A REVIEW OF HOST-PARASITE RELATIONSHIPS

ABSTRACT

Host parasite relationships result from prolonged associations between organisms living in a given environment. The nature and extent of the association will determine the type of relationship existing between the co-habiting organisms. Host-parasite associations usually give rise to four main relationships namely parasitism, mutualism, commensalism and phoresis.

Key words: host, parasite, relationship, associations.

SECTION ONE

1.1 INTRODUCTION

Parasitology has been broadly defined as "a study of symbiosis, or literally speaking "living together"[1] . Naturally speaking, parasitology is defined as the scientific study of parasites. What then are parasites? A parasite is defined by the advanced English dictionary as "an animal or plant living in or on another and getting its food from it"[2].

Taking the broad definition of parasitology into consideration, the word “symbiosis” as used, raises another question. The word itself is taken from Ancient Greek language meaning “living together” [3] ie close and long term interactions between two or more different biological species. In 1877, Albert Bernard Frank used the word symbiosis to describe the mutualistic relationship existing among lichens. This usage conforms to the definition of symbiosis given by the Oxford advanced English dictionary depicting people living together in a community. In 1879, Heinrich Anton de Bary, a German Mycologist defined symbiosis as “living together of unlike organisms” [4, 5].

The meaning of the word symbiosis has become controversial among Scientists. Whereas some Scientists believe symbiosis should refer to relationships that are beneficial to both parties, (ie mutualistic relationships), others believe it should apply to any type of persistent biological interactions [6, 7]. Consequently, four different types of symbiotic relationships have emerged namely:

1. Parasitism
2. Mutualism
3. Commensalism
4. Phoresis

These relationships will be discussed at length as this essay continues.

1.2 TYPES OF SYMBIOSIS

Obligate Symbiosis: This is the type of relationship where both symbionts entirely depend on each other for survival. For example, many lichens consist of fungal and synthetic symbionts that cannot live on their own [6].

Facultative Symbiosis: This is the type of relationship where the organisms may not necessarily live with each other in order to survive

Ecosymbiosis: Here, one organism lives on another eg mistletoe

Endosymbiosis: This is where one partner or symbiont lives inside the other eg lactobaccili and other bacteria on humans or symbiodinium in corals [8].

Conjunctive Symbiosis: This is the type of relationship in which the two organisms have bodily union ie attached to each other. If the opposite is the case, it is called **disjunctive** symbiosis [9].

1.3 HOSTS

The word host as applied to parasitology has been defined as "an organism infected with or is fed upon by a parasitic or pathogenic organism (eg nematodes, fungi, virus etc). It is also described as an animal or plant that nourishes or supports a parasite. The host does not benefit but instead is harmed by the association.

1.4 TYPES OF HOSTS

1. **Definitive or primary host:** An organism in which a parasite reaches sexual maturity eg the mosquito is the definitive host for the malaria parasite, *plasmodium*.
2. **Intermediate (alternative or secondary) host:** An organism in which a parasite develops but does not attend sexual maturity eg humans and other vertebrate animals are intermediate host for *plasmodium*.
3. **Paratenic host:** A host which may be required for the completion of a parasites life cycle but in which no development of the parasite takes place eg the unhatched eggs of nematodes are sometimes carried in a paratenic host such as a bird or a rodent. When a predator eats the paratenic host, the eggs are ingested and it becomes infected.
4. **Accidental host:** One that accidentally habours an organism that is not ordinarily parasitic in the particular species.
5. **Dead-end host:** This is the host in which the disease cannot be transmitted to another animal. Any host organism from which a parasite cannot escape to continue its life cycle. Eg humans are dead end hosts for trichinosis because the larvae encysted in the muscle and human flesh are unlikely to be a source of food for other animals susceptible to the parasite.
6. **Predilection host:** Is the host most preferred by the parasite.
7. **Reservoir host:** An animal or species that is infected by a parasite and which serves as a source of infection for humans or other species.

