FROM ROCK TO TREE
A Thumbnail Sketch of Organism Interactions in the Creation of a Forest

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These exercises are designed to compliment the 'Project Learning Tree' activities "Dynamic Duos"

The exercises from the *Project Learning Tree* are designed for students in grades 5-8. With a modest amount of adaptation, these activities can be elevated or lowered to suit any particular grade level. Unfortunately, the examples used are not very appropriate for Manitoba and in particular the forest regions of the province. It is hoped that the following examples will help you in shifting to a more meaningful sets of exercises for your students. The general theme I am following is to illustrate particular *symbiotic* relationships which have historically led to the development of forests (more specifically the Boreal Forest). There are many other biological processes and physical factors, such as climatic change, which are important but the following examples keep with the intent of the *Project Learning Tree* activities.

INTRODUCTION:

The development of a forest from a bare rock environment is a form of *xerarc succession.* This was typical of what happened of the Precambrian Shield following the Wisconsin' glacier retreat some 12,000 years ago. Succession is described as 'the gradual, sequential, and somewhat predictable changes in the composition of an ecosystem's communities from an initial colonization of an area by pioneer organisms to the eventual development of the climax community". Xerarc refers to the passing from a dry ecosystem to a somewhat more moderate ecosystem. Perhaps that most harsh are where succession could begin would be a bare rock. The soil is non existent, there is no water retaining ability and no way to avoid the harsh extremes of the climate. Very few organisms could continue to grow in such an environment and, in fact. this is where we will begin our examination of the relationships between *symbiosis* and succession.
To link to the background provided in *Project Learning Tree* we will cover three types of symbiosis: associations where both organisms gain ***(mutualism);*** associations where one organism gains and the other is mainly unaffected ***(commensalism).*** All three of these symbiotic associations occur in the development and maintenance of a forest.

<u>LICHENS:</u>

In bare rock succession, the first organisms or ***pioneer community*** are usually lichens. Lichens are actually not one but two distinctly different types of organisms that are able to survive under the extreme conditions of the bare rock because of a **mutualistic association.** The two organisms involved in the association are algae and fungi. Both may live independently in milder conditions, but neither would survive on a bare rock.

What is so unique about this association and what does each benefit? The alga (normally associated with an aquatic environment benefits from a protection against drying, a source of stored water and a supplier of mineral nutrients. The fungus benefits from a constant supply of organic 'food' and in the case where the alga is a member of the blue-green algae, they also provide nitrogen to the fungus. This sharing means that both can live in an area where neither could entirely provide for themselves.

Once the lichens are established, how do they contribute to the succession or change of the ecosystem? There are four ways in which the lichens may alter the habitat. First, their physical presence provides a "net" to capture particles of dust to form the beginnings of soil. Lichens are capable of penetrating rock up to 1 cm. This will provide a mechanical breakdown of the rock which in turn will lead to more soil particles (including much needed mineral nutrients). Third, a by-product of lichen metabolism is a group of week organic acids. These compounds have been attributed with causing an extremely slow breakdown of rock and providing a mechanism for extracting mineral nutrients from the rock. Finally, in death the lichens add the first organic material to soils.

Lichens themselves grow through a 'mini-succession' from *crustose* lichens which 'hug' the rocks, barely emerging above the surface to *foliose* lichens which have upturned edges and larger flattened thalli: to *fruticose* lichens which have a large erect portions and a more finely dissected thallus.

EXERCISE 1: Lichens in their habitats.

This exercise is designed to get students acquainted with the habitat, succession and biology of lichens. It asks the students some fundamental questions about the contribution of lichens to forest ecology and requires that they make some careful observations about the structure and reproduction of these symbiotic organisms. The level of difficulty can be changed to match the level of progress of the students.

A) Identifying types of lichens.

i) Students should first be able to separate lichens from any other organisms they might encounter in these environments.

ii) The second step is to distinguish types of lichens (i.e. Crustose, foliose and fruticose). Identify the lichens further will require chemical tests that are included in your field guide.

