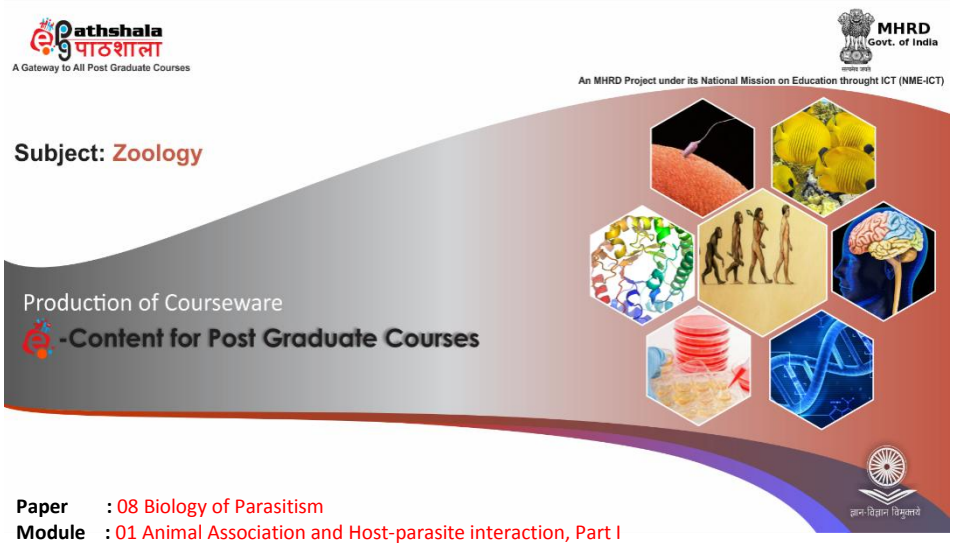

Paper : 08 Biology of Parasitism
Module : 01 Animal Association and Host-parasite interaction, Part I

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ZOOLOGY

Biology of Parasitism

Animal Association and Host- Parasite Interaction. Part 1

Description of Module	
Subject Name	ZOOLOGY
Paper Name	Biology of Parasitism: Zool 008
Module Name/Title	Animal Association and Host-parasite interaction.
Module Id	M01: Animal Association and Host-parasite interaction. Part 1
Keywords	Symbiosis, Mutualism, Protocooperation, Commensalism

Contents

1. Learning Outcomes

After studying this module, you shall be able to

- Understand the meaning of term ‘symbiosis’ and various types of symbiotic relationships.
- Learn about positive and negative interactions
- Evaluate how positive interactions are categorized

2. Introduction

Organisms in a community influence each other either directly or indirectly. Under natural conditions, an organism never lives in absolute isolation and hence must interact for the vital processes of life including growth and reproduction. Organisms biologically influence individuals of same species (intraspecific interaction) e.g. pollination, and grazing or may involve different species (interspecific interaction) e.g. parasitism. They interact with other ecological factors of the environment that ultimately leads to the proper functioning of the ecosystem. Therefore, these complex interactions are indeed fundamental to the survival of an organism. The interdependencies between species lead to spatial and physiological relationships and at times species interactions results in widely separated individuals with taxonomical relationships, for instance bacteria and plants, fungus and plants, bacteria and humans etc. The interactions may be neutral, beneficial or harmful and can be further classified on the basis of the duration of relationship grading from casual to permanent and also on the basis of the strength or mechanism of interactions between organisms.

Different terminologies have been used by several peer authors for different types of relationships shared by the organisms. We would discuss these relations briefly in this chapter.

3. Historical Resume

The ecology of a species is ultimately determined by the interactions between individuals and their environment which includes other individuals of the same species as well as members of other species and other physical factors.

De Bary, 1879 in a broader sense proposed the term symbiosis which includes all types of interactions. Its literal meaning being; living together, this was later on favoured by many ecologists.