8. **Transfer or transport host:** A host which is used until the appropriate host is reached, but is not necessarily to complete the life cycle of the parasite

1.5 HOST-PARASITE SPECIFITY

A parasite can infect one or a limited number of hosts at a given time ie most parasites occur on a restricted number of hosts. This gives rise to the concept of specificity. Host specific parasites generally have a major host and then a few less frequently used hosts in the absence of the major one [10, 11]. Even among parasites that do not discriminate among hosts, there is preference for some species hosts above others [12-14]. It is said that many parasite groups have a drift toward greater host specificity. Host specificity is the characteristic of a parasite that renders it capable of infecting only one or more specific hosts at a time.

1.6 HOST-PARASITE EVOLUTION/SPECIFICITY

Natural selection tends to occur and favour the specialization of parasites to their local environment or hosts [15-18]. The parasite ecosystem is a world of competition between organisms where there is survival of the fittest. Thus the most adapted and fitted host or parasite exists in greater abundance than the least fitted. Host specialization is said to be promoted by host-dependent fitness tradeoffs which is dependent on the relative availability and predictability of hosts [19, 16, 20, 21, 12, 22, 23].

A parasite should specialize if the advantages of using one single host species in a profitable manner outweigh the benefits of interacting less profitably with several less frequent host species [19, 16, 20, 21, 22, 23]. In other words, lack of adequate hosts will promote parasite generalization [11a], while abundance of hosts will make parasites to specialize to the specific environmental conditions [13, 11b].

It is believed that host parasite interactions, and thus host specificity take place simultaneously at several "host" levels. This is probably while such interactions are especially difficult to explain. Studies carried out by Georgi et al [24], using ectoparasitic mites, (*Spinturnicidae*) which infest colonial bats, revealed that parasite specificity may be mediated by three main mechanisms:

1. **Dispersal capacity of the parasite** which depends on the number of hosts it can physically encounter during its life.
2. **Host preference**
3. **Ability to successfully transmit** and establish a population on a new host.

Considering the third mechanism, it is said that highly specific parasites are expected to exhibit a higher reproductive success or survival on traditional or native host species than on less closely related ones [25-27].

SECTION TWO

2.1 PARASITISM

Parasitism is defined as a relationship in which one of the participants (the parasite), either harms its host or in some sense lives at the expense of the host [1]. Wikipedia describes parasitism as a non mutual symbiotic relationship between species, where one species, (the parasite), benefits at the expense of the other (the host). Traditionally, a parasite referred primarily to organisms which were visible to the naked eye, otherwise known as macro-parasites (eg helminthes), but nowadays, parasites include microscopic organisms such as viruses, and bacteria [28] which are referred to as micro-parasites. The word “parasite” was derived from a Latin word “parasitus”which means “one who eats at the table of another” [29].

Although parasites may inflict harm on their hosts, it is not in the best interest of the parasite to kill its host. A parasite which kills its host has invariably committed "suicide". Some of the ways parasites inflict harm on their hosts include:

- Boring a hole into the host eg Schistosomes
- Digging into hosts skin or other tissues eg hookworm larvae
- Stimulation of damaging inflammatory or immune response eg microfilariae
- Robbing of the host of nutrients eg tapeworm, hookworm
- A combination of two or more of the above conditions

Unlike predators, parasites are usually smaller than their hosts and will often live in or on their hosts for an extended period of time. Both parasitism and predators are special cases of consumer resource interactions [30].

Parasites display a high degree of specialization, and reproduce at a faster rate than their hosts. Examples of parasitism include interactions between vertebrate hosts and diverse animals such as tapeworm, flukes, the plasmodium species and fleas.

