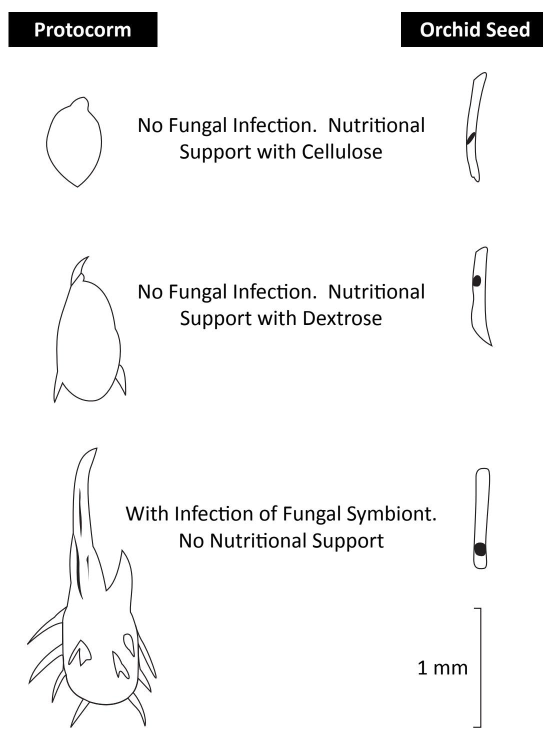

Figure 2. A comparison of protocorm development of the Boat Orchid (*Spathoglottis plicata*) after five weeks. The first two illustrations compare development when the fungal symbiont is absent. The last illustration shows development after being infected by the fungus, *Tulasnella calospora*. (After Smith and Read,[54] p. 355).

Biogeochemistry

Microbes are also a crucial component in biogeochemical cycling. These cycles consist of the paths elements take through the global system for proper functioning and persistence of life. If microbes did not exist, the critical carbon, nitrogen and phosphorous cycles would not be possible and life would cease. Life affects chemistry and chemistry affects life.

Zuill and Standish focused their attention on the nitrogen cycle.[40] Nitrogen is crucial for the existence of all life and is a building block of amino acids needed for protein synthesis, as well as nucleotides and their nucleic acids. The nitrogen cycle's function is to keep its various molecular forms in balance so that life can persist. Through five stages, atmospheric nitrogen is converted into nitrogen compounds that plants require and can assimilate, and it is then recycled back into the atmosphere again. Many chemical steps are involved in various parts of ecosystems and specific enzymes are needed at the right times and places. The nitrogen cycle is dependent on the carbon cycle and requires microbes and other creatures to work in concert. In turn, plants provide nutrition to animals. Amazingly, in order for certain chemical reactions to continue, plants contribute specific chemicals while the biomatrix provides what plants lack in order to complete the required chemical reactions. Many diverse genera are involved and this redundancy is important as a system back up should a certain taxon not be present.

Behe's concept of irreducible complexity in biological systems[41] was enlarged and extended to ecosystems, giving rise to a term 'irreducible interdependence'.[40] Behe discussed this concept in the context of biochemical reactions in single organisms. Zuill and Standish used the term 'ecochemical pathways' to refer to the series of biochemical reactions across multiple species, where each step of the reaction is mediated by one or several species. An irreducibly interdependent system has the following characteristics in this testable model:

1. Potential gaps in the system cannot be reasonably bypassed by inorganic nature alone.
2. It must have a degree of specificity that in all probability could not have been produced by chance.
3. A given function or step in the system may be found in several different unrelated organisms.
4. The removal of any one of the individual biological steps will resort in the loss of function of the system.

The data suggest that the nitrogen cycle may be irreducibly interdependent based on the above criteria. No proposed neo-Darwinian mechanisms can explain the origin of such a system. Compounding matters, Zuill makes a strong case by suggesting that this biodiversity of multi-species interactions have always been required for biospheric regulation and had to have been built rapidly.[42] Several of the above arguments are based on logical inferences, but many of these inferences can be further tested to determine if they meet interdependence criteria. This research could be extended to test other global cycles, and interaction between cycles, for irreducible interdependence.

