COURSE CODE: MCB 306

COURSE TITLE: MICROBIAL ECOLOGY

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COURSE DURATION:

COURSE DETAILS:

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COURSE CONTENT:

COURSE REQUIREMENTS:

READING LIST:

LECTURE NOTES

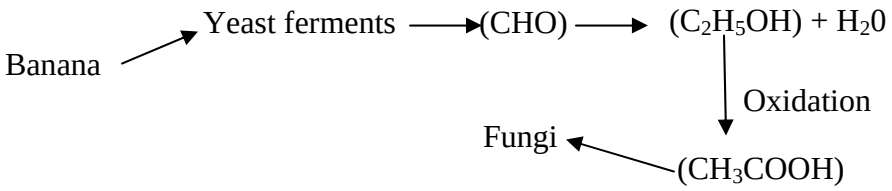
Microbial Ecology is the science that specifically examines and determines the relationship between microorganisms and their biotic and abiotic environments.

MICROBIAL COMMUNITY

- Species a group microorganisms that can interact and breed together
- Population is a group of organism that can interact with each other in an integrated manner
- Community is an integrated assemblage of microbial populations occurring and interacting within a given location called a habitat. It is the highest biological uit in an ecosystem.
- Ecosystem is the totality of the biotic and abiotic components of an environment.

Microorganism tends to live in a community, occupying their own niche in their natural ecosystem. Generally, the species composition within an environment may remain relatively stable provided there's no drastic or unexpected change in the environment. Any change in the environment/condition may lead to shift in specie composition e..g in ripening banana, there's an increase in glucose concentration which causes yeast fermentation. Yeasts ferments carbohydrate to alcohol. The alcohol is then oxidized to acetic acid which is required by a fungus for its existence. Hence a microbial community succession is put in place.

Increase in glucose concentration



Indigenous/Autochthonous: They are the original inhabitant of an environment. i.e. native organisms. e.g. *E. coli* in the GIT of man, *Staphylococcus albus* on the skin, *Streptococcus* in the mouth.

Invaders/Allochthonous organisms: They usually originate from another place. That is they are not native to the environment i.e. either in a vegetative resting stage, spore, cyst, endospore. This include organism present on our skin, on leaf surfaces which are derived and mainly from air. e.g. *Puccinia graminis* on wheat, *Mycobacterium tuberculosis* in the lungs of man, *Staphylococcus aureus o*n the skin. Usually these alien organisms cannot cope with the biological stress or the abiotic conditions in the environment.

Criteria proposed for isolation of indigenous organism

1. Repeatedly isolate the organism many times from the same environ. Repeated isolation indicates the presence of the organism in that very environment.

2. The organisms should be present in high population density in the environment.
3. Such organism should be able to make use of the nutrients in the environ when isolated in pure culture.
4. The organism should be able to tolerate environmental stress that is typical of that particular environment.

SPECIES DIVERSITY

Species diversity varies from one ecosystem to another; however the reasons for the heterogeneity are not known.

1. Diversity is usually limited to their habitat because such organism found would be limited to the environment.
2. Some habitat may be densely populated while others would have low number of organism due to fluctuations of nutrient

   Sewage water $\rightarrow$ Pond $\rightarrow$ Tap water $\rightarrow$ Distilled
3. It is not nutrient alone that determines the extent of diversity i.e. Diversity can be low despite high nutrients and at the same time diversity can be low with low nutrients.
4. Low species diversity characterized areas in the environment is due to one or more ecological factors that approach the extreme

DISPERSAL AND COLONIZATION OF MICROORGANISMS

Dispersal - (1) Active method of dispersal

(2) Passive method of dispersal

Dispersal is essential for the continuous existence of the microorganisms. The microorganism either being a fastidious or obligate parasite will still need to be dispersed from place to place.