McDOUGALL, 1918 classified symbiosis into two major groups of association whether they have beneficial or harmful effects on the basis contact. If the organisms are not in constant contact, they are classified under disjunctive symbiosis while those dissimilar organisms that live in constant contact are grouped into conjunctive symbiosis. These groups were further classified on the basis of direct or indirect food relationships. The organisms having no direct nutritive relationship, like lianas and epiphytes, are classified under social conjunctive symbiosis, while those which have direct food relationships falls under the category of nutritive conjunctive symbiosis. Nutritive conjunctive symbiosis may be antagonist like in parasite or reciprocal as shown by the lichens, mycorrhizae and nitrogen fixing organisms. The interactions between organisms leads to different symbiotic phenomena which have been explained and classified by various authors in their own different ways. For example, Harskell, 1949,proposed number of terminologies like symbiosis, ammensalism, commensalism, neutrality, allotropy, synnecrosis, predation, parasitism and allolimy based on the strength of interaction between the organisms where one interacting partner is stronger and the other is weaker.

These classifications were further elaborated by Burkholder, 1952, who proposed effects of "0", "+" and "–" and their combinations are grouped into nine types of relationships. A zero (0) indicates non-significant interaction between species, "+" indicates growth, survival or the population has benefited and "-" indicates adverse effects of one over the other, by inhibiting growth, survival or other attributes.

Odum, 1971 used the term "symbiosis" in a broader sense and divided the interactions between organisms into two groups (a) positive and (b) negative interactions.

3.1.Positive interactions

Broadly mutualism, commensalisms and protocooperation are the three major groups included in the positive interactions between species. A positive interaction is a relationship where the interacting organisms derive benefits from one another and neither is harmed.

3.2.Negative interactions

Negative interactions are the relationships where one of the interacting organism unfavourably affects the survival, growth and other population attributes of the other directly or indirectly. They may compete for the common resources like food, water, space, sex etc. Negative interactions have been further sub divided into four types:

(a) Competition, (b) Predation, (c) Antibiosis and (d) Parasitism.

In 1987, Abrams classified the interacting population on the basis of mechanism and effects of interactions and six interactions were identified:

1. Competition
2. Predation
3. Herbivory
4. Parasitism
5. Disease
6. Mutualism

The classifications are more often used in combined forms like some ecologists identify parasitism and disease under same group or predation and herbivory under similar headings. In ecological literature, these terms are used loosely, giving rise to a great variability (Table1).

In agreement with the use of the term "symbiosis" in its broader sense, all kind of possible interrelationships are grouped into two major groups positive and negative interactions; which are briefly explained in this chapter for the better understanding of various types of relationships between populations.

Table1: Table depicting different types of interactions with examples in details

S.No.	Types of Interaction	Combinations of effects	Details of effects	Examples
1.	Mutualism	+/+	Bothobligatory associated individuals are benefitted, neither is harmed	Pollination, Lichens, Mycorrhiza
2.	Protocooperation	+/+	Non-obligatory association where both interacting individuals are benefitted.	Sea anemone attached to hermit crab shell
3.	Commensalism	**0**/+	Individuals called as commensal benefits while host is not affected	Lianas, Epiphytes, crab in the mantle cavity of oyster
4.	Neutralism	**0/0**	Interacting individuals do not affect each other	No true example in a complex network of interactions
5.	Predation/Herbivory	+/-	Individual derives benefit by killing and eating another individual	Grazing, browsing, carnivore plants.
6.	Parasitism	+/-	Individual derive benefits from host without causing its death	Malaria parasite viruses, Cuscuta, hookworms, tapeworms, plasmodium

7.	Ammensalism	**-/0**	One individual is harmed, another is unaffected	Grazing animals and grass interaction
8.	Antibiosis	-/-	Neither individual is benefitted	Actinomycetes and lichens inhibiting molds and bacteria
9.	Competition	-/-	Direct/ indirect inhibition of one individual by another for resource utilization	Finches in Galapagos islands, *Paramecium* species competiting for resources etc.

4. Positive Interaction

Organisms exist in the matrix of other living beings consisting of many species and interact directly or indirectly, where either both or one is benefited. The association between populations can be obligatory or facultative, temporary or continuous, where one organism derives benefit in respect of food, substratum, shelter or transport. Types of positive interactions are as follows:

4.1. Mutualism

In 1982, Boucher *et al* defined mutualism at the individual level or population level into a positive and reciprocal relationship between two different species. Later on, J. Holmes and Barrett,1983, elaborated and suggested that mutualistic relationships are more reciprocal exploitations then cooperation between individuals, and both interacting species enhances the survival, growth, and reproduction of each other.

