Subject: Zoology

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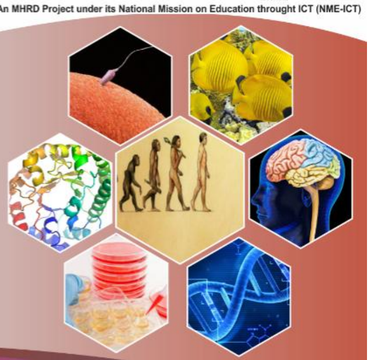

Paper : 12 Principles of Ecology

Module : 11 Population interaction- evolution, process and theories of parasitism, amensalism, and mutualism

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Description of Module	
Subject Name	ZOOLOGY
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Module Name/Title	Population interaction
Module Id	M11 Population interaction- evolution, process and theories of parasitism, amensalism, mutualism
Keywords	Evolution, parasitism, amensalism, allelopathy, antibiosis, diffuse evolution, co-evolution, mutualism

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3. Parasitism
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1. Learning Outcomes

After studying this module, you shall be able to

- Describes parasitism and the evolution and process of parasitism
- Understand the basic theories of parasitism
- Illustrate the amensalism association and its types
- The understand the process and evolution of mutualism
- Define the evolutionary relationship

2. Introduction

Single species populations involve species of similar types interacting and interbreeding within their own population. These species not only interacts with their own types but with other species from different population also. These interactions or associations can negatively or positively affect the growth and development of the population. Rarely, the type of interaction is **neutral,** where two interacting species do not effect population growth. This type of interaction is designated as 0/0 affect in a two species system. Positive interactions are those where either both or only one interacting population is benefitted.

When both the association population are benefitted, the type of interaction is called **mutualism** and designated as +/+. However, when only one type of population is benefitted forming a one sided relationship where the interaction is neither harmed nor benefitted, this type of interaction is called **commensalism** and designated as +/0. On the other hand, the other type of one-sided relationship is called as **ammensalism,** where one population is neither harmed nor benefited but the other population is negatively affected. This type of interaction is designated as -/0 types. Ammensalism is a nebulous relationship which involves chemical interactions such as **allelopathy** effect in plants and antibiosis. Other types of interactions where one population is positively affected at the expense of another population, is called as **Predation (fig.1)**. It's designated as +/-. Predation is possible in forms of **herbivory, cannibalism, parasitism and parasitoidism**. Finally, the type of interaction where both the interacting populations are being negatively affected are called as **competition**, which can be intra- or interspecific competition, and designated as -/-. The evolution, process and theories of some of these interactions are briefly discussed in this chapter.