This is important so that the species may be able to escape from detrimental or nutrient depleted environment, to continue its existence in a more favourable environment. Microorganisms are usually dispersed from centres of dispersals. This serves as the point from which the propagules are disseminated e.g. *Bacillus anthracis* found in cattle. The greater the efficiency of our dispersal mechanism, the smaller the number of propagules that will be necessary for successful dissemination of microorganisms e.g. during sneezing, a lot of microorganisms are released into the air for respiratory infections e.g. *Mycobacterium tuberculosis* these are expelled in large quantities. *Puccinia graminis* disperses large quantities of spores. Algae also disperses large quantity of spore. Transmission can be initiated as a result of some physical contact between the source of propagule and the physical carrier/vector e.g. many of the propagules will not develop in the soil unless it comes in contact with a suitable host e.g. *Bacillus anthracis,* unless it comes in contact with a ruminant. *Clostridum tetani* which is a soil-borne organism will not cause infection unless it comes in contact with an open wound.

ACTIVE TRANSMISSION

This can be either by locomotion or taxis movement. Locomotion may be by swarming, swimming or by the use of some locomotory organelles e.g. swimming in the protozoans mastigotes, ciliates and the sarcodina. Presence of flagella on some bacteria e.g. *Salmonella sp.* In fungi and algae, the production of zoospores.

Taxis movement

I) Response to light i.e. phototaxis exhibited by *Rhodospirillim sp.* It initiate movement in the presence of light.

II) Chemotaxis: Movement due to the presence of chemical substance in the environ e.g. phycomycutes

III) **Thigmotaxis:** Movement initiated by avoiding obstacles on their way.

IV) **Thermotaxis**

V) **Geotaxis**

PASSIVE METHOD

Most microorganisms are dispersed mainly by the passive method of dispersal. This is carried out through various media.

1) Air
2) Water
3) Soil
4) Biological vectors
5) Inanimate objects

Dispersal by air is very common among fungi, because many of the organisms are blown by air, once in air they are propelled.

Features

1. Possession of a means of being picked up i.e. they grow out of their substratum, which render them vulnerable to the air.
2. They are resistance to fluctuations in temperature and humidity.
3. They possess spores or other features that maintain them in the air.
    a) Release spores
    b) The spores may be powdery e.g. puffballs

The type of organism in the air varies with altitude and climatic condition. Some pathogenic organisms can be spread through the air, which may be discharge through sneezing, coughing

e.g. *Mycobacterium tuberculosis*, etc among the organisms that are carried in the dust, in human washes etc. For plant derived microorganism they can be obtained by splash.

Soil/Water

The dispersal of microorganism in water is diverse, a lot of microorganisms can be encountered. Organisms can be transfered through water from far east to the heart of Europe by the ship hull. In ground water, no photosynthesis microorganisms in them but surface water can serve as an efficient environment for photosynthesis microorganisms. For microorganism that can penetrate the layer of the soil. They can be found in septic tanks polluted water.

Factor affecting the distribution of microorganisms

1) The amount/type of microorganisms found in water depends on the presence of nutrients in the water.
2) Floating object present in water bodies may act as a vector of dispersal of microorganisms form one place to another.
3) Lateral movement during rainfall may cause dispersal of microorganisms from soil to water.
4) Discharge of industrial wastes and domestic sewage into water bodies may be a source of transmission of microorganism from water to soil.

Inanimate

1) It is possible when viable propagules comes in contact with an inanimate object.
2) Inadequate cleaning of working equipment may lead to microorganism dispersal which may affect the product.

3) Unhygienic handling may lead to contamination of the product e.g. using unsterilized materials, contaminated hospital equipment, toilet seats, agriculture implements, food and food products e.g. salmonella and shigella.

   Milk and milk product may spread: *Mycobacterium tuberculosis, Brucella*, *Streptococcus sp* Coxiella (indicator for pasteurization)

Biological Vectors

Some microorganisms would not survive on their own in the environment unless transported by biological vectors. They may act as a mean of transport while others live on the biological vector as a parasite. The biological vector may gain access into the host through the environment e.g. the honey bee may act as a good vector to *Botrytis arthrophilia* (a fungus). from one organism to the other, like can act as a vector for the transfer of Rickettsia, dog is the carrier of the Rabies virus, earthworm can be a vector for many soil heterotrophic microorganisms. snails – *Phytophthora palmivora.*

COLONIZATION

In any environs, that is colonized by microorganism, there are some that are pioneer microorganism. They are the first to occupy a site or the group that seems to appear first through they may not be sterile, but they are found to be the dominant microorganism there.

