7-1963

The Teaching of Succession through the use of Pond Infusion Cultures

James E. Cole

THE TEACHING OF SUCCESSION THROUGH THE USE OF POND INFUSION CULTURES

by

James E. Cole

A thesis presented to the
Faculty of the School of Graduate
Studies in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
July 1963

184405

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Drs. Beth Schultz and William VanDeventer, both of Western Michigan University, for their encouragement and assistance in obtaining materials and providing advice for the production of this thesis.

I would also like to thank Dr. Thane S. Robinson for his time spent in critically reading this manuscript, and Dr. Casey vanNeil, of Stanford University, who, perhaps unknown to him, provided encouragement through his discussions with me.

James E. Cole

TABLE OF CONTENTS

LIST OF TABLES

Chapter I

INTRODUCTION

The approach to teaching biology for general education is significant. In a course of this nature, the learning of biological principles should be of primary concern. It is hoped that such principles then will lend themselves to the understanding and use of the scientific approach to everyday happenings. To do this, however, requires that the teacher use the inductive method for developing an understanding of the principles, and the deductive method for applying them.

Planners of these basic biology courses attempt to define areas of real concern and interest to students. Having defined these areas, the planners then develop experiences which, they hope, will result in the student's insight into principles that are basic to an understanding of biology.

The purpose of this experimental laboratory unit is to develop a unit of study for a general education biology course on the subject of ecological succession, using the pond infusion culture as the illustrative material.

The phenomenon of succession embodies many principles, and these are apparent only as information is accumulated and organized. Many of these principles are mentioned in research done by Downing (1932), Washton (1952) and Martin (1948).

From the results of four studies done at the University of Chicago, Downing (1932:221-222) formulated a list of 28 principles

of biology that are important for solving problems of everyday life. Of these 28, nineteen were listed as being subordinate principles, and nine as being major principles. Of these nine, the study of succession through the use of the pond infusion culture is concerned with the following three:

(1) All organisms must be adjusted to the environmental factors of the habitat in order to survive the struggle for existence.

(2) All life comes from previously existing life and reproduces its own kind.

(3) Food, oxygen, and certain optimal conditions of temperature, moisture, and light are essential to the life of most living things.

Washton (1952:228), utilizing the principles formulated by others (Bergman, Downing, Winokur, and Martin), compiled forty-two principles of biological importance for general education. These forty-two principles were judged by twenty-five college biology teachers as either "most important" or "important" in attaining the objective of providing students with necessary knowledge, skills, and attitudes in order that they may understand the world of nature and be able to interpret natural phenomena. Of these forty-two principles, the study of succession involves the following fourteen:

1. Life is perpetuated through the biological process of reproduction which provides new individuals.

2. Living organisms perform common life processes, reproduction, nutrition, growth, irritability, locomotion or movements or orientation and mutability.

3. Different kinds of plants and animals form communities based on their inter-relationships with one another and with their physical environment.

4. Food, oxygen and certain optimal conditions of temperature, light, and moisture are required for the life of most living organisms.

5. All living things receive and respond to stimuli and attempt to adjust themselves in their environment.

6. The ultimate source of the energy of all living things is sunlight, and is obtained by organisms through oxidation of food.

7. Saprophytes cause decay by which process necessary raw materials are produced from dead matter for the growth of new organisms.

8. The earth's surface and its surrounding atmosphere are changing constantly and demand that organisms migrate, hibernate, aestivate, build artificial shelters or otherwise become adapted to these changes.

9. The higher forms of life are complex in structure and are accompanied by an increase in division of labor.

10. Living things are more likely to survive and reproduce when they are structurally and physiologically best fitted to their environment.

11. All living things with the exception of several anaerobic and autotrophic bacteria, obtain their energy through the oxidation of food.

12. Living things produce a multitude of individuals, many more than can survive, varying more or less among themselves, and all competing against each other for the available food and energy.

13. Living things require food and other substances; fuels to supply energy, materials for growth and replacement, minerals and water for cell structures and cell products.

14. The modes of reproduction of living things fall into two categories: asexual and sexual.

Of the major principles of ecological relationships important for general education, compiled by Martin (1948:24-25) this study is concerned with all of those listed under <u>Environment and Living Things,</u> and five of the twenty listed under <u>Interdependence.</u>

Environment and Living Things

1. The environment acts upon living things, and living things act upon their environment.

2. The environment of living things changes continually.

3. All living things are continually engaged in an exacting struggle with their environment.

Interdependence

1. Changes in the numbers of organisms in communities may be rapid even though the environmental conditions apparently alter slowly and gradually.

2. The existence of organisms depends upon their interrelations with the environment which includes both the inorganic world and other organisms.

3. A balance in nature is maintained through interrelations of plants and animals with each other and with their physical environments.

4. When the balance of nature is disturbed, disastrous results often follow.

5. Certain associations of plants and animals are the result of a struggle for survival; for example, community and social life, parasitism and symbiosis.

The Infusion Culture As Illustrative Material

The use of the infusion culture as illustrative material was prompted by its practicability. It is inexpensive, and the materials necessary to carry out a study of succession within it are available to any high school or college biology classroom.