2.2 TYPES OF PARASITES

- **Ectoparasites:** Are parasites living on the surface of their hosts eg bed bugs, mites, ticks etc
- **Endoparasites:** Are parasites living within the body of their hosts eg schistosomes, tape worm, ascaris etc

- **Obligate parasites:** Cannot complete their life cycle without spending at least part of the time in parasitic relationship eg *plasmodium*. However many obligate parasites have free living forms which can exist outside the host for some period of time in the external environment in a protective egg shell or cyst eg hookworm larvae, ascaris, *Entamoeba histolytica*.
- **Facultative parasites:** These are not normally parasitic but become so when they are accidentally eaten or enter a wound or other body orifices eg certain free living amoeba such as *N.fowleri* and free living nematodes of the genus micronema [31]. Infection of humans by any of these facultative parasites is always very fatal.
- **Accidental/incidental parasites:** This occurs when a parasite enters or attaches to the body of species of host different from its usual preferred host eg nematodes parasitic in insects can live for a short time in the intestines of a bird or rodent. Fleas can live for a while in dogs or humans. Accidental parasites usually do not survive in the wrong host but in some cases they can be extremely pathogenic eg *Toxicara, baylis ascaris.*

Parasitism usually results from a long history of evolutionary symbiosis between the parasites and the hosts in which both parties are fully adapted. It is no wonder then why accidental parasitism is fatal for both host and the parasites because neither of the two parties is adapted for the co-existence.

- **Permanent parasites:** These are parasites which live their entire adult lives within or on their hosts
- **Temporary or intermittent parasites:** These feed on their hosts and then leave eg mosquitoes, bed bug. They are also called micropredators because they also prey on several different hosts or the same host at several discrete times.
- **Mesoparasites:** Are those parasites living in an intermediate position ie half ectoparasites and half endoparasites
- **Epiparasites:** Are parasites which feed on other parasites. This is sometimes referred to as hyperparasitism eg a protozoan living in the digestive tract of a flea living on a dog.
- **Social parasites:** Are parasites which take advantage of interactions between members of a social group of organisms such as ants or termites eg *Phengaris arion*, a butterfly whose larvae employ mimicry to parasitize certain species of ants [32].

2.3 TYPES OF PARASITISM

KLEPTOPARASITISM: In this type of relationship, parasites appropriate the food gathered by the host eg brood parasitism practiced by many species of cuckoo and cowbird which do not build nests of their own but rather deposit their eggs in nests of other species and abandon them there. The host behaves as a “baby sitter” as they raise the young ones as their own. If the host bird ventures to remove the Cuckoos eggs, some cuckoos will return to attack the nest to compel the host bird to comply with their wish [33]. In the case of the cowbird, the host's brood is not necessarily harmed but this is not so with the cuckoo which may remove one or more of the host's eggs to avoid detection or the young cuckoo may heave the hosts eggs and nestlings out of the nest entirely. What a wicked act!

INTRASPECIFIC SOCIAL PARASITISM: This may occur in the form of parasitic nursing where some members of the relationship take milk from unrelated females eg in wedge capped capuchins, higher ranking females sometimes take milk from low ranking females without any reciprocation. That is to say high ranking females benefit at the expense of the low ranking ones [34].

CHEATING OR EXPLOITATION: Parasitism can also occur as isolated cheating or exploitation among more generalized mutualistic interactions eg broad classes of plants and fungi exchange carbon and nutrients in common mutualistic mycorrhizal relationships. However, some plant species known as mycohetrotrophs "cheat" by taking carbon from a fungus without donating it.

PARASITOIDS: These are organisms whose larval development takes place inside or on the surface of another organism (the host) leading to the death of the later [35]. This differentiates parasitoids from true parasites which normally do not kill their hosts. Thus parasitoid relationship is similar to predation where the host is always killed. Parasitism differs from parasitoid relationship in the sense that parasitoids generally kill their hosts [36]. Parasitoidism occurs in a similar variety of organisms to that in which parasitism occurs. A parasite can reduce the host's biological fitness in a variety of ways:

- parasitic castration of the host ie impairment of the hosts secondary sex characteristics
- modification of the hosts behavior

Parasites can also increase their own fitness by exploiting the host for resources necessary for their own survival such as food, water, heat, habitat and transmission.