The very 1st group of microorganism can withstand very hard environ are the algae. But to be able to survive in any environment microorganism should posses some degree of invasiveness i.e. being able to utilize the nutrients that are present in the environ e.g. the blue green algae on bare rocks e.g. (*Oscilltoria*).

But in a rich environ, the heterotrophy are the usual colonizers. In the GIT of neonates, it is expected to be sterile, but along the line it is occupied by some organism ref to as the normal flora e.g. *Streptococcus, Lactobacillus* after taken some food or milk.

Three are different barriers that can be overcome, e.g. the fatty acids on the skin, enzymes in the blood, the body fluids and other barriers found on the GIT.

In plants, tree barks contains alkaloids which are antimicrobial in nature. These are produced by plant to present colonization by microorganisms also, resins, gum, quinines and quinones etc.

SUCCESSION AND CLIMAX

Environmental feedback is the situation whereby the organisms which are able to colonize an environment may be subjected to shift in specie composition. It is the modification of the habitat resulting from the presence of one or more microbial population such feedbacks may affect: the size, activities as well as survival. After the organisms has been dispersed by the air, they try to make use of the materials in the environment. Once established, they tend to annexe all the nutrients in the environment to provide for their metabolic activities.

When simple organism materials are introduced into the soil, there is always the appearance of specialized groups of organisms and they are able to utilize the materials present in the compound. The first group of the organisms may be replaced by such organism that can make use of the waste products of the pioneer organism.These organisms may not be new organisms coming in but that they can utilize the product of the primary organisms.

When an organic matter is introduced into the environment (e.g. acetic acid). There's a progressive development from the pioneer community which contain few species than a series of stages characterised by an increasing number of organisms and to a phase that typified a high

species diversity. e.g. Palm-wine when from the tree contains sucrose mainly. After the tapping it derives microorganisms from the air, gourd and during dripping. These microorganisms aid the fermentation of it to Alcohol, which when left over or for sometime it turns to Acetic acid (oxidation process) by acetic acid bacteria. This is a good example of bacterial succession (Autogenic succession).

1) **Autogenic:** It is the one in which the indigenous alter their environment in manner such that they are replaced by species better suited to the modified environment.
2) **Allogenic succession:** This is one in which one type of community is replaced by another because the habitat is altered by non-microbial factors. Such factors include physical and chemical factors.

FACTORS THAT DETERMINES SUCCESSION

1. The provision by one community of nutrient that confers an ecological advantage on that species constituting the next stage of succession.

   E.g. in pioneer community that are able to utilize the nutrients that are present in the environments. e.g. On a rock surface.

2. Making available of a population of nutrient present in sufficient supply to allow for the growth of latter population such situation may occur when the primary colonization excretes carbonaceous material that may be utilizable by other specie present in the surrounding e.g. (a) Lactic acid bacteria action on milk to produce acid. (b) Cellulose can be decomposed anaerobically by *Clostridium* specie. (c) Algae during photosynthesis can produce some intermediates products such as organic acid, simple CHO that may be ideal for other organisms in the habitat. (d) Alteration in the colonization of an inorganic

nutrients, any influence succession e.g. sudden bloom in rivers and lakes e.g. The Red sea which is due to the presence of Red algae in the sea.

3 Modification of the heterogenous substrates such that constituents favouring the growth of the main species are exposed to attack while the initial constitutes is lost to composition e.g. *Phycomyces* that are replaced by the slow growing fungi, which will utilize the product of the *Phycomyces*.

4. **Autointoxication:** This is as a result of the fact that some organisms' produces toxins against themselves e.g. the Lactic acid bacteria in the wine help in stabilizing the wine and destroy itself by its own high activity due to the high acid level.