The relatively short duration from the beginning community to that association which may be comparable to a climax community makes the infusion cultures ideal for classroom observation.

Finally, the phenomenon of succession in the infusion culture may be compared to that of other successions which take place outside the laboratory. Consequently, the laboratory study of the pond infusion culture enhances the student's understanding of succession.

Chapter II

THE BIOLOGY OF THE POND INFUSION SUCCESSION

A Review of the Research

The phenomenon of succession in the pond infusion culture involves two important facets, the description of the plants and animals involved, and the causes of the replacement of one plant-animal community by another. To understand succession, one must at least hypothesize causes for certain organisms appearing when they do.

A study of the succession of invertebrates in pond infusion cultures was carried out by the writer (Cole:1963) in the summer of 1962. I found that the observable succession seemed to occur in three stages. The first was characterized by large numbers of both green and non-green flagellates and metazoans; the second, by dense populations of ciliates; and the third, by an increase in filamentous algae and rotifers, and a decrease in ciliates.

Eddy (1928:303) made a study of succession of protozoans in hay infusion cultures under controlled conditions. From this study he concluded that similar cultures maintained under the same conditions have a similar succession of dominant organisms.

Buchsbaum (1957:102) described a sequence of plants and animals confined to a jar of water containing a source of organic matter and some pond water organisms. In this study, the initial stage was characterized by bacteria and a few other plants and animals that

entered from the air. This stage was followed by the appearance of flagellates (many bacteria still remaining); then as the flagellate population declined, there was a rise in the population of a small ciliate, Colpoda. As the number of Colpoda decreased, hypotrichs became dominant, followed by the appearance of Paramaecium as the hypotrichs decreased in number. The stable or "climax" state which followed was characterized by green algae, rotifers, micro-crustaceans, and amoebae, with a few representatives of each preceding stage remaining.

The reasons for the succession in infusion cultures have not been worked out thoroughly. From his studies to determine the relations of protozoans to some controlled physical factors, Eddy (1928:303-304) concluded that the amount of dissolved oxygen present in the culture is the foremost factor in governing the sequence of communities, and that the pH of the culture is not a very important factor in controlling the succession of protozoans, but it is indicative of other factors which may control succession.

Cole (1963:327) indicates that pH may be indicative of the amount of carbon dioxide and ammonia present. The quantity and quality of materials present in the culture are also determining factors in the succession, according to Eddy (1928:304).

Woodruff (1912:257) concluded that the catabolic products of the protozoans might be important in determining the succession of protozoan populations. Woodruff (1911:577) found that the excretion products of paramaecia had an inhibitory influence on their rate of reproduction. Buchsbaum (1957:103), likewise, indicates that when animals exploit an environment, their own activities tend to make the environment unsuitable for their continued growth.

In addition to those physical factors mentioned above, Cole (1963:328 & 331) states that turbidity and temperature may affect the succession. Turbidity may influence the population of photosynthetic organisms which may have an indirect effect on dissolved oxygen content and pH. Temperature influences succession in that it determines to a great extent the rapidity with which organic decay takes place.

Of the biological factors affecting succession in infusion cultures, Cole (1963:331) believes that food availability, population dynamics, predator-prey relationships, and space are important. Noland (1925:451), in studying ciliates, stated that the nature and amount of available food had more to do with the abundance and distribution of fresh-water ciliates in natural habitats than any other single factor.

These reports of studies done on the effects of the environment on invertebrates indicate that there are a variety of factors which bring about population fluctuations, and hence, succession. Undoubtedly, light, temperature, turbidity, dissolved carbon dioxide, dissolved oxygen, space, and the nature of the cultures are important physical factors, while food availability, predator-prey relationships, population dynamics, and the accumulation of wastes are important biological factors.

The fundamental difficulty involved in the study of succession in a pond infusion culture, however, is the difficulty in measuring, controlling, and assessing the relative significance of the many interacting factors which are involved.

Chapter III

THE TEACHING UNIT

Laboratory Study of Succession in Pond Infusion Cultures

Ecological succession is a universal phenomenon which involves the replacement of one community by another through time. The changes which bring about replacement are initiated by changes of various environmental factors, thus making a particular habitat more suitable for certain organisms and less suitable for others. The plants and animals that are best adapted for a particular habitat, therefore, tend to reproduce more rapidly and thus become more numerous than do the less well adapted forms.

As the environmental factors of a particular habitat change, there is a change in the kinds of organisms that will inhabit that area. This shift in the composition of the biotic community may be a drastic one or a gradual one depending upon the kinds and numbers of organisms that comprise the community, and the magnitude of changes of the various environmental factors. The adjustment which the community must make in response to environmental changes results in succession.

In general, ecological succession is a relatively orderly, progressive change in plant and animal life. Although succession constitutes a continuum, it may for the sake of convenience be categorized to the extend that particular successional stages exhibit certain characteristic features of their own which differentiate them from one another.