ADELPHO-PARASITISM: An adelpho parasite is one in which the host species is closely related to the parasite, often being a member of the same family or genus eg the citrus blackfly parasitoid, *Encarsia perplexa* whose unmated females may lay haploid eggs in the fully developed larvae of their own species. These result in the production of male offsprings. Secondly, the marine worm *Bonellia viridis* has a similar reproductive strategy, although the larvae are planktonic [37].

AUTOINFECTION: Is the infection of a primary host with a parasite, particularly a helminth, in such a way that the complete life cycle of the parasite occurs in a single organism without passing through other hosts i.e the primary host is at the same time the secondary host. Examples include *Strongyloides stercoralis, Enterobius vermicularis, Taenia solium and Hemenolepsis nana*. *Strongyloides* for example can cause premature transformation of a non infective larva to infective lava, which can then penetrate the intestinal mucosa (internal autoinfection) or the skin of the perineal area (external autoinfection). Thus infection can be maintained by repeated migratory cycle for the rest of the person's life.

2.4 HOST DEFENSES AGAINST PARASITES

The host responds to parasitism in a variety of ways ranging from morphological to the behavioural. Some of these ways include:

1. **Toxins:** Some plants produce toxins which are antiparasitic to inhibit the growth of parasitic fungi and bacteria [38].
2. **Immune systems:** Vertebrate animals develop complex immune systems which fight parasitic organisms to get rid of them. In humans parasitic immunity involves IgE.
3. **Behavioural defenses:** For example sheep avoid open pastures during spring when roundworm eggs are known to accumulate enmasse over

the previous years. Secondly some infected fruit flies ingest alcohol as a form of self medication against blood borne parasites [39].

2.5 EVOLUTION OF PARASITES

Biotrophic parasitism is said to be a common mode of life that has arisen independently many times in the course of evolution. It is also believed that as many as half of all animals have at least one parasitic phase in their life cycles [40] and it is also frequent in plants and fungi. Secondly, almost all free living animals are hosts to one or more parasitic organisms at one time or another [40]. A study [41] has shown that holes in the skull of several specimens might have been caused by Trichomonas-like parasites.

Furthermore, parasites have been known to evolve in response to the defense mechanisms of their hosts. As a consequence of their host defenses, some parasites evolve adaptations that are specific to a particular host taxon, specializing to the point where they infect only a single species. Such parasites may pay dearly over time if the host species become extinct. Consequently, many parasites evolve to infect a variety of more or less closely related host species with different success rates.

Host defenses also evolve in response to parasitic attacks. In theory, parasites may have advantage in this evolutionary arms race because parasite generation time is commonly shorter ie hosts reproduce less quickly than parasites and therefore have fewer chances to adapt than their parasites do over a given range of time.

In some cases a parasite may co-evolve with its host taxa. It is said that long term co-evolution may lead to a relatively stable relationship tending towards commensalism or mutualism since it is in the best interest of the parasite that the host remains alife. A parasite may evolve to become less harmful for its host or a host may evolve to cope with the unavoidable presence of a parasite- to the extent that the parasites absence causes the host harm. For example it is known that animals infected with parasitic worms are often clearly harmed, such infections may also reduce the prevalence and effects of auto immune disorders in animal hosts, humans inclusive [42].

Competitions between parasites often occur and this tends to favour faster reproducing, and hence more virulent parasites. Parasites which kill the host in the course of their life cycle, in order to enter a new host, evolve to be more virulent or even change the behavior or other properties of the host to make it more vulnerable to predators. Parasites that reproduce largely to the offspring of the previous host, tend to become less virulent or mutualist, so that its hosts reproduce more effectively [43].

The presumption of shared evolutionary history between parasites and hosts can sometimes explain how host taxa are related. For instance, the relationship between flamingos and storks or their relatives and ducks, geese and their relatives has been controversial. It has been said that the fact that flamingos share parasites in common with ducks and geese is evidence or proof that these groups may be more closely related to each other than either is to the storks.

Parasitism has been used to explain the evolution of secondary sex characteristics seen in breeding males throughout the animal kingdom eg the plumage of male peacocks and manes of male lions. According to this theory, female hosts select males for breeding based on such characteristics because they indicate resistance to parasites and other diseases.