5. **Elimination of microorganisms by physical means:** Removal of a group of microorganisms from their natural habitat, will affect the level of succession in the environment.

6 Appearance of barriers with environmental feedbacks

Usually possible in areas where there are antibodies, phytoalexins and phagocytes. They are able to contribute to allogenic succession by selectively destroying or retarding the growth of some microorganisms living in the host. Such feedback mechanisms may provide a response resulting to the displacement of the population that is sensitive to the foreign substances

7. Selective feeding by animals on microbial population

e.g. fishes that feed mainly on algae and thus others organism will be more dominant.

8. Change in temperature and light intensity

CHARACTERISTICS THAT AIDS/FAVOURS COLONIZATION AND SUCCESSION

1. Presence at the colonizable site at the right time. It is only possible with good dispersal mechanism and the organism is able to grow.
2. The organism should be able to survive for some time if conditions are not yet suitable.
3. The organism should be able to develop when good condition set its.
4. They should be able to obtain all required nutrients from the ecosystem.
5. They should have the capacity to tolerate all the ecological abiotic factors in the environment; pH, temperature, osmotic pressure, ox-red potential etc.
6. The organism should possess adequate mechanism to overcome or cope with environmental resistance that may be caused by the inanimate components of the environment.
7. Ability to overcome environmental resistance due to presence of other microorganisms. This is usually common in parasitic organisms.

AIR-MICROBIOLOGY

Air is almost an inert medium but contain a lot of numerous substances. It is made up mostly of gases: nitrogen – 75%, oxygen – 25%, carbon dioxide 0.33%, rare gases – 0.933% oxides of nitrogen about 0.000033 while the oxides of sulphur is about 0.000002%. Hydrocarbons are also present. Ammonium also contains minimum particles of solid, that largely may be of biological origin, such materials include spores from fungi, bryophytes,etc. There are

also pollen grains, cells of algae, vegetative spores of bacteria, cyst of protozoans, as well as viral particles. They are called air spora. The various types of air spora are derived from different sources.

PHYSICAL PROPERTY OF AIR

1) Variation in the amount of radiation E^+ in the air

   May influence the diversity of microorganisms present in the air at a particular period of time. There is a net transport of heat from the equator to the poles at where it will be reduced due to seasonal changes. The air spora can be generated from different sources, e.g. (1) in wheat, *Puccinia graminds* would be of a plant source (2) *Cercospora* sp (fungi). Also from forceful injection into the air e.g. the *Pilobolus, Ascomycetes, Basidiomycetes*. May be by passive discharge into the air.

2) Light intensity can also influence the air spora. i.e. some vectors of these microorganism are nocturnal while some are diurnal.

MICROBIAL INTERACTIONS

Microbes are very close to the environment. They interact with each other and their environment. Interaction between two populations may either be detrimental or beneficial. When it leads to increase in growth rate it is called positive interaction while it is referred to as negative interaction when it leads to decrease in growth rate. Interactions with increase in growth is called co-operation, such interactions lead to increase in population of the organisms. When organism co-operate with one another they may do so as a protective mechanism against a hostile environment. Negative interaction can be in form of toxic material production as well as competition for resources in the environment. Competition leads to death or decrease in final number of organisms present. There are different kinds of interactions or relationships.

Neutralism Is a situation whereby the two members are not loosing anything from the relationship. If the two populations are separated by distance. e.g. soil microorganism affecting the root and another affecting the leaf. Due to separation or gap, there's no serious interaction between the two microorganisms. Species with dissimilar nutrients requirement can exhibit neutralism. It is not a serious form of interaction.

Commensalism: It is a relationship whereby a population producing the nutrients is not affected by the presence of another organism that feeds on its products e.g. metabolites from population A are utilized by population B to produce its nutrients. Commensalism is very common among microbial populations, they are usually not obligatory. It is a unidirectional relationship .For example, *Flavobacterium brevis* secrets cysteine which *Legionella pneumophilla* can use in aquatic habitats. Also, under certain conditions, *Desulfovibrio* can supply *Methanobacterium*

with acetate and hydrogen from anerobic fermentation, using sulfate and lactate to generate these products.