The first stage in a natural succession is a pioneering stage and, hence, the group of organisms that makes up this stage is termed the pioneer community. After a period of time, the pioneer group has so changed the original environmental conditions that the organisms of this community are no longer able to live in the place to which they were originally adapted. Consequently, they are replaced or pushed out by different organisms better capable of living in the new environment. The succession of organisms continues until a relatively self-sustaining community is produced. This self-sustaining community is able to propagate itself indefinitely and remains in a kind of equilibrium in which there is a limited number of dominant organisms and the "turnover" of plant and animal types is almost unobservable. This is the stabilized stage of succession and is termed the climax. The whole series of communities that leads to a climax is called a sere. Therefore, each stage between the pioneer community and the climax community is known as a seral stage. The plants and animals which characterize each seral stage are known as index organisms.

Hence, a pond with few organisms and a bare bottom in the northeast quadrant of the United States may, and usually does if left alone, go through successional stages which eventually lead to the formation of a beech-maple forest. Likewise, an open beach on southern Lake Michigan may, within a period of years, become a beech-maple forest after going through seral stages characterized first by pioneer grasses, then poplars, then pines, then oaks and, finally, the beech-maple association. In all cases, the interacting forces cause continuing change toward some dynamic equilibrium. In both instances, the beech-maple forest is considered the self-sustaining, climax community.

The fact that two such different pioneer communities (the open pond and the sandy beach) succeed to similar climax communities illustrates the phenomenon of convergence. Convergence is the successional development from widely diversified communities in different habitats to similar or identical climax communities.

Succession is not confined to ponds and beaches, but is going on in nature all the time. If a landslide occurs, or a forest fire, the original vegetation usually is eventually restored through the process of succession. If a cultivated field in a formerly forested area is abandoned following soil depletion or excessive erosion or for any other reason, it goes back to brush. If left alone long enough, forest trees will grow on it again.

Obviously, it is impossible to bring an abandoned field, pond, or beach into the laboratory. Even if this were feasible, the time required for succession to take place from the pioneer to the climax community would be many years. It is for these reasons that the pond infusion culture is ideal for the laboratory study of succession.

The succession in the infusion culture does not begin with a truly pioneer community since the organisms have been placed in the culture. It, therefore, would best be termed a primary community. A true pioneer community is one that establishes itself in a place that was not previously supporting a biotic community.

Succession in the culture is brought about by changes in the relative number of organisms, including extinction of some. It is not succession by addition as in the populating of an artificial lake in nature, nor is it succession by invasion as in an abandoned field or sand dune succession. The succession which follows the

primary community, and the final stablized condition of the culture are, however, comparable to other successions. As vanNiel states (1955:216),

> "...the microbiologist can take heart from the knowledge that the material he deals with represents life in a relatively simple form and can often be investigated under conditions far more favorable than those needed for similar studies on higher plants and animals, while yet the fundamental principles he may discover by his efforts will be applicable to all living organisms."

Methods

The collecting of the materials for the infusion culture is a simple operation, but it is important that the directions be followed carefully. A good place to secure a culture is from a quiet pond in which there is much vegetation growing. Fill a quart-sized fruit jar, or other container of similar size, approximately half full with vegetal material, including some floating and submerged green vegetation, and some dead vegetal matter from the pond bottom. Then fill the jar with water taken at the place where it has been stirred up. This gives a broad sample of the microscopic and smaller macroscopic organisms in the pond community at this location. This pond infusion culture is different from the commoner hay infusion culture in that the vegetal matter is taken directly from the pond at the time of collection and contains a wide variety of microorganisms in an active state. A hay, or "dry" infusion culture is composed of dry hay or grass to which has been added pond water. The living organisms which it contains are generally those which are able to assume a form resistant to drying.

If the pond material is collected during the winter months, the collection procedure is the same, even though it may be necessary to cut a hole in the ice to obtain the material. In winter, the organisms that are introduced into the culture are generally dormant or inactive (many being encysted). Bringing them into the laboratory results in their becoming reactivated and excysting. This is accompanied by an increase in their metabolic rate paralleling the increased temperature of the environment.

The only materials necessary to carry on this study are a microscope, slides and cover slips, a pipette, and the infusion culture. Since in a classroom of students many cultures will be collected, a comparative study of succession is possible.

The culture should be placed on the window sill so that it will receive the sunlight that is necessary for photosynthesis. Often, it is wise to place white paper around areas of the jar that are not reached by the sunlight to allow for a more even distribution of light throughout the culture. If paper is not used, many of the chlorophyll-bearing organisms will be found only in samples taken from the top film of water near the side of the jar next to the window.

After collecting, it is best to wait about 24 hours before observing the culture under the microscope. Most of the organisms will have moved to the surface of the water during this time, since dissolved oxygen is probably most abundant there. It is wise, therefore, to concentrate on observing samples taken from the surface of the water. In almost all cases, the organisms found in the surface film are the same as those found throughout the culture. Their

numbers, however, are usually the greatest at the surface. A sample consists of a drop of water taken from the culture with a pipette.

Observations of the culture should be made at least two or three times per week for three weeks, and then once a week until a stabilized stage has been reached. Observe one drop of water at a time, using the microscope. Avoid moving the culture after it has been placed on the window sill. It is also important that the same pipette be used for a particular culture at all times. After observing the culture, place the lid lightly over the jar.

It is important that accurate records be kept of the successional changes after observations have been made. A sample data sheet for recording this information is shown in Appendix I.