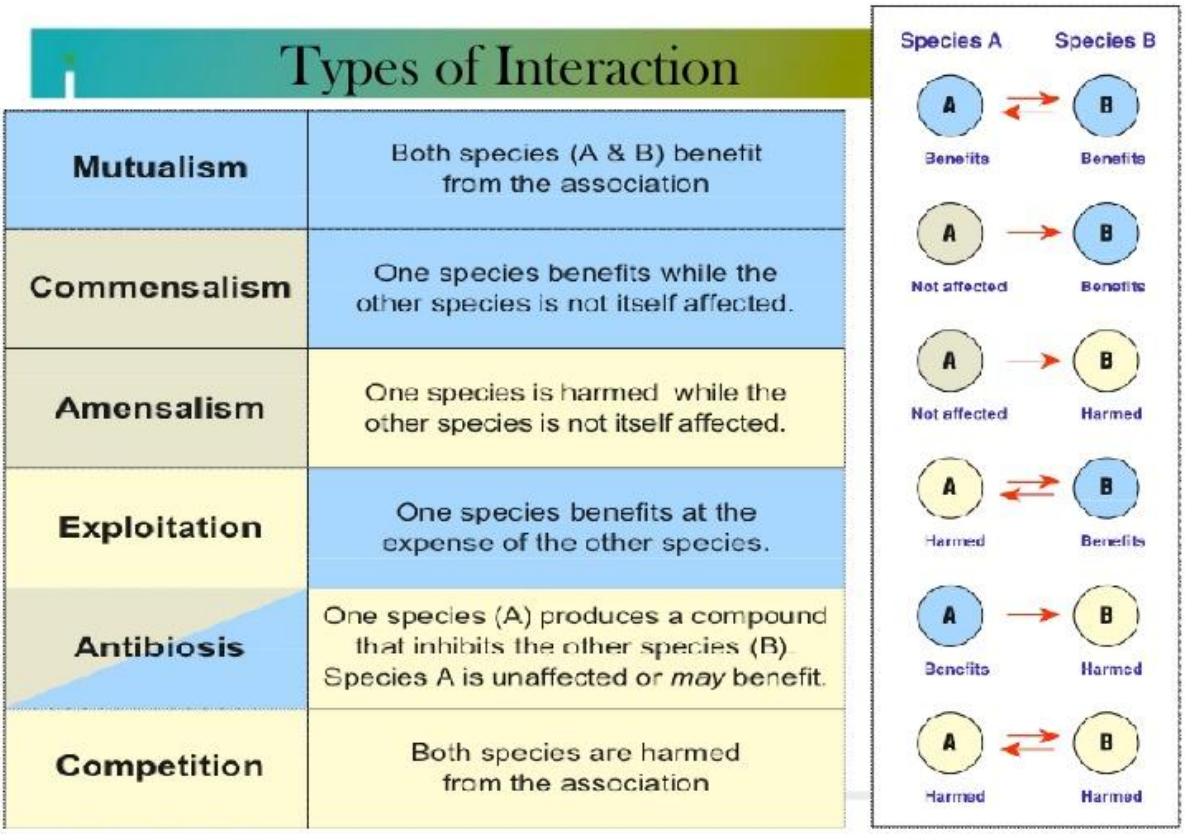

Figure 1: Different types of interactions

Species Interactions

Symbiosis = close living relationship.

Relationship	Definition	Example
Mutualism	Both species benefit, neither are harmed	Lichen is a combination of a fungus (absorbs minerals and water) and an alga (photosynthesizes). Rhizobium (nitrogen-fixing bacteria)

		in root nodules of legumes (which provide carbohydrates and space to live).
Commensalism	One or both species benefit, but neither are harmed	The remora fish attaches itself to a shark, hitches a ride, and scavenges when the shark makes a kill.
Exploitation - Parasitism	One species lives in or on and feeds off another (host)	Fleas living on a dog. Tapeworms living in a mammal's gut.
Amensalism, 0,-	One organism is inhibited, the other is unaffected	Shade from trees allows only light tolerant plants to grow.
Antibiosis, 0/+,-	One species is unaffected (or benefits), the other is harmed by a **poison/toxin** from the first	Rhubarb producing oxalic acid, which prevents other organisms from growing. Penicillium mould (blue-green, powdery) producing penicillin, which inhibits the growth of bacteria.

3. Parasitism

Parasitism is a type of predation in which an organism called as parasite (act as predator) lives on or inside the host organism (prey). It may not kill the host organism directly but the host organism may die due to the negative effects of parasitism. A parasite receives nourishment and/ or shelter from the host. It is a type of non-mutualistic and negative relationship between parasite and host organism. The association can be temporary or permanent resulting into a complex interaction.

The parasites are called **endoparasite** that lives inside the body of the host, such as *Schistosoma mansoni*, whereas those parasites that superficially attach themselves to the outer surface of host body are called as **ectoparasites** such as Head lice. Those parasites which are intermediate to both, endo- and ecto-parasite are called **mesoparasites** such as Copepods (fig.2).

Figure 2: (A) Ectoparasite; Head Lice, (B) Endoparasite; *Schistosoma mansoni*, (C) Mesoparasite; Copepods.

The parasites are classified into two types: microparasite and macro-parasite based on the size of parasites. **Micro-parasites** are small sized, rapidly multiplying with short generation time parasites which are capable of inducing immune response in host body, although the infection persists for short duration only. These parasites can travel between host by direct transmission or *via* vector and intermediate host. Bacteria and viruses are good examples of microparasites.