2.6 PARASITES ADAPTATIONS

Parasites are adapted to infect hosts that exist within their same geographical area (sympatric host) more effectively than hosts found outside their own geographical area (allopatric hosts). This phenomenon is said to support the so called “Red Queen hypothesis” which states that interactions between species (such as hosts and parasites) lead to constant natural selection for adaptation and counter adaptation [44]. Experiments conducted by the later authors, using two snail populations from different sources substantiated the fact that parasites were more infective to sympatric hosts than they were to allopatric hosts ie although the allopatric snails were equally infected, by the digenetic trematodes(parasites), the infectivity was much less when compared to the sympatric snails. Hence the parasites were found to have adapted to infecting local populations of snails [44].

PARASITIC TRANSMISSION

Since parasites inhabit living organisms (hosts), they are faced with numerous problems emanating from the host which will mount many forces aimed at repelling or destroying these invaders. Consequently, parasites develop several strategies to evade these host defense mechanisms to ensure their movement from one host to the other. This is referred to as parasitic transmission or colonization. Some endoparasites infect their host by penetrating its external surface (eg hookworm larvae), while others must be ingested in food by the host (eg *Entamoeba histolytica*). Once they are inside the host, adult endoparasites (eg tapeworm, ascaris) must shed their offspring to the external environment so as to infest other hosts. Many adult endoparasites live in the host's gastrointestinal tract, where the eggs can be shed along with the hosts excreta or faeces. Examples here include tapeworms, thorny headed worms, and most flukes. Some other parasites like malaria parasites (plasmodium) or trypanosomes use insect vectors to transmit their infective stages. Furthermore some larval stages of endoparasites infect sites other than the blood or gastrointestinal tract eg muscle tissue. In such cases, larval endoparasites require their hosts to be consumed by the next host (predators) in the parasites life cycle in order to survive and to reproduce. On the alternative, some larval endoparasites may shed free living transmission stages that migrate through the host's tissue into the external environment where they actively search for or await ingestion by other hosts. The above mentioned strategies are used variously by larval stages of tapeworms, thorny headed worms, flukes and parasitic round worms.

Furthermore, some ectoparasites eg monogenian worms, depend on direct contact between hosts eg lice. Some ectoparasites may shed eggs which may survive off the host (eg fleas), or wait in the external environment for an encounter with a host (eg ticks). Some aquatic leeches locate hosts by sensing movements and only attach when certain temperatures and chemical cues are present.

Host behavior: Some parasites modify hosts behavior to make transmission to other hosts more likely. For instance, in California salt marshes, the fluke *Euhaplorchis Californienses* reduces the ability of its killifish host to avoid predators [45]. This parasite matures in egrets which are more likely to feed on infected killifish than on uninfected fish. Another example is the protozoan *Toxoplasma gondii*, a parasite which matures in cats, though it can be carried by other animals. Uninfected rats avoid cat odours, where as infected rats are attracted to cat odours which causes their being easily devoured and hence transmission [46].

2.7 ROLES OF PARASITES IN THE ECOSYSTEM

Although parasites are often omitted in the depiction of food webs, they usually occupy the top position of every food web. Thus they function like keystone species, thereby reducing the dominance of superior competitors and allowing competing species to co-exist. Many parasites require multiple hosts of different species to complete their life cycles and rely on predator-prey or other ecological interactions to get from one host to another. Thus the parasite in an ecosystem reflects the health of that system.

2.8 IMPORTANCE OF PARASITES

- They account for as much as more than half of life's diversity.
- They perform an important ecological role (by weakening prey) that ecosystems would take some time to adapt to.
- Without parasites, organisms may eventually tend to asexual reproduction thereby diminishing the diversity of sexually dimorphic traits [47].
- They provide an opportunity for the transmission of genetic material between species. On rare occasions, this may facilitate evolutionary

changes that would not otherwise occur, or taken longer time to occur [28].