Culture Environment and Pond Environment

When observing the successional changes, you must remember that the kinds of life which you find in this community within a jar depend on what species you introduced at the time of collection, and what organisms were able to survive the changed conditions which were brought about as a result of confining them in an infusion culture. It is obvious that the limited space in which the organisms are now confined constitutes one environmental factor to which these organisms were not previously subjected while living in the pond. In fact, the infusion culture imposes environmental factors which are quite different from those found in a pond.

In the pond there is probably an ample supply of oxygen and a low supply of carbon dioxide at both the top and bottom. This is the result of wind action which disperses the oxygen throughout the pond

because of the currents it initiates. Living green plants are also continually using the carbon dioxide in photosynthesis and giving off oxygen as a by-product. In the pond there is also direct sunlight for a portion of the day and much temperature fluctuation from day to day.

The infusion culture, on the other hand, has a high concentration of carbon dioxide and a low concentration of oxygen, especially in areas below the surface of the water. The laboratory cultures receive little direct sunlight and usually are subjected to few extreme temperature fluctuations.

The amount of carbon dioxide present may have much to do with the kinds of organisms that occur in the culture. An indirect method of measuring the amount of carbon dioxide present is by the use of a *p*H meter or some other device sensitive enough to measure small changes in *p*H. *P*H (or hydronium ion concentration) is a measure of the acidity of the water. This method, of course, allows only for daily comparisons to be made rather than an assessment of exact amounts of carbon dioxide present.

In addition to those physical factors mentioned above, the biological factors in a pond are much different from those in the infusion culture. Many of these are a result of the difference in the space in which the organisms live. The food relationships of the pond may be different from those of the culture. The food chains in the pond are based on the green organisms which carry on photosynthesis. Since these green forms are able, through photosynthesis, to produce their own food, they are called autotrophs or self-sustaining organisms. They provide food for other organisms not

equipped to make their own food. The latter organisms are called heterotrophs. Thus, green algae and green protozoans may be eaten by rotifers and micro-crustaceans, which in turn may be eaten by still larger organisms. This type of feeding progression in which the smaller organisms are eaten by succeedingly larger ones is termed a food chain. All of the food chains of the community when taken together are called a food web.

Since light is less available in the cultures, there is less photosynthesis. Therefore, green organisms play a lesser role, and the food chains which develop are based on the bacteria (colorless plants) which thrive and multiply in connection with the decaying of the dead organic matter which the jar contains. These organisms thrive in a place where there is little light, a relatively high non-fluctuating temperature, and an abundance of dead organic matter. Bacteria, in turn, provide a food source for a multitude of organisms, especially non-green protozoans, as well as set up changes in other environmental factors.

Pond Infusion Succession Study

During the summer of 1962, the writer studied the invertebrate succession in pond infusion cultures (Cole:1963). The observations were started on June 13 and ended July 25. In this study, the observable succession seemed to occur in what might be considered three stages.

The first stage, which was short lived, lasted about a week. It was during this time that the turbidity (or cloudiness of the water) was relatively low, allowing for the abundance of green organisms

which depend upon light for their carrying on of photosynthesis. Since the turbidity was low, light penetrated more readily. Because the cultures were still quite "young", this period was characterized also by the presence of many of the larger micro-metazoans which include insect larvae, snails, annelids, and crustaceans. These larger metazoans died within a short time, probably because of the limited amount of space, the lack of available oxygen and food, and the fact that some of the animals were undergoing metamorphosis.

Following this initial stage, there was a great increase in bacteria, feeding upon the decay of the dead organic matter which was included when the culture was made, the dead bodies of the larger green plants, and the dead metazoans. The increase of bacteria caused an increase in turbidity and, hence, the death of many of the smaller green forms which were dependent upon light for photosynthesis. This provided even more food for the bacteria and, likewise, the turbidity was increased even more.

Another effect which bacterial decay had on the cultures was to increase the amount of carbon dioxide, hence, to increase the acidity.

The increase in bacteria created an ideal environment for bacteria-eating organisms. These were largely cilates (Paramaecium, Urocentrum, Colpidium, and Halteria, as examples), and their presence initiated the second stage characterized by dense populations of ciliates. The fact that there were such dense populations of ciliates may also have caused a crowding out of other organisms that might have been prevalent at this time.

The great numbers of ciliates, in turn, provided a food source for carnivorous organisms. Two common predators of protozoans are

Dileptus and Didinium, which are themselves ciliate protozoans. During this stage these carnivorous protozoans multiplied to a sufficient extent, due to the abundant food supply, that the chances of observing them in a sample drop of water were relatively good. This predator-prey relationship was another environmental factor which had an effect upon the population density of the bacteria-feeding ciliates.

Many of the common ciliates seen at this time where those which seemed to thrive in a high free carbon dioxide concentration. These ciliates included: Urocentrum turbo, Colpidium colpoda, Dileptus gigas, and Spirostomum teres.

During this period the population densities of the various ciliates fluctuated, probably as a result of over-crowding and the accumulation of nitrogenous wastes (usually in the form of ammonia) which may have been toxic to many of the organisms.