Mutualism in biology is a type of interaction where both the interacting species derives benefit and neither is harmed. When we consider mutually benefitted interacting species, interspecific interactions are more common in the tropics characterized by a close, obligatory contact and often permanent association necessary for the survival, growth and reproduction of each interacting species. Many plant-animal interactions enter into some sort of physiological exchange exhibiting a gain for both species as we saw for the **ant-acacia system** (Figure 1). Ants and acacias is a relationship where ants may form mutualistic relationship with plants, particularly in tropical areas or with herbivore insects such as homopterans. In the swollen thorns of acacia, live American ants from which ants gain shelter and food for all developmental stages. Ants protect plants from the grazing herbivores. Pollination and fruit dispersal are two additional interactions that can be beneficial for both plants and the herbivores.

Figure 1:Mutualistic relationship in ant-acacia system

Mutualism may be symbiotic or non-symbiotic and obligatory or facultative. An obligate non-symbiotic mutualist depends upon each other, but they lead independent live. Non-obligatory facultative mutualists include interaction among guilds of species involved in dispersal of pollen and seeds where plants reward animals with food, fruit, nectar, and oil. Some common examples of mutualism are as follows:

4.1.1. Obligate Symbiotic Mutualism

Obligate symbiotic mutualists are physically dependent on each other, one usually living within the tissue of others, such as lichens. Some forms of relationships are so permanent and obligatory that distinctions between interacting populations become blurred.

4.1.2. Non-obligatory mutualism / Protocooperation

According to older literature a non-symbiotic mutualism is proto-cooperation where both members of the pair benefit each other, but they do not live together. Their relationship is often facultative or opportunistic and they can survive without each other. Example of protocooperation is sea anemone (coelenterate) attached to shells of *Pagurus prideauxi* (Hermit crab). Sea anemone uses crab for its locomotion to feeding sites and in return crab is protected from its enemies (Figure 2).

Figure 2: Sea anemone symbiotically associated with *Pagurus prideauxi* (Hermit crab).

4.1.3. Examples of Mutualism

Some common examples of mutualism in our ecosystem are described here below.

4.1.3.a. Lichens

An example of obligate symbiotic mutualism is fungi-algae symbiosis in the **lichens**(Figure 3). Colonies of multiple cells of algae constitute a thin zone in the mass of fungal hyphae that formulates the basic structure of lichens. Fungi and algae live together for each other's benefit where lichens depends on algae for nutritional gain and provide protection to the algae from desiccating and damaging radiations.

Figure 3: Lichens on trees

4.1.3.b. Pollination

The relationship of plants and their pollinators has been investigated for years, Real, 1983. The literature is large to support the information. A plant depends upon animals for pollen transfer and many examples of non-symbiotic obligate mutualism relationship exist in nature representing the plant-animal pollination systems. Examples include species of *Yucca* that depends entirely on *Tegeticula*, Yuca moth for pollination (Figure 4A). Orchids in lowland neotropical forest are another example of non-symbiotic obligate mutualism, which depends exclusively on male *Euglossine* or golden bees (Figure 4B), specialist in the pollination of orchids. Orchids offer rewards to *Euglossine* in return.

Figure 4. Mutualism between flowering plants and their pollinators.
(A) *Yucca* moth *Tegeticula* on Yucca plant, (B) Male *Euglossine* or golden bees on Orchids

4.1.3.c. Seed dispersal

Seeds and fruits are too heavy to be dispersed by wind and therefore dependent on animals for their dispersal from the parent plants. The fruits are eaten by birds, mammals, etc and seeds are dropped in surrounding soil for seedling emergence and establishment. For instance, some myrmecochorous plants have "*elaiosome*" which is a coating over the seed that attract ants (e.g. Honey-pot ants) as food body (Figure 5A, 5B). Their seed coating serves as food to ant larvae, and seeds are discarded within ant's nest that provide favourable site for seed germination. Plants also use an alternate approach to seed dispersal by attracting fruit eating animals called frugivores, e.g. Asian koel (Figure 5C).