Baraminology/biogeography

Creation biologists have been discussing the origin, variation and global dispersal of species for decades.[43] In recent years, the progressing discipline of baraminology, a uniquely creationist biosystematics method for determining 'created kinds' (*baramin*), has become an important area of study for the biblical history of biodiversity.[44] Evidence suggests that rapid intrabaraminic diversification has occurred since the animals dispersed from the ark.[45] Genetic and environmental mechanisms to explain how this happened are unclear, but exciting vistas of research, testing for mediated design, have been proposed.[46] Baraminological analysis seems to be a useful biological tool and a recent synthesis of 66 studies highlight research already done, but there is much work to do.[47]

One area of study that will shed light on diversification is biogeography. Evolutionists previously used biogeographic models as proof of evolution, but these models have since fallen into disfavour as an evolutionary mechanism.[48] Data learned from biogeographical modelling have implications for mechanisms involved in both geographical distribution and diversification of baramins. For example, it has been hypothesized that the Noahic Flood would have ripped apart large chunks of terrestrial materials that became rafts which travelled on water by wind currents. This creation biogeography model envisions these giant rafts in the form of log masses, plant debris and vegetation mats that dispersed organisms world wide.[49] The authors made 18 predictions that test it for validity, including distributions of wind dispersed organisms which should reflect distributions of rafted organisms and the directions of transoceanic dispersal which correspond to marine current movements.[49]

This preliminary synthesis of ecological concepts doesn't scratch the surface of the intricacies and complexities of systems and subsystems continually being discovered. For example, space prohibits discussing challenges to understanding food web dynamics, in particular fungal symbionts preying on soil arthropods and translocating the invertebrate nitrogen compounds to its plant host.[50] Or why heterotrophyid parasitic trematodes from the Genus *Ascocotyle*, are obligate parasites on at least three disparate and different hosts, where at least two of these hosts must ingest the worm in order to complete their reproductive cycle.[51] To illustrate, a subsystem of food web dynamics in the complex mycorrhizal symbioses of orchids will be analyzed in the light of a creation ecology model.

Mycorrhizal symbioses in orchids

The 'evolution' of angiosperms remains one of the frustrating and mysterious puzzles of neo-Darwinian botany. The fossil record suggests sudden appearances and does not mean that intrabaraminic diversification did not occur; it is consistent with fully designed flowering systems.[52]

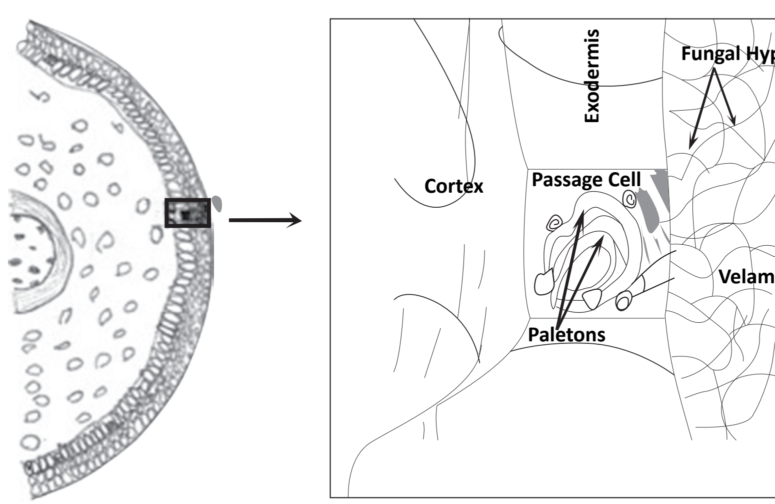

Figure 3. Cross section of an epiphytic orchid root. In this illustration, symbiotic fungi enter the orchid root through the spongy velamen. Then they enter passage cells, which are exodermis cells with delayed or absent cell walls. These cells are thought to be important in attracting fungi and absorbing ions. The hyphae may also enter the root cortex which is responsible for moving nutrients to the transport tissue. It is thought that carbohydrate transport takes place at the orchid/fungus interface.