On the contrary, **macroparasites** are relatively larger in size and have longer generation time. They allow short duration of immune response and the infection persists for longer time. Fungi, lice, mites, parasitic worms etc are the examples of macroparasites (fig.3).

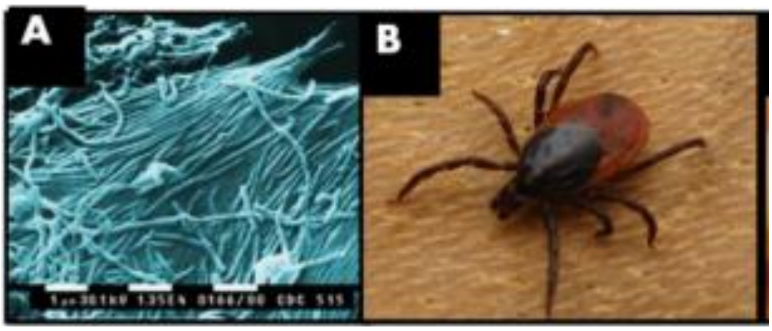

Figure 3: (A) Microparasites: Ebola Virus, (B) Macroparasites: lice

Based on the dependence of parasites on host, parasites are classified into two forms: Permanent/ full time or **facultative parasites** that are those parasites which are not necessarily live the parasitic life but under certain circumstances are capable of adapting to parasite-host relationship. **Obligatory parasites** are part-time or temporary parasites which completely or partially depend on the host organisms to complete their life cycles.

4. Evolution and process of parasitism

The parasites are extremely diverse in nature. The behaviour of parasites differs in the closely related parasites also, causing different pathologies, infecting distinct host species or infecting different tissues. For instance, a typically harmless bacteria, *Escherichia coli*, that inhabitant the human intestine, can cause different diseases in different forms such as urinary tract infections (UTI), diarrhoea, kidney bleeding, intestinal bleeding, meningitis and other disorders. Evolution is the underlying cause of occurrence of this immense diversity in parasites.

It is broadly appreciated that parasites due to their characteristic high population density and short generation time are more prone to swift evolution. Moreover, the evolution is far more immediate in parasites in comparison to their hosts. About half a century ago, the evolution of drug resistance in bacteria is the first observation of drug resistance that trigger the series of attempts to understand the cause and relevance of parasite evolution to diseases. However, the original research has achieved its fertile ground based on the application of evolutionary theory to parasites. In the recent years, the parasitology and evolutionary biology have undergone rapid advances, disabling the observers to keep shoulder to shoulder of both.

There is no obvious answer to the question of when and where these parasites arise from. All agreed to the assumption that parasites have evolved from free-living ancestors. The origin of parasitism especially endoparasites are postulated as accidental introduction of free-living forms into the hosts. The host provide new-environment conditions to the free-living forms and spontaneous mutations in these forms under the selection pressure resulted into the selection of only those mutants which have more profitable mutations that are necessary to sustain them in the new-environment. This exemplified the common concept of "survival of the fittest". To support this concept tapeworms are good examples that have efficiently adapted to parasitism. Successive occurrence of mutant forms among tapeworms leads to the establishment of tapeworm species with degenerated digestive system. These mutants form are well adapted and successful survivors that can absorb food from the new environment that consist of matrix of partially or completely digested nutrients. Thus, degenerated alimentary canal is a more efficient and advanced condition for these organisms. Furthermore, under these circumstances the digestive system, modes of locomotion, enzymatic system and sensation of tapeworm becomes adapted to parasitism. Other group of parasites have also adopted similar modifications.

Pre-adaptation

The concept of pre-adaptation is important to understand the evolution of parasites from their progenitor's free living forms. Pre-adaptation does not imply that the organisms have predestined potential of becoming parasites. It merely means that organisms in its free living forms have distinct un-manifested potential (potential to live parasitic life) in addition to its natural adaptive characteristics but never manifest these potentials (parasitic) in their free form. However, under modified environment conditions when these free-living forms accidently invade the host body, these organisms utilize their internal but prior un-manifested potential to adopt in its new environment. These pre-adaptations can be both structural and physiologic adaptations.