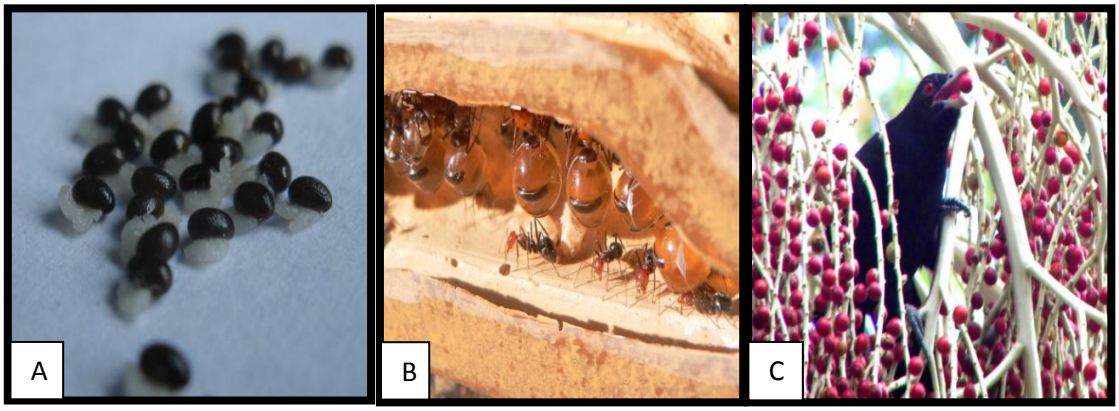

Figure 5: (A) *Myrmecocystus seeds*, (B) honeypot ants, (C) Asian koel as frugivore birds

4.1.3.d. Mycorrhizae

Mycorrhizae are fungal hyphae closely associated with plant's roots transporting mineral nutrients from soil to host roots and gets energy from plants reciprocally. Mycorrhizae helps in translocation of nutrients from soil to root tissues and decomposing litter in nutrient poor soil. They also increase host plant resistance to invading pathogens by utilizing chemicals attractive to the pathogens and root carbohydrates. Possible example is *Lactarius blennius* or Slimy Milkcap or Beech Milkcap is a mycorrhizal mushroom in European beech forests (Figure 6).

Figure 6: A Mycorrhizal mushroom, Beech Milkcap in European beech forests.

4.1.3.e. Symbiotic nitrogen fixers

Association of bacteria with leguminous or non-leguminous plants are well known examples of mutualism. "Rhizobium" is the bacterium that lives symbiotically in the roots of leguminous plants forming nodules to fix gaseous nitrogen. Plants avail this fixed nitrogen and in turn provide food to the bacteria (Figure 7).

Figure 7: Nodules of rhizobia on *Vigna unguiculata*

4.1.3.f. Other examples

Abundant examples of mutualistic relationships are offered by the oceans that aid in exploiting nutrient-poor environment by the organisms especially among the coral reefs. Arthropods occupy self-formed calcareous substrate known as Coral reefs, enormously found in warm nutrient poor sub-tropical and tropical waters (figure 8A).

Zoochlorella is algae associated with the outer tissues of certain coelenterates, worms, sponges and molluscs and offer an example of mutualism. Zoochlorella parasitizes on materials released from host metabolism and in exchange provides beneficial nitrogenous compounds to host *via* photosynthesis. Hydra's basic structure is composed of gastrodermal cells, parasitized by the unicellular green algae, *Chlorella vulgaris* which provide nutrients and oxygen to Hydra (Figure 8B). Chlorella gain in turn CO_2, nitrogen wastes and shelter.

A photosynthetic dinoflagellate alga *Symbiodinium* spp. alsoknown as **Zooxanthella** symbiotically lives in the tissues of gastrodermal cells of host, parasitized by the heterotrophic anthozoans for nutritional gain (Figure 8C). The coralline anthozoans recycle nutrients and flourish in nutrient-poor environment by utilizing photosynthetic products of symbiotic algae that additionally enhance

anthozoans ability to form calcified coral structures and build reef at faster rate. These structures help to increase their benthic cover and counteract destruction.

Termites offer an example of obligate mutualism between associated animals. A termite feeds on wood but is not capable of digesting wood's cellulose for which it requires a species of *Trichonympha* present in their guts. *Trichonympha* are protozoans that obtain food and shelter to the host and in return digest food for the host (Figure 8D).