SECTION THREE

3.1 MUTUALISM

Mutualism is the type of relationship where two organisms of different species exist together with each one benefitting. A similar interaction between organisms of the same species is known as cooperation. Mutualism differs from interspecific competition in which each species experiences reduced fitness and exploitation, or parasitism where one species benefits at the expense of the other. Mutualism is one aspect of symbiotic relationships.

Examples of mutualism include:

- Relationship between ungulates (eg bovines) and bacteria within their intestines. The ungulates benefits from the cellulose produced by the bacteria, which facilitates digestion, while the bacteria benefit from the abundant nutrient present in the host environment.
- Humming bird Hawkmoth and Dianthus. Here, the hawkmoth drinks from the dianthus and in the process helps to bring about pollination.

- The Oxypecker (a kind of bird) and the rhinoceros or zebra. Oxypeckers land on rhinos or zebras and eat ticks or other parasites that live on their skin. The birds get food while the beasts get pest control. Also when there is danger, the oxypecker fly upward and scream a warning which helps the animal to run away.
- The bee and the flower. Bees fly from flower to flower sucking nectar which serves as food. In the process bees bring about cross pollination which benefits the plant.
- The spider crab and the algae. Spider crabs live in shallow areas of the ocean floor, and green brown algae live on the crabs back, thus making the crabs blend in with their environment thereby becoming unnoticeable to predators. The algae gets good place to live while the crab gets camouflage
- Humans and bacteria. A certain kind of bacteria lives in the intestines of man and other animals. The bacteria eat the food humans cannot digest and partially digest it, allowing the human to complete the job. The bacteria benefit by getting food while the human benefits by being able to achieve full digestion.

3.2 IMPORTANCE OF MUTUALISTIC RELATIONSHIPS

1. Mutualistic relationships are important for terrestrial ecosystem function since more than 48% of land plants rely on mycorrhizal relationships with fungi to provide them with inorganic compounds and trace elements.
2. Mutualism is thought to have driven the evolution of much of the biological diversity we see, such as flower forms (which is important for pollination mutualism) and co-evolution between groups of species [48].

Despite its importance in ecology, mutualism has received less attention from Scientist than other relationships such as predation and parasitism [49-50].

3.3 TYPES OF MUTUALISTIC RELATIONSHIPS

Mutualistic relationship has been described as a form of “biological barter” [51] in which species trade resources (eg carbohydrates and inorganic compounds or services, such as gamete, offspring dispersal or protection from predators**.**

Resource-resource mutualism: This is probably the most common form of mutualism where one type of resource is traded for a different resource. Examples include:

a) Mycorrhizal association between plant roots and fungi in which the plant provides carbohydrates to the fungus while the later provides inorganic phosphates and nitrogenous compounds.

b) Rhizobia bacteria that fix nitrogen for leguminous plants (family fabaceae) in return for energy containing carbohydrates [52].

Service-Resource relationship: These are also common. Examples include:

a) The Oxypecker eats ticks on the zebra's skin. Whereas the bird gets food, the zebra gets service of pest control.
b) Pollination in which nectar or pollen (food resource are traded for pollen dispersal (service)
c) Ant protection of aphids where the aphid trade sugar-rich honey dew, a by-product of their mode of feeding on plant sap) in return for defense against predators such as ladybugs.
d) Phagophiles feed (resource) on ectoparasites thereby providing anti pest service as in cleansing symbiosis.
e) Elacatinus and Globiosoma, genus of globies also feed on ectoparasites of their client while cleaning them [53].
f) Zoochory- an example where animals disperse the seeds of plants. This is similar to pollination in that the plant produces food resources (eg fleshy fruits, over abundance of seeds) for animals that disperse the seeds (service).