This stage lasted four to five weeks. The numbers of bacteria, however, were gradually reduced and, consequently, so were the numbers of ciliates and other organisms dependent on either bacteria or ciliates for food.

This reduction in numbers of ciliates and bacteria initiated the third stage which was characterized by a decreased number of protozoans and an increase in filamentous algae and rotifers. The turbidity during this time also became relatively low. It is this stage, or at least the latter phase of it, that constitutes a stage of dynamic equilibrium, and may be compared to the climax community. This community within the jar is then equivalent to a "balanced aquarium", but one in which the interacting organisms are all at the microscopic or near-microscopic level of size.

This balanced condition of the community was not the most prosperous. In fact, it was conspicuously less prosperous, when judged by the criteria of numbers of organisms and activity, than any of the previous stages. In the development of the new balanced state many of the organisms of the pond community which were included in the culture became extinct and no new ones were added.

This has been a general view of the succession in the infusion culture studied at this time. You must remember that succession is a gradual process, and that describing changes that occur as particular stages may often lead to erroneous conclusions. Defining the stages merely serves as a means of comparison.

You must also keep in mind that the plants and animals mentioned in the above study are by no means all of those organisms which you will see in the culture.

In observing the general succession of the culture you should also note the influences of the environment on particular organisms. For example, you may follow the population fluctuations of Paramaecium, a common ciliate, and try to deduce reasons for these fluctuations.

Organisms Seen In the Culture

It is necessary when studying succession in the infusion culture that you have at least a superficial basis for recognizing the organisms that you see. Although it is not within the scope of this unit on succession to classify organisms to species, you must remember that different species within the same genus may react quite differently to environmental changes. Perhaps, the best identification

key to this study is that by Eddy and Hodson (1961). Microscopic fresh-water organisms are mostly world-wide in distribution, so this reference will apply outside the geographic area for which it was written.

Most of the organisms that you will observe will be microscopic in size. These include: green and blue-green algae (both filamentous and single-celled), bacteria, protozoans, rotifers, flatworms, gastrotrichs, micro-crustaceans, insect larvae, aquatic annelids, and possibly the fresh water coelenterate *Hydra.*

Of the macroscopic organisms that you will probably see, the most common ones are: insect larvae, snails, water mites, and the aquatic angiosperm *Lemna* (duckweed).

The kinds of protozoans found in the cultures may be grouped into three classes depending upon their means of locomotion. The first class moves by means of one or more whip-like projections called flagella which usually protrude from the anterior part of the body. In most cases, the movement of the flagellum causes the organism to move in a zigzag fashion.

The second class of protozoans move by means of a great many short, hair-like extensions called cilia. These may be distributed over the entire body surface or concentrated in certain areas. These cilia function much in the same way as do oars on a boat. Ciliates usually move quite rapidly, and to observe them in detail and identify them often requires the addition of a viscous substance (usually methyl cellulose) to slow them down. Observations under natural conditions, however, are necessary for determining habits and habitat relationships.

The third group of protozoans move by means of pseudopodia which appear to be finger-like projections of the body.

The common flagellates (those that move by means of flagella) often seen in cultures may be either green or colorless. The green, or autotrophic, forms are capable of producing their own food. The colorless forms, called heterotrophs, must rely on an outside food source. In the absence of light, however, some of the green flagellates may lose their color and become heterotrophs.

The term "monad" is used to include an ecological group of minute, colorless, flagellates belonging to the genera Monas, Phytomonas, Chilomonas and Bodo.

In studying the organisms found in the cultures you should learn something about their nutrition because this is, perhaps, the greatest single factor in determining their presence in the culture. It will also be easier to recognize food chains as they exist in the culture if you understand the food habits of the organisms. Table 1 describes the food habits and relative sizes of some of the organisms that you are likely to see.

Table 1. Food habits and approximate size range of organisms seen in pond infusion cultures. The size range when observed under low power (10_x) with a field diameter of 1600 microns is given. (Key to food symbols: A-algae, B-bacteria, bm-bacterial metabolites, P-protozoa, d-non-living debris: Capitalization indicates a primary food source.).

Organism	Food Habits	App. Size
Green flagellates		
Chlamydomonas	autotrophic	15-25μ
Euglena	autotrophic	35-400μ
Volvox	autotrophic	320-500μ
Phacus	autotrophic	35-150μ
Colorless flagellates		
monads	B, bm	10-40μ
Peranema	A, P	20-70μ
Ciliates		
Paramaecium	B, a, d	120-350μ
Urocentrum	B, d	50-80 μ
Colpidium	B	50-70μ
Cyclidium	B	25-30μ
Halteria	B, a	25-30μ
Spirostomum	B, d	1000-3000μ
Stentor	B, A, P	800-2000μ
Vorticella	B, a, d	50-150 μ
Stylonichia	B, A	130-160μ
Dileptus	P	200-450μ
Euplotes	B, A	80-100 μ
Oxytricha	B	130-160μ

Organism	Food Habits	App. Size
Coleps	P, a	80-110μ
Didinium	P	80-200μ
Lacrymaria	P	500-1200μ
Loxodes	B, d	200-700μ
Rhizopods		
Arcella	omnivorous	30-150μ
Difflugia	omnivorous	200-230μ
Euglypha	omnivorous	125-160μ
Amoeba	omnivorous	200-600μ
Actinophrys	omnivorous	40-70μ
Metazoans		
Rotifers	omnivorous	250-400μ
Micro-crustaceans		
Cladocerans	omnivorous	1000-5000μ
Copepods	omnivorous	1000-5000μ
Ostracods	omnivorous	800-3000μ
Flatworms	usually invertebrates	macroscopic
Nematodes	various	400-2000μ
Annelids (oligochaetes)	usually omnivorous	macroscopic
Insect larvae	various	macroscopic
Bettles	usually carnivorous	macroscopic
Snails	usually herbivorous	macroscopic

Study Guide

The following questions are meant to serve as a guide in your study of succession. In answering these questions, it is wise to consult a variety of references.