The Orchidaceae is considered one of the largest flowering families within Angiospermae and is incredibly diverse. Orchids are cosmopolitan and include terrestrial herbs, epiphytes, lithophytes and lianas. They are famous for their unique inflorescences and intricate symbioses, one of which is their obligate associations with mychorrizal fungi. Many of the orchids, particularly the epiphytes that grow on branches without soil, are subject to extreme conditions and these symbiotic associations with fungi help them to survive.

The term 'mycorrhizae' literally means 'fungus root' and refers to the relationship between soil fungi and plant roots. Fungal diversity is estimated to include about 100,000 species, and like angiosperms, their fossil record provides no evidence that neo-Darwinian mechanisms produced these complex life forms which represent about one-quarter of the earth's biomass.[53] There are different types of mychorrizal associations and species within at least three fungal phyla; Ascomycota, Basidiomycetes and Glomeromycota which play crucial roles in various associations. The classification of fungal symbionts continues to be difficult but it seems that a large percentage of orchid mycorrhizae are Basidiomycetes, from the form genus *Rhizoctonia*.[54] Genetic tests have verified the identity of *Rhizoctonia* to specific genera that include *Tulasnella*, *Ceratobasidium*, and *Thanatephorus*.[55]

Coupled with the complexities of identifying the players in these complex associations, is the need to determine what the relationships are and how they work. Consider the case of orchid seeds which are tiny (0.3–14 µg), undifferentiated and lack endosperm. Under laboratory conditions, with carefully formulated soil and nutrients, orchids can be germinated asymbiotically (figure 2). However, in the wild, a complex system of mycorrhizal symbionts is prerequisite if the orchid is to germinate and develop.[56] Orchid-fungus specificity in ecosystems is controversial. Most orchid endophytes are widespread in soil and are found globally. Some have likened their common presence in orchid roots as a relational one. Others have interpreted the associations as a reflection of their universal distribution. The latter interpretation would also be consistent with properties of a designed biomatrix. Nevertheless, there is evidence that at least some orchid species are specific toward particular fungi.[54]

Orchid seeds contain small amounts of high energy proteins and lipids, but very little sugar.[54] Once dispersed, they imbibe water and swell. Fungal hyphae enter the testa through either epidermal hairs or the suspensor which is zygote tissue involved with pushing the embryo to the centre (figure 3). As the hyphae breach the cell wall, there is no evidence of distortion or cell wall thickening which suggests that the hyphae enter by the process of hydrolysis rather than the application of pressure. At this juncture, three things can happen:

1. Functional symbiosis between orchid and fungus begins.
2. The fungus parasitizes and kills the seed.
3. The fungus does not penetrate and the seed never develops.

It is hypothesized that since the onset of the curse, biological organisms have experienced deleterious mutations, decreasing biochemical function, and dysfunctional relationships. These hypotheses could be tested in the cases where the fungus kills the seed or does not penetrate.

In functional symbiosis, the fungus has access to key soil carbohydrates and translocates them to the orchid, enabling the seed tissue to grow and differentiate. The fungus may also synthesize vitamins and growth factors for the seedling, but this has not been demonstrated. The fungus colonizes mostly the basal cells of the orchid, while the apical cells elongate and become the protocorm or the microscopic first stage of orchid germination. The plasma membrane invaginates and the fungal hyphae forms tight coils called peletons (figure 3). It is at the peleton/orchid cell interface where carbohydrate transport probably takes place. Cells in the orchid do not show signs of stress when they change in response to hyphal presence. Cytoplasm streaming remains active, mitochondria become numerous, major organelles like the Golgi apparatus and endoplasmic reticulum are well developed, the nuclei hypertrophy and they contain higher amounts of DNA than uninfected cells.[54] It is unclear what is happening in the nuclei and why. Do parts of the genetic apparatus, from both organisms, combine to form a cooperating genetic system that enables the relationship or does the orchid simply multiply what it has?