Examples could be seen in free living forms of nematodes found in decaying organic materials which are associated with insects, beetles etc as intestinal parasites. These nematodes were free living creatures before they were accidentally ingested by the insects/ beetles. In the gut environment, these nematodes survived attributing to its prior un-manifested internal potential of surviving in low oxygen containing environment.

5. Theories of parasitism

There are three generalizations that are suggested to be responsible for the evolution of parasitism and parasites based on the results of theoretical speculations. These generalizations are broad concepts with numerous exceptions.

a. **Fahrenholz's Hypothesis**: The present day host have common ancestors that are parasitized by the common progenitors of modern parasites. Thus, this hypothesis can be employed to seek clues about the degree of relationship between parentages of modern host to modern parasite. Parasites of wild animals are the best supporting evidence for the findings of this hypothesis. Although exceptions are there such as the close relationship between humans and domestic animals.
b. **Szidat's Hypothesis**: This hypothesis states that the more evolutionary specialized the parasites, the more specialized the host group, on the other hand, the parasite are less specialized if the host group are primitive in nature. Thus, this hypothesis seeks clues about the degree of specialization of parasite group to the phylogenetic location of the host group.
c. **Eichler's Hypothesis**: This hypothesis serves as a clue to measure the degree of relationship between parasitic diversity and host diversity. It states that the greater diversity of parasites can be harboured by the hosts belonging to large taxonomic group in comparison to the hosts belonging to limited taxonomic group.

6. Amensalism

Amensalism is a symbiotic relationship between two interacting species in which one organism restrict the growth of other individual without being affected. It's a biological association of -/0 types (fig.4). The common process of growth inhibition is the secretion of a special chemical compound by one living organism as a part of its normal metabolic process that acts detrimental to other.

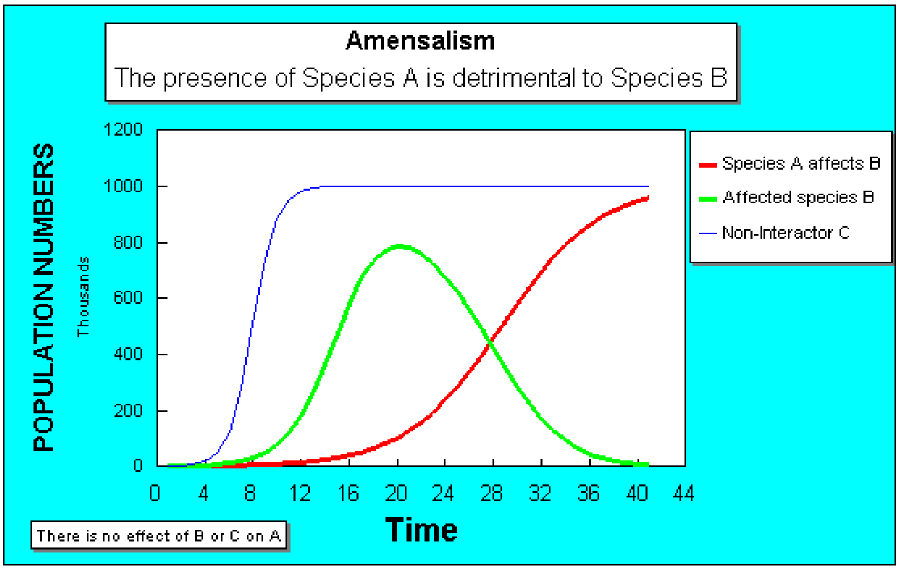

Figure 4: The graphical representation depicting the amensalism relationship between species A and B. Species A presence is detrimental to species B exhibiting amensalism association between these species, whereas the non-interacting species C is not affected by other two species.