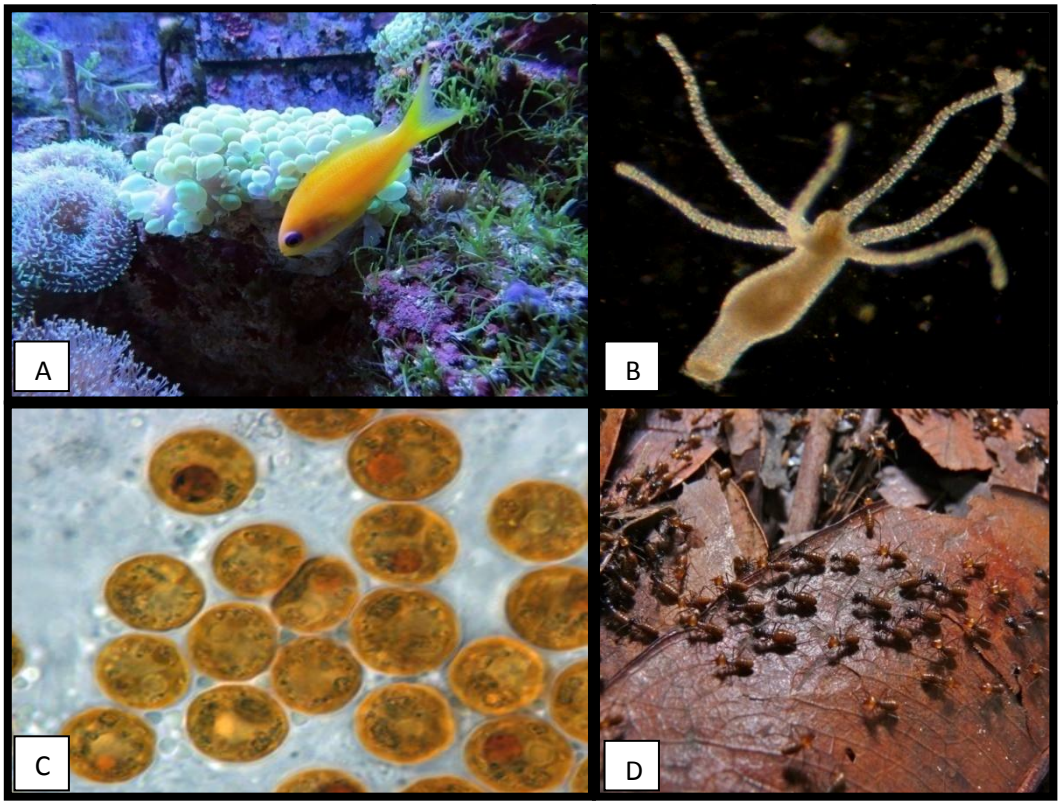

Figure 8: (A) Coral reefs, (B) Zoochlorella e.g. Hydra parasitized by algae *Chlorella vulgaris*, (C) *Symbiodinium* spp. as Zooxanthella, (D) *Trichonympha* in Termites gut

4.2. Commensalism

Commensalism, in ecology, is an association between two organisms in which one organism obtains benefits in the form of food or other benefits while the other associated organism is neither benefited nor harmed. The organisms that obtain substantial benefits are known as "commensal". Commensal is derived from medieval latin "*Commensalis*" meaning "sharing a table", which in human social interaction phrased as "eating at the same table". The commensal may obtain benefits in form of food, space, support or locomotion from the other species which is unaffected by the interaction and hence,

commensals adopt great structural modifications in accordance with its habitat. For instance, various biting lice and louse feed harmlessly on sloughed off flakes of the skin from animals.

Commensalism differ from mutualism where both the associated species obtains benefits from each other, ammensalism where one has detrimental effect on another, by itself being unaffected and from parasitism, where one obtains benefits at the expense of other.

4.2.1. Types of Commensalism

Commensalism is an ecological interaction that varies in duration and strength of interaction from weak to strong and from brief to long intimate associations. It is mainly divided into three types: Phoresy, Inquilinism and Metabiosis (Figure 9).