B) Identifying stages of pioneer colony development.

i) Students should be able to find the steps from crustose alone; through foliose growing on a crustose base; to a 'mini community of all three forms.

ii) As the community of lichens gets more complex, students should look for a build-up of soil particles, organic material and even small animals making use of this tiny amount of shelter.

C) Recognizing forms of lichens reproduction.

i) *Reproduction of the fungal component.*

These may be subtle or rather obvious and often colored structures. The fungal component may reproduce sexually or asexually. The cup-like structures on some lichens or the colored, more globose structures on other forms, are sexual reproductive structure of the fungi. These structures cannot produce another lichen.

ii) *Reproduction of the lichen.*

The lichens can reproduce in one of three ways, but all ways are asexual. The simplest mechanism is that the thallus can be *fragmented* and each piece begins a new organism. The other two mechanisms involve the production of a specific structure that includes part of both the fungus and the alga. *Soridia* are small structures formed inside the thallus and then breaking out in a 'blister'. They contain a small amount of fungus wrapped around one or more alga cells. *Isidia* are small outgrowths of the thallus which break off and are dispersed.

EXERCISE 2: Lichens in an urban environment.

It is interesting that lichens on the one hand are able to live in such an extremely harsh environment as a bare rock and yet are one of the first organisms affected by human pollution. Lichens are unable to withstand atmospheric pollutants, particularly sulfur dioxide. If there is any increase in the amount of these pollutants, the lichens will quickly die our.

i) As an indication of pollution in your area, have the students count the number of different kinds of lichens they can find on the trees in their immediate vicinity.

ii) Construct a map of the city or town where you live. Draw concentric circles away from the school and have the students count the lichens on trees in different areas.

iii) Have them put the number of species/tree on the map. Try to estimate the areas of most pollution and the source of the pollution. The further the students can sample from the school and even city/town, the more dramatic will be the results.

<u>MOSS:</u>

Moss form the second stage in the succession of a bare rock ecosystem. They may require the primitive soil the lichens have created or they may start in small crevices or other more shaded, moist areas. As they become more successful, the moss will eventually crowd out the lichens. They also contribute to the succession in a number of ways. As a by-product of their metabolism, moss produce acids which further breakdown the rock. The rhizoids and water penetrating into small crevices expand and contract putting more physical stress on the rock. The tight clump growth provides a catch basin for soil or dust particles. Dead organic material collects but does not decay rapidly (due to the acidic conditions which inhibit bacterial growth). Small animals add more organic material and so a new thicker layer of soil begins. This in turn will provide a habitat for the next group of plants in the succession. It will also lead to the demise of the moss.

One of the reasons for the success of the moss in bare rock succession could be considered a form of ***commensalism.*** The difference between this example and most is that the commensalism is between two stages in the life of the same organism. In most plants, there is a life cycle which separates the haploid stage of the plants life with the diploid stage. Animals do not go through this process. In most instances the diploid plant is dominant and protects the haploid stage. In the moss, the haploid (gametophyte) plant is dominant and not only protects the diploid (sporophyte) plant but always retains it and provides it with food, minerals and water. The gametophyte plant itself gains nothing (although the species has a better chance of survival). Almost all of the adaptations for survival are found in the gametophyte plant.

The following are special adaptations of the gametophyte moss that allow them to survive on the bare rock habitat.

i) Ability to loose over 70% of their water and still remain alive. Lichens also have this ability. Higher plants are in trouble with losses of over 30%.
ii) Ability to get water and minerals directly from the atmosphere.
iii) Ability to withstand a temperature range from 70°C to - 100°C if the changes are gradual *(3°C/hour).*
iv) Ability to withstand desiccation and dark for extremely long periods of time (5 years of dark dryness).