Penicillium, a bread mold is the best example of amensalism that produces bacteria killing chemical compound called penicillin antibiotics. The biological relationship is not necessarily a symbiotic type but may represent a non intimate biological interaction between two species such as Elephants; cattle etc trample the green grass while searching for food or water resources. The cattle or Elephant is unaffected but the grass is damaged (fig.5). Although, this type of interaction is listed as 0/- types but in a symbiotic amensalism relationship the interaction is listed as +/- type as the first species which is secreting the chemical and inhibiting the other species is able to restrict competition for resources. Thus, it gains its survival.

Figure 5: Elephant stepping on flower field

In plants, it's a site specific association where one species is restricted while the other is unaffected. In plants, *Juglans nigra*, the black walnut tree is a good example for amensalism (fig.6). The neighbouring plants of black walnut tree are killed by the chemical called juglone secreted from the roots. Deserts, chaparral and many other related types of biomes have plants that depend on amensalism type of association for their survival. This type of relationship in such biomes reduces the competition among organisms for low level of nutrients in the water. Gum tree roots also secrete chemical compounds and show amensalism. Another common example is shading out of small plants under tall trees (competition for light). The trees although not directly by secreting any toxic chemical but indirectly by restricting the amount of available sunlight at the ground level prevent the adequate supply of light to the shaded plants. Thus, the forest ground covers have only shade tolerant plants that require less light for survival.

Figure 6: An example of amensalism: Black Walnut Tree (*Juglans nigra*)

Allelopathy

It's a form of interference competition among plants. One plant species produces and secretes chemical substances that prevent the growth of other plant species. These chemical substances can be simple organic compounds, or acids or bases in nature that reduces competition for space, light and nutrients. In natural communities many of the produced secondary chemical substances remains harmless but few of them influence the structure of the community with their impactful negative effects. For instance, in the world the most widely distributed vascular plant called *Pteridium aquilinum* (Bracken fern) release phytotoxins that gets concentrated in the soil's upper surface (fig.7). These accumulated plant toxins inhibit the growth of seedlings in many plants such as conifers by killing their germinating seeds. These allelopathic effects dominate large areas of ground on accumulation of dead fronds in heavy smothering overwinters.

Figure 7: An example of allelopathy: Bracken fern (*Pteridium aquilinum*)

The direct inhibition in the growth of organisms such as herbivores, soil organisms and other plants is carried out by the secretion of toxic chemical compounds. This is known as **allelopathy**. Many plants secrete toxic chemicals that are harmful to animals such as algae blooms with red, blue and green algae release metabolites toxic to fish, It's an example of a specific type of amensalism called **antibiosis**. Antibiosis is not specific to plants but simply indicate the production of toxic metabolites that are harmful for other organisms. Such as antibiotics (penicillin) released by *Penicillium* mold inhibit the growth of bacteria (fig.8). Allelopathy can be defined in various ways. Some suggested that it is only associated with the release of chemicals from plants to compete for scarce resources while others says that some plants use it as a defense mechanism. Some ecologists also consider allelopathy and antibiosis as a +/0 type of effect.

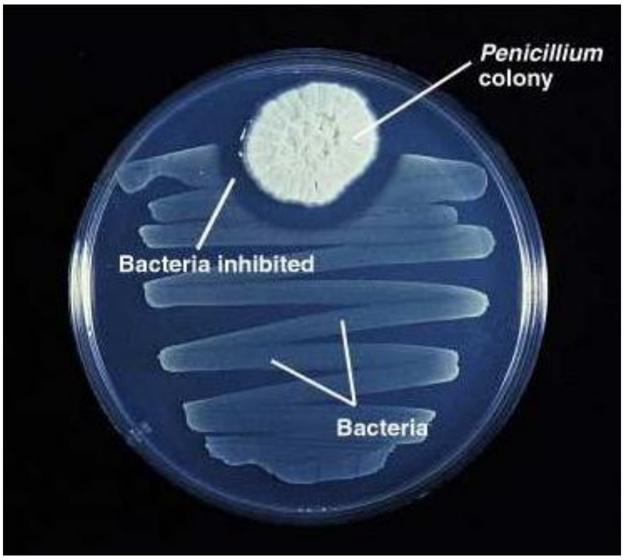

Figure 8: An example of antibiosis: *Penicillium* inhibit the growth of bacteria

7. Mutualism and evolution

When the selection pressure favours the two interacting species, the relationship is called mutualism. It's a reciprocal association between two different species that positively affect both the interacting species. For example, mutualism between flowering plants and their pollinators such as *Yucca* moth *Tegeticulaon* Yucca plant and Male *euglossine* on orchids (fig.9). In this mutual association both species increases their growth, survival and fitness. Mutualism can be facultative or obligatory, non-symbiotic or symbiotic, for more details please read module from Biology of parasitism.

