have the competitive advantage in such a situation.

(b) **Plant pathogen**

Amongst the many actinomycetes present in soil only a few act as plant pathogens. The most common pathogen is *Streptomyces scabies* which is responsible for potato scab disease. *Streptomyces alni* is associated with *Alnus glutinosa* (alder) and the organism forms root nodules which are now considered to be associated with nitrogen fixation. This aspect has been dealt with in a separate chapter.

(c) **Antibiosis**

Some species of *Streptomyces* are capable of synthesizing antibiotics. On account of this unique characteristics, the *actinomycetes* group as a whole has attracted the attention of many workers. Almost three-fourth of the *Streptomycete* isolates may produce antibiotics. The amount of antibiotics being produced in soil is not of much significance, but in the laboratory, when the conditions are optimal large amounts of antibiotics are produced. In soil, the situation is not that conducive due to limited nutrient availability and competition amongst the soil microorganisms. Though the amount detected in soil is very small it can exert a localized inhibitory effect. This behaviour in the root region has a special significance.

After the discovery of antibiotics, continuous screening of the actinomycetes and fungi of soil is done to assess their antibiosis activity. Actinomycetes are responsible for the synthesis of certain important antibiotics like streptomycin, chloreamphenicol, chlorotetracyline, oxytetracyline and cycloheximide.

(d) **Microbial equilibrium**

Besides the production of antimicrobial metabolites, few species of *Streptomyces* liberate extra-cellular proteases which lyse bacteria (Born, 1952). This has importance in the microbiological equilibrium in soil. Generally, in natural soil, there is a well balanced and typical microflora. The various factors which characterize the particular soil, maintain the microbial equilibrium. A decrease in the population of actinomycetes, particularly of *Streptomyces*, has been reported in cultivated fields of barley by Rehm (1960). However, in most cases such changes are short-lived and temporary and the original equilibrium is soon restored. Similarly with amendment of soil by fertilizers and organic manures, such changes are noticed but sooner or later equilibrium is again achieved. In all such cases the role of actinomycetes is of equal importance.

ALGAE

In contrast to bacteria, fungi and actinomycetes which are generally heterotrophs, the algae group as a whole being mostly autotrophic, occurs predominantly on

recolonization of the soil by higher plants.

As indicated earlier the most important function of soil algae, particularly of certain members of cyanophyceae, is to fix atmospheric nitrogen. A large number of cyanophycean members can fix atmospheric nitrogen symbiotically or non-symbiotically. This aspect will be dealt with in a separate chapter.

Protozoa

The phylium protozoa is represented by primitive, unicellular organisms, which vary in size from several microns to one or more centimeters. Though the microorganisms discussed earlier constitute the major population of soil and are categorised in microflora, protozoa being representatives of the animal kingdom are in no way less important in soil ecosystem. Along with soil microflora, this group plays an important part in the ecological and biochemical processes operating in soil. Normally cells of protozoa are devoid of chlorophyll, but interestingly there are a few transitional genera which resemble algae and are provided with chlorophyll pigments. Furthermore, there are certain genera which are claimed both by plant and animal experts as being in their domain. The animal representatives grouped in protozoa exhibit the simplest form of animal life.

Two prominent stages are encountered in the life cycle of protozoa - an active phase in which the organism feeds, multiplies and leads an active life and a resting or cyst stage. The latter stage is usually observed when conditions are unfavourable. The cell then secretes a thick covering around itself and forms a cyst. Resting or cyst stage helps the organisms to withstand unfavourable conditions and on the return of normal conditions the cyst germinates to give rise to an active cell. The normal mode of reproduction in protozoa is asexual. The mother cell divides longitudinally or transversally into two halves which are called daughter cells. In certain protozoans sexual reproduction has also been reported. The process of sexual reproduction is very simple; morphologically similar mating cells fuse and exchange of genetic materials takes place between the two. After the exchange, the two cells separate and new individuals emerge.

Protozoa are of wide occurrence in different types of soil. Like other soil organisms they are also recorded in almost all sorts of soil. Variation in the density and composition of protozoa is quite common in different soil types. Certain soils may contain a few types only whereas others may exhibit a wide variety of them. Similar ecological niches harbour different faunas as a result of accidents of zoogeography.

Protozoan species are generally defined on morphological grounds. Mode of locomotion forms the basis of classification of protozoa. Some protozoa are provided with one or more long flagella, others have short hair - like cilia and there is a third group where movement is by means of temporary organelles known as pseudopodia. Some of the parasitic genera on the other hand lack specialized structures for movement. The following are the five major classes identified in the phyllum protozoa.

parasitize only specific plants, animals or microorganisms. Viruses normally grow and multiply only when they are inside the host body. They do survive outside the host for varying periods but no activity is noticed during the period. Certain plant viruses like those responsible for mosaic disease of wheat, oats and tobacco and big vein disease of lettuce, persist in soil when the respective host plants are harvested. In a true sense, such viruses are not a native resident of soil and they simply live in the soil and retain their infective capacity as long as the host crop is not available. The period thus spent in soil may be for a year or little more. There are reports that certain animal and human viruses also survive in soil and retain their infective ability for some time. By and large the soil is more rich in bacterial and actinomycetes viruses i.e. bacteriophages and actinophages. Morphologically bacteriophages possess head and tail like structures. The diameter of the bacteriophage normally does not exceed 0.05 to 0.10 μ and the tail which is somewhat longer and quite narrow measures approximately 0.2 μ in length.