1. How might turbidity play a part in controlling the population of green protozoans?

2. What influence do you think increased temperature might have on the succession? Explain.

3. How might the number of organisms (population density) influence the changes in the culture?

4. How does the presence of bacteria influence the changes in the culture?

5. What are the relationships between food supply and size of populations in the culture. Cite examples.

6. Account for the death of many of the larger metazoans and filamentous algae in the early stages of the culture.

7. What are some of the environmental factors (both physical and biological) which play a part in the succession of the pond infusion culture?

8. What organisms, if any, were present throughout the succession? Suggest reasons for this.

9. Construct a food chain using those organisms seen in the culture.

10. Cite an example of succession other than that observed in the culture. Where have you observed it?

11. What are some characteristics of a climax community? Of a pioneer community? What stages in the infusion culture are comparable to these? Why?

12. If all environmental obstacles were removed from a population of particular organisms except food availability, what do you think would be the long range results?

Appendix 1. Sample Data Sheet

Date of observation: Culture number:

Number of days since culture was collected:

Appearance of culture water: Very turbid ____ Moderately turbid ____

Clear ____

List organisms by name or description and record as indicated.

Organism	Abundant	Moder. Abund.	Present but not Abundant
Plants:			
Microscopic Animals:			
Macroscopic Animals:			

Possible reasons for appearance of the abundant organisms:

Comments:

References for the Student

Buchsbaum, Ralph and Mildred Buchsbaum. 1957. Basic ecology. The Boxwood Press.

Cole, James E. 1963. Preliminary investigation of succession of invertebrates in pond infusion cultures. School Science and Mathematics. April. Vol. 63. No. 4. pp. 325-331.

Cooper, Charles F. 1961. The ecology of fire. Scientific American. Vol. 204. No. 4. pp. 150-160.

Cooper, W. S. 1926. The fundamentals of vegetative change. Ecology. Vol. 7. pp. 391-413.

Dice, Lee R. 1955. Natural communities. University of Michigan Press. Chapter XVI.

Eddy, Samuel and A.C. Hodson. 1961. Taxonomic keys to the common animals of the North Central States. 3rd Ed. Burgess Publ. Co., Minneapolis. i-iv+162 pp.

Mohr, Carol O. 1943. Cattle droppings as ecological units. Ecol. Monog. Vol. 13. pp. 275-298.

Storer, John H. 1953. The web of life. The New American Library. Signet Key Book.

Selected List of Films and Fiom Strips

The following films and film strips will supplement the laboratory study and aid in an understanding of succession.

Films:

Succession-From Sand Dune to Forest. 20 min-color-sound. Encyclopedia Brittanica Films, Inc.

The Grasslands. 20 min-color-sound. Encyclopedia Britannica Films, Inc.

The Temperate Deciduous Forest. 20 min-color-sound. Encyclopedia Britannica Films, Inc.

Life In a Drop of Water. 11 min-color-sound. Coronet Films, Chicago.

Protozoa: One-celled Animals. 11 min-color-sound. Encyclopedia Britannica Films, Inc.

What is Ecology? 11 min-color-sound. Encyclopedia Britannica Films, Inc.

Filmstrips:

Principles of Biology Series Set. Part 3- Interdependent Living Things. Part 7- Effects of Environment. McGraw-Hill Book Co., New York.

Chapter IV

UTILIZATION OF THE TEACHING UNIT

I presented the preceding unit on ecological succession in pond infusion cultures to two classes in a biological science course for non-biology majors at Western Michigan University. One class studied the infusion culture succession in the latter part of October, 1962, and the other class studied the succession in the last two weeks of May, 1963. In both cases, the students were provided with prepared slides of some of the organisms which they were likely to see in the cultures that they collected. This was done before the actual observations of the infusion cultures took place so that they could become more adept at identifying microscopic organisms and handling the microscope.

Following this, I gave a brief explanation of community ecology and succession. Examples of succession, other than that which occurs in the pond culture, were stressed.

Each student was asked to keep records of the organisms he had observed while making his study. A data sheet, as shown in Chapter III, Appendix 1, was used to record these results. All of the observation and sampling procedures, as described in Chapter II, were carried out. Observations were made every Monday, Wednesday and Friday for a two week period.

After each day's observations, the data collected by all of the students were tabulated and made available to the class so that the results could be discussed during the following class meeting.

It was during these discussions that the students were expected to deduce reasons for the presence of the organisms they had observed.