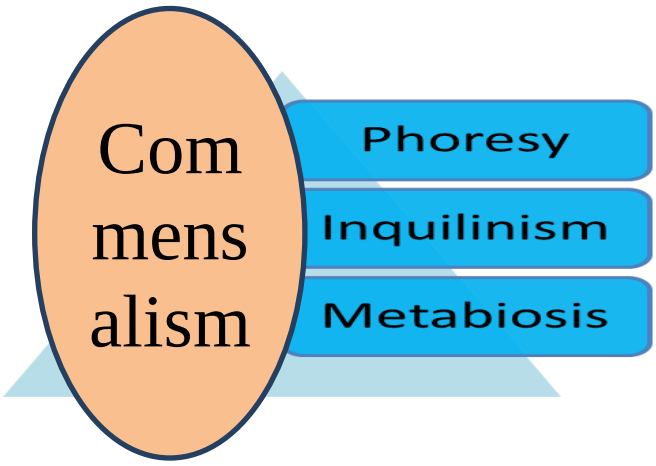

Figure 9: Cartoon illustration of types of commensalism

i. Phoresy

Phoresy is an obligate or facultative interaction whereone species is associated to another for locomotion exclusively, mainly arthropods. Examples are *Triungulin* on a butterfly, beetles on birds etc (Figure 10).

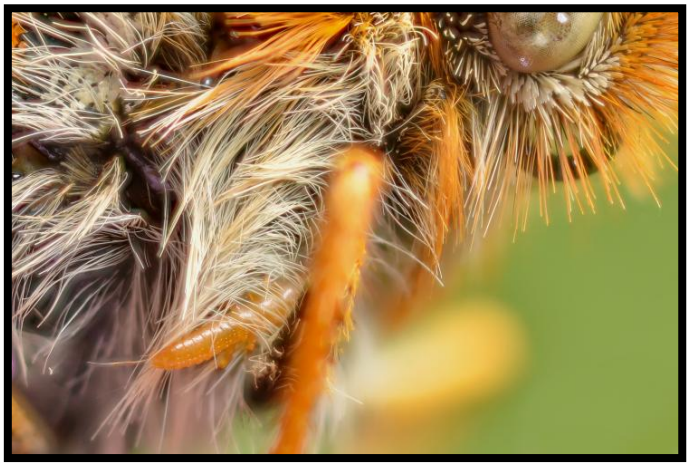

Figure 10:*Triungulin* on a butterfly exhibiting phoresy

ii. Inquilinism

Inquilinism is a type of association where a organism obtain benefits from another unaffected organism for permanent shelter or housing, for instance, birds living in the tree holes demonstrates the concept of inquilinism (Figure 11B). Another prominent example is larvae of *Wyeom yiasmithii* mosquito residing in the structures of the aquatic carnivorous plant *Sarracenia purpurea* (Figure 11A).

Figure 11: (A) *Wyeomyias mithii* mosquito's Larvae, (B) Owl living in tree holes

iii. Metabiosis

Metabiosis is an indirect interaction between species where an unaffected species creates a favourable habitat for the other species. This indirect dependency includes gastropod shells that protect the body of hermit crabs (Figure 12).

Figure 12:An example of metabiosis is Hermit crabs in gastropod shells

4.2.2. Examples of Commensalism

Among various known examples of commensalism, lianas, epizoans and epiphytes are best self-explanatory examples discussed below.

4.2.2.a. Lianas

Most commonly found in the moist climate of dense tropical forests. Lianas are vascular plants associated with their objects for support to maintain their stems erect and with the help of their mechanical tissues obtain better light. They may be thorn lianas; leaner's, tendril or twiners lianas based on the device types that aid to climb on their support. Lianas grow on their support without any direct nutritional relationship. Some common examples of lianas are *Tinospora, Ficus, and Bauhinia* (Figure 13).