Viruses, as stated above, being submicroscopic are recognized by the symptoms they induce in the host. However, this recognition is possible only for macroscopic hosts which can be seen with the naked eyes. In case of microorganisms it is not easy to see the symptoms even under light microscopes. Indirect tests are adopted for the detection of bacterial and actinomycetes viruses. This can be done by growing the host on suitable nutrient media, on solid media the appearance of plaques or in liquid media the clearing of turbid cell suspension are indications of the presence of viruses within the inoculated host. The phages may then be spotted and later inoculated on cultures of susceptible host and allowed to grow. The phage particles can then be separated and purified by filtration and high speed centrifugation. Following this, the presence of bacteriophages can be demonstrated in a soil sample. A sample of soil may be inoculated with the host bacterium and incubated for 24-48 hrs. A small quantity of the treated sample is then added to a nutrient medium previously inoculated with the host and incubated again. The lysis is then clearly observed in the medium of the host cells. The suspension is then passed through a sterile bacteriological filter and the filtrate tested for its capacity to lyse a fresh growing microorganism. Using the technique bacteriophages of *Agrobacterium*, *Pseudomonas*, *Rhizobium*, *Streptomyces*, *Azotobacter* and *Nocordia* have been demonstrated in soil.

In soil, the bacteriophages infect bacterial cells and through the tail end, the content of the former is injected into the latter. Inside the bacterial cells the injected particle of the bacteriophage multiplies rapidly and produce a number of daughter cells. Such a type of bacteriophage is known as lytic or virulent. In most cases the daughter cells of bacteriophage are released after the death of the host cell and they form the fresh stock for further infection of healthy bacterial cells and the process continues resulting in the destruction of a large number of bacteria. Sometimes, however, the daughter bacteriophage cells are not immediately released out side the bacteria, rather they are retained with in the

has some advantage over the dilution plate method in that the presence of the microorganisms *in situ* is recorded. However, it is extremely difficult to identify all the microorganisms seen on the stained Rossi-cholodny slides. Also, inspite of all the care being taken there is a great possibility of dislodging a few organisms from the slides during the operation. Through this method, however, the presence of clusters of bacteria in the root region and an abundance of fungal mycelium too have been demonstrated.

(c) **Direct observation**

Linford (1940, 42) used glass observation boxes for the direct observation of rhizosphere microflora. Krassilinkov (1958) described a method in which plants were grown on glass plates which are mounted in such a way that the roots spread over the glass leave their "imprints" on the glass. Microscopic slides are placed on the inner surface of the glass plate to facilitate the microscopic observation. These are removed at regular intervals for observation. Profuse microbial development on the surface of roots, between root hairs and some distance away from them can be demonstrated by this technique.

(d) **Impression slide technique**

The technique was designed by Brown (1958) and extensively used by Parkinson (1958). Microscopic slides are thinly coated with adhesive material like nitrocellulose in amylacetate and are pressed against freshly collected root samples containing adhering rhizosphere soil. After sometime, when the rhizosphere soil gets stuck to the slides they are removed carefully, stained and examined for rhizosphere microorganisms. The difficulty faced with this technique as in the case of the Rossi-Cholodny method, is the proper identification of the organisms. Furthermore, the amount of soil screened for the microorganisms is not definitely known.

Microbial population in the rhizosphere : A vast microbial population has been noticed on the surfaces of roots, root hairs and in their vicinity. Bacteria are generally localized in colonies and chains of individual cells. Filamentous fungi and actinomycetes though frequently observed in the rhizosphere are not that numerous. Among the protozoan, flagellates and large ciliates are conspicuously present in the water films on root hairs and on the epidermal tissue.

It has generally been noted that Gram-negative, non-spore- forming bacteria are stimulated to develop in rhizosphere soil. *Agrobacterium radiobacter* and *Pseudomonas* have been found to occur abundantly. In fact, it has been reported that the latter constitute 40-50% of the bacterial population of some rhizosphere (Rouatt and katznelson, 1961). *Mycobacteria* and *Corynebacteria* are other important genera of many rhizospheres. Most of the studies in the rhizosphere indicate that motile forms, chromagenic forms, ammonifiers, denitrifiers, gelatin liquefiers, forms giving an acid or alkaline reaction with glucose-peptone media and