Toward the end of the unit, old cultures which had stood for as long as a year were made available so that the students could observe the community in the infusion culture which might be compared to the climax community of successions outside of the laboratory. It was pointed out by the instructor that the community within the "old" culture was similar to the community within a balanced aquarium.

Usually, the students were asked to observe the cultures for a period of about forty-five minutes to an hour. This period corresponded to the length of their apparent interest span. The remainder of the two-hour laboratory period was taken up with analysis and summary of the laboratory experience under guidance of the instructor.

Perhaps the greatest aid to this study is that the students be adequately prepared to identify at least the kinds of organisms that they are most likely to see. This requires a somewhat detailed lecture dealing with the recognition of algae and invertebrates prior to attempting the microscopic work with living materials. When this has been done, the observations apparently become more profitable and the data gathered from them seem far more reliable.

The reactions of students to the unit were carefully observed and systematically noted. Many of their reactions were of an informal nature, taking place in connection with questions asked and answered in class, and in brief conversations following the laboratory period.

In general, the reactions to the study of succession through the use of pond infusion cultures were favorable. When making their first

observations, most of the students seemed fascinated with the variety of microorganisms seen. In succeeding periods they began to take an active part in comparing the succession observed in the cultures to the sucessions which go on outside the laboratory.

After the unit had been presented to the students, a test was given to try to evaluate their understanding of succession. A copy of this test follows.

This test was designed to give the students some latitude in answering the questions. In most cases, a knowledge of principles rather than facts was necessary in answering the questions correctly.

The test was graded on the basis of one hundred possible points. Two classes were given this examination. The results are summarized in Table 2. Using the t-ratio, or Student's t, no significant difference between the mean scores of the two classes at the 10 per cent level was noted.

Test on Succession

Multiple choice (3 pts. each):

Choose the best answer of the four or five foils and circle the letter preceding it.

1. Which one of the following protozoans possessed both plant and animal characteristics?

   a. *Paramaecium*
   b. monads
   c. *Euglena*
   d. *Amoeba*
   e. None of the above

2. One characteristic that separates plants from animals is:

   a. that they take in CO_2 and exhale oxygen in respiration.
   b. that they are all green.
   c. that they are all stationary.
   d. none of the above
   e. all of the above.

3. The balanced aquarium is most like:

   a. the primary community of an infusion culture.
   b. the stage of ciliate dominance in an infusion culture.
   c. the early stages of the culture.
   d. all of the above.
   e. none of the above.

4. The whole series of communities that leads to a climax is called

   a. a seral stage.
   b. a food chain.
   c. a sere.
   d. a food web.
   e. none of the above.

5. The term monad refers to:

   a. small ciliates.
   b. any small organisms.
   c. small, colorless, flagellates
   d. a colony of stentors
   e. none of the above

Matching (3 points each):

_____1.	rotifer	a.	eats just plants
_____2.	Arcella	b.	produces own food
_____3.	autotroph	c.	common rhizopod
_____4.	colorless plants	d.	ostracod
_____5.	heterotroph	e.	bacteria
		f.	relies on outside food source
		g.	common metazoan
		h.	a vertebrate

Short essay: (5 points each):

1. List specific ways in which an increased temperature might speed up the succession in an infusion culture.

2. Define carnivore, herbivore, and omnivore and cite one example of each which is found outside of the infusion culture.

3. Define succession.

4. Differentiate between biological environmental factors and physical environmental factors.

5. How might bacteria cause a decrease in the pH of the water in an infusion culture?

6. How might turbidity play a role in the succession of organisms in the infusion culture?

7. If all environmental obstacles, other than food availability, were removed from a deer population, what would the long range results be? Explain.

8. Cite an example in the pond infusion study which parallels the above situation (question 7).

9. Support this statement: "The environment is an important screening mechanism in determining what organisms will survive."

10. (25 points) For the organisms listed below, give one environmental factor (for each organism) that probably accounts for its presence in the infusion culture. Explain how the factor increased the population size of the organism.

    a. Chlamydomonas or Euglena-

    b. Paramaecium-

    c. monads-

    d. Didinium or Dileptus-

    e. bacteria-

Table 2. Results of test given to two general education biology classes on the subject of ecological succession.

	1st class	2nd class
Number of students:	31	29
Range:	62	62
Median:	72	70
Mean	68	67
Frequency Distribution:		
	f	f
97-	0	1
92-96	1	0
87-91	2	2
82-86	4	2
77-81	3	4
72-76	6	4
67-71	6	3
62-66	2	1
57-61	0	3
52-56	0	2
47-51	1	3
42-46	2	3
37-41	2	1
32-36	2	0
	$\Sigma f = 31$	$\Sigma f = 29$

Chapter V

SUMMARY AND CONCULSIONS

The purpose of this study is to develop a laboratory unit for a general education biology course on the subject of ecological succession. To do this, pond infusion cultures were chosen as the illustrative materials because (1) they are inexpensive, (2) the materials necessary to carry out this study of these cultures are readily available, (3) there is a period of short duration from the beginning to the stable community in the cultures, and (4) the succession which goes on in the cultures may be compared to other successions which take place outside of the laboratory.