Figure 9: Pollinators sharing a mutualistic relationship with the flowers. (A) *Yucca* moth *Tegeticulaon* Yucca plant, (B) Male *euglossine* on orchids

Origin of evolution

Ecologists postulated that commensal relationships, parasite-host relationship or predator-prey interactions led to the evolution of mutualism. In the beginning, one of the interacting partners enhances the stability of available resources levels for the other partner. In time the benefit gained in form of energy are ensued to the other partner and probably its activities contribute to the fitness of first partner. For instance, assume that the host-plant manifest the host parasitic relationship for its benefit, however, it has tolerance for parasitic infections indicating that the host deliberately allowed the parasite to infect itself. In time, the interacting organisms exploit one another such as in case of microrrhizal-plant mutualism. Under selection pressure, the mutualistic relationship is favoured till it become obligate symbiotic mutualism i.e. until the two interacting species become completely dependent on each other. At the final phase, under extreme selection pressure the two interacting organism starts behaving as one individual such as lichens.

The mutualistic relationship initiates with exploitation whether it is facultative or obligatory or non-symbiotic interaction between species. Insects, frugivores or birds came to the plant to consume the nectar, pollen or fruits and meanwhile accidently carried the seeds or pollen away from parent plants. These parent plants have more fit and adapted and ultimately exploit these occasionally visiting organisms as a seed and pollen dispersing mediators. This biological evolution of mutualistic association occurs in an indirect manner. The insects or flies or other organisms involved in Pollination do not deliberately help the plant in completing its life cycle but came to tap nector or collect pollen. Similarly, frugivores (fruit eating organisms) do not deliberately help in seed dispersal but came to eat fruits of the plants. Mutualism do not began as one-to-one interaction. Several different kind of insects, birds and mammals attack the plants. These organisms are not specialized, except in some cases, for one plant. Thus, array of these animals (different taxa) encounter with various groups of plants which differ locally. These interactions resulted into diffuse co-evolution. Various taxa of animals with similar of animals with similar type of eating habits (called as Guild) evolved the potential of exploiting a range of plants species. The result was novel ecological relationship showing diffused co-evolution rather than paired co-evolution.

DIFFUSE CO-EVOLUTION----- MUTUALISM

The diffuse co-evolution was favoured by number of constraints such as multiple relationships, asymmetrical evolution etc. for example many pollinators visited plants for pollen but among them only one or two species can serve best for flowers. Seasonally, the frugivores may consume variety of different fruits but only one type of frugivore can most efficiently disperse the seeds of a particular plant. Thus, it is not implausible that one seed disperser or pollinator and just one plant will undergo close evolution.

Additionally, asymmetrical evolution is another type of constraint that causes diffuse co-evolution. In 1985, Herrera suggested that the woody plants are very ancient and evolution in them occurs at a slower rate than any of their seed disperser or pollinator.

Furthermore, the other constraints that prevented the tight co-evolution are seasonal changes in animal distribution and abundance, variation in the abundance and distribution of animals and plants, and seasonal differences in fruiting and flowering.

8. Evolutionary relationships

It’s a popular concept that phoresy led to the evolution of symbiotic commensalism which in turn led to the evolution of parasitism.

Phoresy ⟶ Commensalism ⟶ Parasitism

These evolutionary processes are still occurring in nature. However, there is evidence that at the beginning of the evolutionary pathways, commensalism exclusively does not led to the evolution of all parasitic relationships. Although, at one time, it was believe that parasitism is a highly primitive type of association is a popular one. But presently this concept is no longer accepted due to the reasons discuss afterwards.