Figure 13: Monkey ladder vine (*Bauhinia glabra*) an example of lianas

4.2.2.b. Epizoans and Epiphyte

Epiphytes are non-rooted plants found mostly in tropical rain forests. They are growing perched on trunks or leaves of shrubs, trees or larger submerged plants without any nutritional relationship but only for support. Most common example of epiphytes is Bromeliads, orchids, hanging mosses, *Alectoria* etc (Figure 14A). Some plants (example green algae) grow on the long-grooved hairs of the animals (sloth). Various examples of Plant-animal interactions, micro-organism-plant or micro-organism-animal interaction exists in nature explaining commensalism. *Basicladia* are plants that grow on the freshwater turtles back. Epizoans examples include *Entamoeba coli*, a microbe found in lower intestine of human. Some molluscs and tube worm's species are attached to the *Limulus polyphemus* (horseshoe crab), for instance horseshoe crab with attached *Crepidula* shells. Within the basic structure of sponges called spongocoel, a rich fauna is harboured (Figure 14B).

Figure 14:(A)An epiphyte *Bromeliads* in the tropics, (B) An epizoans example is Horseshoe crab with attached *Crepidula* shells

5. Cleaning Symbiosis

It is a unique type of heterospecific symbiotic relationship during which certain bacteria, ectoparasites, injured and diseased tissues and waste food material of hosts are removed by organisms called "Cleaners". Cleaners in turn are benefitted with food. They have specific sites called "cleaning sites" to perform their function. Besides certain species of fish and crustaceous, various species of remoras act as cleaner's along with some terrestrial associations, example Egyptian plover as cleaners to crocodiles, tick birds to rhinoceros etc (Figure 15).

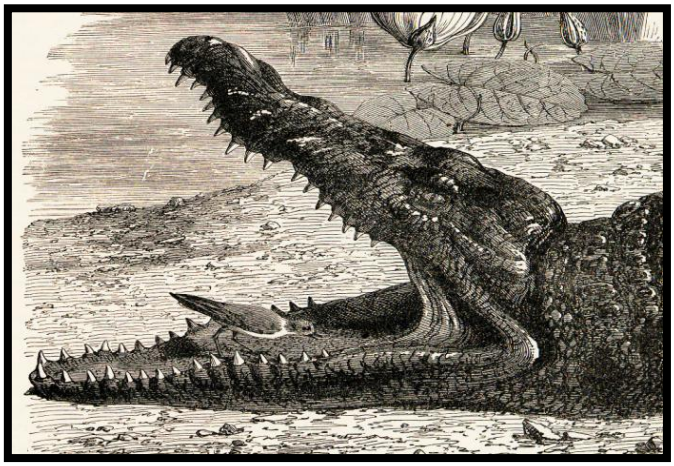

Figure 15: Egyptian plover as cleaners to crocodiles

6. Neutralism

Neutralism describes insignificant or negligible interactions between associated species, in which neither is harmed or benefitted by each other. Most ecologists agreed to the non-existence of this type of interaction which has absolutely no effects on one another.

7. Summary

Under natural conditions, organisms must interact with another organism for food, shelter, growth and reproduction. Burkholder put forth a holistic approach to study symbiosis between two interacting organisms in terms of "+", "-" or "0" indicating benefit, harm and no effect to one or both respectively. Odum suggested that although the interactions are very much complex but they can be broadly categorized into positive and negative interaction based on the effect of association. These interactions between organisms are found in various gradations, being temporary or permanent for whole life. Moreover, interdependency may exist between associated individuals who may belong to same species (intraspecific interaction) or different species (interspecific interactions). Either one way or reciprocal relationships between populations benefitting each other are referred to as positive interactions which broadly include mutualism, protocooperation and commensalism. A positive relationship between individuals of different species is known as mutualism. This relationship may be facultative or obligatory symbiotic or obligatory non-symbiotic, direct or indirect. Examples are plant-animal interactions as inant-acacia system**,** pollination, seed dispersal, mycorrhizal association, rhizobium bacteria in roots, coral reefs etc.Commensalism is a type of symbiotic relationship where

one is benefitted and other is unaffected, categorized on the basis of contact into phoresy (locomotion), inquilinism (shelter) and metabiosis. For example, *Triungulin* on a butterfly, larvae of *Wyeomyias mithii* mosquito and hermit crab in gastropod shells. Ahead of commensalism is an association where both interacting organisms are benefitted but this association is not essential for their survival (non-obligatory) known as protocooperation. Examples are sea anemone symbiotically associated with hermit crab.

The relationship varies from beneficial to both as in mutualism and cleaning symbiosis, harmful to both in negative interactions, beneficial/harmful to one, to neutral for both in neutralism.