EXERCISE 3: Recognition of moss survival strategies.

i) Students should be able to recognize features with permit the survival of the moss in conditions where they can't necessarily grow. To help them in the exercise, have them also examine moss in damp shaded areas.
ii) Features to look for are:

-tight clump growth
-even growth within the clump
-more damaged plants at the periphery
-leaves appressed to the stems
-red to brown pigmentation
-small size of individual plants
-sporophytes attached to gametophytes
-other features are physiological or cytological and can't be seen

iii) Have the students remove a small piece of moss clump, place it in a shoe box and store it for several weeks. Have them do the same thing to a vascular plant for the same period of time. After several weeks, have the students place the two types of plants in the light and water them well. If the bottom half of the moss is submerged in water, they should soon (several hours) see small air bubbles on the surface of the submerged leaves. This is O_2 being evolved from the photosynthesis in the leaf.

EXERCISE 4: Urban succession.

You do not have to take your class to the Precambrian Shield to see xerarc succession. There are plenty of areas in the city/town where these processes are continuously occurring. If there is not too much air pollution, you should be able to find lichens and moss growing on the concrete in the school yard. Although this might be considered secondary succession, the process remains the same and given a sufficient amount of time and lack of disturbances the school yard would be changed back into a grassland or forest.

MYCORRHIZAE

Mycorrhizae are another type of relationship found in the forest. The difference between this symbiosis and the previous examples is that the mycorrhizae were not developed to enhance succession. Rather they are associations which evolved, to enhance the survival of the organisms in more well established or climax communities. The two partners in mycorrhizae are a fungi and a plant. The fungi encircle and penetrate the roots or rhizoids of the plants. To understand the advantage of the symbiosis to both organisms, you must know a bit about their anatomy or physiology.

The root systems of plants are somewhat deceiving with regard to their absorptive surface. When you look at the anatomy of a root you would find that about 15mm back from the tip, the root is covered with a waxy cuticle. This is to prevent water loss and infection by bacteria and most fungi. It also prevents the uptake of water and minerals. A large tree can transpire several hundred liters of water daily. It would be extremely difficult for them to replace that water using only the tips of the roots. This is where the fungal association is invaluable. The mycorrhizal fungal encircle the roots in many places. From this circle of fungal filaments (hyphae) some filaments enter the roots while other fan out into the soil. This provides a conduit which greatly increases the absorptive capacity of the tree.

Jack pine, which lives in sandy soil would be in a great deal of difficulty since any rainfall would quickly percolate through the soil or evaporate to the atmosphere. In a forest, you should envision a whole net of fungal hyphae spread out through the upper layers of soil. These hyphae will absorb much of the rainfall and pass it to the tree before it is lost. The fungi are also capable of removing mineral nutrient such as $P0_4$ from the soil at much lower concentrations than the tree. They can also undergo ‘luxury consumption’ of the nutrients, saving them for a time of scarcity.

The fungus also gains in this association. Organic food for fungi is often scarce and there is a great deal of competition between fungi and bacteria. The mycorrhizal fungi do not need to compete for the food since they receive a constant supply from the plant.

EXERCISE 5: Detection of the presence of mycorrhizae.

Mycorrhizal fungi mainly belong to the group Basidiomycetes. The mushrooms are in this group. When you see mushrooms around a tree, you can be reasonable certain they are mycorrhizal fungi. To get further evidence, lift up the litter zone and you should see masses of white fungal filaments. Trace these to at shallow root. Examine the roots. If there are mycorrhizae, the root should have swollen areas where the fungi have caused abnormal growth. Some fungi form a smooth black ring around the roots.

BLACK KNOT OF CHOKECHERRY:

This example represents the last form of symbiosis mentioned in *Project Learning Tree.* Black knot is the symptom of a **parasitic** relationship between a fungus and the chokecherry. In this relationship, the fungus benefits from a food source provided by the tree while the tree is harmed by reactions between its cells and chemicals produced by the fungi. There are many examples of parasitic symbiosis in the forest and they are all part of the natural cycle where some organisms are used by other for a variety of reasons. If the parasite is virulent enough of if the host is in a weakened condition, the host will die and decomposers will release the nutrients that were part of the host's body. These nutrients will then be available to support further forest growth.

EXERCISE 6: Identification of forest parasites.

Students should be able to identify several parasitic associations either in the forest or in their own school yard. They should also be able to realize how these associations are part of a natural cycle in the ecosystem.