The basic laboratory research for this unit was carried out by the writer (Cole:1963) in the summer of 1962. It dealt with succession of microscopic and near-microscopic invertebrates in a series of pond infusion cultures.

The unit was presented to two biological science classes at Western Michigan University in an attempt to evaluate its usefulness as a means of teaching succession. After presenting the unit to the students, they were tested over the factual material of the unit and the concept of succession.

The results from the test given to the students of the two classes indicated that they had an adequate knowledge of the process of succession and the mechanisms (the biological and physical factors) involved in bringing about the replacement of one community by another.

Also, my informal observations of the student's reactions toward this unit, as well as their comments, indicated that the pond infusion cultures may be useful "tools" in the study of succession.

Literature Cited

Buchsbaum, Ralph and Mildred Buchsbaum. 1957. Basic ecology. The Boxwood Press. Pittsburg. vii+192 pp.

Cole, James E. 1963. Preliminary investigation of succession of invertebrates in pond infusion cultures. School Science and Mathematics. Vol. 63, No. 4. April. pp. 325-331.

Downing, Elliot. 1932. The course of study in biology. National Society for the Study of Education. Thirty-first Yearbook, A Program for Teaching Science. pp. 221-222.

Eddy, Samuel. 1928. Succession of protozoa in cultures under controlled conditions. Trans. American Micros. Society. Vol. 47. pp. 283-319.

Eddy, Samuel and A. C. Hodson. 1961. Taxonomic keys to the common invertebrates of the North Central States. 3rd Ed. Burgess Publ. Co., Minneapolis. i-iv+162 pp.

Martin, Edgar. 1948. The major principles of the biological sciences of importance for general education. Selected Science Services. U.S. Dept. of Health, Education, and Welfare. Circular No. 38. pp. 1-34.

Noland, Lowell E. 1925. Factors influencing the distribution of fresh-water ciliates. Ecology. Vol. 5. pp. 437-452.

vanNiel, C.B. 1955. Natural selection in the microbial world. Journal of General Microbiology. Vol. 13. pp. 201-217.

Washton, Nathan S. 1952. A syllabus in biology for general education. Science Education. Vol. 36. pp. 227-237.

Woodruff, L.L. 1912. Observations on the origin and sequence of the protozoan fauna of hay infusions. Jour. Exp. Zool. Vol. 12. pp. 205-264.

Woodruff, L.L. 1911. The effects of excretion products of *Paramaecium* on its rate of reproduction. Jour. Exp. Zool. Vol. 10. pp. 555-581.

Bibliography

1. Allee, Emerson, Park, Park, and Schmidt. 1950. Principles of animal ecology. W.B. Saunders Co. pp. vii + 837.

2. Bullington, Robert Adrian. 1952. The subject-matter content of general education science courses. Science Education. Vol. 36. No. 5. pp. 285-292.

3. Dice, Lee, R. 1955. Natural communities. University of Michigan Press. pp. v + 547.

4. Dressel, Paul L. 1960. How the individual learns science. Rethinking Science Education. The Fifty-ninth Yearbook of the National Society for the Study of Education. University of Chicago Press. pp. 39-62.

5. Dressel, Paul L. and Lewis B. Mayhew. 1954. General education: explorations in evaluation. American Council on Education. Washington, D.C.

6. Edmondson, W.T. (Editor). 1959. Fresh-water biology. By Henry Baldwin Ward and George C. Whipple. John Wiley and Sons, Inc. 2nd Ed. New York. pp. xvii + 1248.

7. Haun, Robert Ray. 1960. Science in general education. Wm. C. Brown Co., Inc. Dubuque, Iowa. pp. v + 291.

8. Hynes, H.B.N. 1960. The biology of polluted waters. Liverpool University Press. pp. v + 202.

9. Jahn, T.L. 1949. How to know the protozoa. Wm. C. Brown Co. Dubuque, Iowa. pp. 1-234.

10. Pennak, Robert W. 1953. Fresh-water invertebrates of the United States. The Ronald Press. N.Y. pp. vii + 769.

11. Schultz, Beth. 1961. The use of ecology in teaching science to children. Science Education. Vol. 45. pp. 96-113.

12. Unger, W.B. 1931. The protozoan sequence in five plant infusions. Trans. American Micros. Soc. Vol. 50. pp. 144-153.

13. VanDeventer, W.C. 1955. Designing a basic science course for a specific college situation. School Science and Mathematics. Vol. 55. pp. 91-103.

14. _______________. 1958. A simplified approach to the problem of scientific methodology. School Science and Mathematics. Vol. 58. pp. 97-107.

15. _______________. 1955. The teaching of basic premises as an approach to science and general education. Science Education. Vol. 39. No. 5. pp. 389-398.

16. _______________. 1960. Science for general education in the college. Rethinking Science Education. The Fifty-ninth Yearbook of the National Society for the Study of Education, Part 1. University of Chicago Press. pp. 97-111.

17. vanNiel, C.B. 1949. The "Delft School" and the rise of general microbiology. Bacteriological Review. Vol. 13. No. 3. pp. 161-174.

18. Washton, Nathan S. 1952. Teaching biology for general education. Science Education. Vol. 36. pp. 237-240.