Based on the concept that host has a potential of recognizing "self" molecules from the "non-self" molecules or foreignness of an organism or parasite. The non-self recognization of foreign entity causes a host immune response against that foreign molecule which is more severe when the relationship between host and parasite is relatively new. Based on this concept, we assumed that if we examine among a large number of host species, in nature they are closely related to an array of parasites (particular tissue parasite) then the severest host tissue reaction is evident in those hosts which have relatively new acquired parasites. Moreover, experiments were performed to test this hypothesis in a number of instances where the parasite which is normally found in the host were experimentally introduced into host tissues resulted into less severe host tissue reactions.

Thus, these experiments concluded that the new host tissue reaction elicited by parasitism represent the initial stages of heterospecific host parasite relationship. At the progressive stages, spontaneous mutations causes changes that accumulated in time in the parasite which later becomes less foreign to host and has evolved towards commensalism.

Nowadays, availability of experimental evidences suggested that pathogenicity of parasites is not necessarily dependent in the relatively new relationships with hosts. For example, in case of *Plasmodium*, malaria-causing protozoa when introduced into a range of new hosts, it causes moderate malaria in some while death in others and in some hosts remains asymptomatic. Thus, these differences in the response of new hosts against Plasmodium pathogenicity led to the conclusion that not all new hosts exhibit drastic reaction which results into diseases.

9. Summary

Species not only interacts with their own types but with other species from different population also. The type of interaction is **neutral,** where two interacting species do not effect population growth and designated as 0/0. When both the association population are benefitted, the type of interaction is called **mutualism** and designated as +/+. However, when only one type of population is benefitted forming a one sided relationship where the interaction is neither harmed nor benefitted, this type of interaction is called **commensalism** and designated as +/0. On the other hand, the other type of one-sided relationship is called as **ammensalism** where one population is neither harmed nor benefited but the other population is negatively affected and designated as -/0 types. Ammensalism is a nebulous relationship which involves chemical interactions such as **allelopathy** effect in plants and antibiosis. Other types of interactions where one population is positively affected at the expense of another population, is called as **Predation**. It's designated as +/-. Predation is possible in forms of **herbivory, cannibalism, parasitism and parasitoidism**. Finally, the type of interaction where both the interacting populations are being negatively affected are called as **competition**, which can be intra- or interspecific competition, and designated as -/-.

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Evolution is the underlying cause of occurrence of this immense diversity in parasites. There is no obvious answer to the question of when and where these parasites arise from. All agreed to the assumption that parasites have evolved from free-living ancestors. The origin of parasitism especially endoparasites are postulated as accidental introduction of free-living forms into the hosts. The host provides new-environment conditions to the free-living forms and spontaneous mutations in these forms under the selection pressure resulted into the selection of only those mutants which have more profitable mutations that are necessary to sustain them in the new-environment.

There are three generalizations that are suggested to be responsible for the evolution of parasitism and parasites based on the results of theoretical speculations: **Fahrenholz's Hypothesis, Szidat's Hypothesis and Eichler's Hypothesis.** *Penicillium*, a bread mold is the best example of amensalism that produces bacteria killing chemical compound called penicillin antibiotics. Elephants; cattle etc trample the green grass while searching for food or water resources, the cattle or Elephant is unaffected but the grass is damaged. In plants, *Juglans nigra*, the black walnut tree is a good example for amensalism. **Allelopathy is** a form of interference competition among plants. For instance, in the world the most widely distributed vascular plant called *Pteridium aquilinum* (Bracken fern) release phytotoxins that gets concentrated in the soil's upper surface. Many plants secrete toxic chemicals that are harmful to animals such as algae blooms with red, blue and green algae release metabolites toxic to fish, It's an example of a specific type of amensalism called **antibiosis**.

It's a reciprocal association between two different species that positively affect both the interacting species. For example, mutualism between flowering plants and their pollinators such as *Yucca* moth *Tegeticulaon* Yucca plant and Male *euglossine* on orchids

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