Synergism: Relationship between two microbial populations in which both members benefits from the relationship. It is different from mutualism because it is not an obligatory interaction. This is because each member can produce its own food individually. It is a loose relationship because, one member can be replaced by another microorganism. It allows microbial population to perform such function which it may not be produced individually. e.g. population 1 which is able to utilize compound A and it breaks it down to compounds B but it cannot go beyond that stage, but population 2 can breakdown compound B to compound C. At the end both population 1 and 2 can utilize compound C to produce energy + CO_2. Such a co-operation is called syntrophism, when two populations provides nutrient for each other. For example the relationship between *Enterococcus faecalis* and *Lactobacillus arabinosus.*

E. faecalis requires folic acid for growth whereas *L. arabinosus* requires phenyl-alanine for good growth. When grown in medium that does not have any of the required nutrient *E. faecalis* supplies phenyl-alanine while *L. arabinosus* supplies folic acid required. Hence they have co-operated to produce their required nutrients which encourage their rapid growth rate. Also the synergistic relationship between algae and bacteria. Algae utilize light to produce organic compounds and O_2 while bacteria utilize the organic compound to produce CO_2 and vitamins which is utilized by the alga.

Mutualism: It is an obligatory interaction between two populations in which both of them benefits. It usually required close proximity between one another. The interactions are highly

selective and cannot be replaced by related species. It can be considered to be an extended form of synergism. When they exist separately the physical tolerance and metabolic activities will be different between single symbionts.

Symbiosis theoretically can lead to the production of a higher species or a balance parasitism e.g. Lichen – relationship between algae and fungi or algae and cyanobacteria. The fungus is referred to as the mycobiont and the alga as the phycobiont. The first population (algae) it is the primary producer, because it makes use of sunlight to produce nutrients for the other e.g. *Nostoc* specie. Mycobiont give protection to the phycobionts. In some instances it can give it vitamins. Lichens can be used as environmental indicators to detect pollution. Mutualistic association can be disrupted by changes in the environment e.g. accumulation of SO_2.

1) Algae and protozoans: (Paramecium and algae). Algae when ingested by paramecium photosynthesis thereby making oxygen available to the organism. But in an anaerobic environment, the oxygen produced enables paramecium to be able to survive the hostile anaerobic environment. Hence used as an environmental indicator for pollution. e.g. *Paramecium caudatum and Spirogyra* sp.

Competition represent negative relationship in both are adversely affected (survival and growth). They strive for the save nutrient or resources. The struggle thus result to decrease growth rate for both population and in some instances may bring about ecological separation of closely related population. Competition may lead to survival of the fittest (development of dominant offspring). Some factors may influence competition. Such factors may be abiotic such as light e.g. photoautotrophic organisms close to water surface are able to trap more light E+ and there is decrease in penetration of light into water (turbidity or shading of overlying water, thereby affecting the other population.

Amensalism (Antagonism)

Usually arises when one population produces inhibitory substances to the other population or the population may gain a competitive edge which is beneficial to it. Antibiosis or allelopathy are forms of antagonisms or amensalism. Allelopathic chemicals are usually produced from plants and also production of bacteriocins in milk products by Lactic acid bacteria (*Lactobacillus sp*). Oxidation of sulphur by *Thiobacillus sp* produces sulphuric acid in acid mine drainage. This will lead reduction in the pH of the water body, thereby eliminating most microorganisms and other life forms. Acid produced by microbes in the vaginal tract, prevents pathogens like *Candida albicans*. Antibiotics are substances that will kill/inhibit another microorganism at low concentration. Antibiotics are secondary metabolites. They do not accumulate in natural habitats. Examples of common antibiotics include e.g. bacitracin, polymyxin, erythromycin and streptomycin etc.

Parasitism

The first population is harmed and the parasite benefits. Usually the parasite is smaller (not in all cases). There are viral parasites of bacteria, fungi, protozoan and algae. For example bacteriophages, like the T_2, T_4 of E. coli, cyanophages that destroys Cyanobacteria blooms etc