Most of the time, adult orchids that can photosynthesize still contain mycorrhiza but their relationship is unclear. There is growing evidence that mycorrhizae are important in providing mineral nutrition such as nitrogen (N) and phosphorous (P). In *Goodyera repens,* mycorrhizal colonization is associated with an increase in both N and P uptake.[54] Mechanisms showing how this is done have not been worked out, but research with other mychorrizal forms, such as Arbuscular Mycorrhizal Fungi (AMF), may shed some light. AMF has been shown to produce the genes that establish symbioses with nitrogen fixing bacteria.[57] This suggests that the presence of AMF in the rhizosphere increases legume nodulation, thereby increasing nitrogen fixation and utilization by symbionts. AMF are also more efficient at P uptake than plant roots alone and can change soil chemistry to increase N and P concentrations and rates of uptake.[57] Further research may show whether orchid mycorrhiza also have these capabilities.

As complex as the above associations are, recent observations further complicate matters. More than one fungal species can form peletons in an orchid root or individual cell. Some orchids experience a *fungal succession* in which different fungi occur at different developmental stages. For example, the achlorophyllous orchid, *Gastrodia elata*, needs one fungus for germination (*Mycena osmendicula*), but full orchid development can only occur if a secondary colonization by *Armillaria* takes place.[54] Other research has found that epiphytic orchids contain interlaced fungal hyphae and filamentous nitrogen fixing cyanobacteria that form a sheath on the aerial roots.[58]

There is growing evidence that *Rhizoctonia* can form concurrent orchid mycorrhizas and ectomycorrhizas with other photosynthetic plants. The implication is that there is a three-way relationship with the fungus capturing the carbon from the other photosynthetic plant and translocating it to the orchid. Fungal succession and links with other microbe taxa bring the complexities of these relationships to a new level and presently it is unknown how common they are or whether they exhibit irreducible interdependence.

Orchid fungi are mysteriously unique in the world of mycorrhizae. It does not yet appear that the fungus gains anything from the relationship, but there is still much to learn. The interactions between the two are variable and dynamic; some likening them to enemies on a battlefield.[54] For example, the genera *Armillaria* and *Rhizoctonia* are strongly pathogenic species. In some situations, the fungus advances towards the seed, yet once colonization begins the orchid produces secondary compounds to lyse the peletons, clearly controlling fungal growth. Some have interpreted the relationship as the orchid taking defensive measures against a potential parasite. Others interpret the lysis of peletons as the mechanism for nutrient transfer. What controls the process of balancing 'infection' between the two is a mystery and dependent on the relationships involved. The following hypotheses have been suggested:

1. The aggressive nature of the fungus is balanced by defence mechanisms of the orchid.
2. The fungus alters its metabolism upon penetration and plant tissue enzymes are no longer produced.
3. Some defence mechanisms operate at low levels in both.[59]

Research suggests that in some cases there is alteration of fungal metabolism which no longer makes it parasitic once it breaches the testa. If true, it would also be consistent with orchid lysis of fungal peletons as one of accessing fungal nutrients and not a defensive measure.

Conclusions

Worldview matters when scientific observations are interpreted. Orchid mycorrhizae are just one of thousands of ecological subsystems that can be used to test creation predictions based on biblical presuppositions. Their highly complex associative systems, beginning at the genetic level, reflect marvellous design and possible irreducible interdependence. Parasitism and inability to colonize orchid seeds may be due to disruptions and system knock outs brought on by the curse, causing relational malfunction. The fact that microbes are crucial bridges between orchids and their environment suggests that they were not only designed as a biomatrix, but also part of the functioning system of the original orchid baramin. The more humans understand rhizospheric relationships within a creation ecology model, the better managers they will be. The potential is there to create opportunities for representing God, in the management of his resources, for the benefit of all.

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14. Romans 1:20
15. John 1
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