Service-service relationship: Strict service-service relationships are very rare for reasons which are not clear [51]. Examples of service to service relationships include:

a) Relationship between sea anemones and anemone fish in the family Pomecetridae. The anemone provides the fish with protection from predators, while the fish defends the animal against butterfly fish which eats anemones. However, it is believed that there is more to this relationship than service-service mutualism. For instance waste ammonia from the fish feed the symbiotic algae that are found in the anemones tentacles [54-55]. Thus what appears as service- service relationship has a service-resource component.

b) Relationship between some ants in the genus Pseudomyrmex and trees in the genus Acacia such as the Whistling thorn and Bullhorn Acacia. The ants nest inside the plants thorns thereby obtaining shelter whereas the plant gets protection from attacks by herbivores, which they frequently eat, thereby introducing service-service relationship) and competition from other plants by trimming back vegetation that would shade the Acacia. In addition, another service-resource component is obvious since the ants regularly feed on lipid-rich food bodies called Beltian bodies that are found on the Acacia plant

c) In the neotropics,the ant, Myrmelachista Schumani builds its nest in special cavities in Duroia hirsute. Plants in the vicinity that belong to other species are killed with formic acid. This selective gardening can be so aggressive that small areas of the rain forest are dominated by Duroia hirsute. These peculiar perches are known by the local people as “devils gardens” [56].

d) Cordia species trees in the Amazonian rain forest have a kind of partnership with allomerus species ants, which make their nests in modified leaves. The ants often destroy the trees flowerbud to make more living space available. As the flowers die, more leaves develop and take their place, thus creating more room for the ants.

e) Another type of allomerus species ants lives with the Hirtella sp tree in the same forest; but unlike in the former relationship, when the tree wants to make flowers, the leaves habouring the ants dwellings begin to wither and shrink, thus forcing the ants to flea thereby leaving the trees flowers to flourish free from ants attack [56].

3.4 HUMANS AND MUTUALISM

Mutualistic relationships between humans and other species abound in life**:**

a) Humans and gut flora: The gut flora helps man to digest food efficiently [57].

b) Head lice and Man: It is apparent that head lice confer some immunity to man thereby helping to reduce the threat from body louse-borne lethal diseases [58].

c) Humans and domesticated animals: Dogs and sheep were among the first animals to be domesticated by man and they are beneficial to him.

d) **Man and some agricultural varieties of maize:** The later are unable to reproduce without human intervention. First the leafy sheath does not fall open, and secondly, the seed head (the "corn on the cob") does not shatter to disperse the seeds naturally unless man intervenes

e) **In traditional agriculture,** some plants have mutualists as companion plants, providing each other with shelter, soil fertility and or natural pest control. For example, beans may grow up corn stalks as trellis, while fixing nitrogen in the soil for the corn. This phenomenon is applied in the Three Sisters farming [59].

f) **The Boran people of Ethiopia and Kenya** traditionally use a whistle to call the honey guide bird. If the later is hungry, it usually guides them to a bee's nest where they (Boran) harvest the honey leaving some for the birds to eat [60].

g) **In Laguna Brazil,** a population of bottle nose dolphins communicates through body language with local net using fishermen in order for both to catch schools of mullet [61].

SECTION FOUR

4.1 COMMENSALISM AND PHORESY

Commensalism simply means "eating at the same table". It is a type of symbiotic relationship where one partner benefits whereas the second partner (the host) is neither helped nor harmed. Commensal relationships mainly involve feeding on food "wasted" or otherwise not consumed by the host. Examples of commensalism include:

a) **Remora sharks and Whales:** The remora sharks have adhesive disk on the dorsal surface of their head which they use to attach to larger animals such as whales which tend to be sloppy eaters. When food floats away from the whale's mouth, the remora shark can unhitch itself and collect the scraps of food from the host.

b) **Barnacles and Whales:** Barnacles are crustaceans whose adults are sedentary. The motile larvae find a suitable surface and then undergo metamorphosis to the sedentary form. The barnacles adhere to the skin of a whale or shell of a mollusk and are transported to areas with new sources of food.

c) **The titan triggerfish (Balistoides viridescens) and smaller fish:** The former fish creates feeding opportunities for smaller by moving large rocks which are too big for the smaller fish to shift.

d) **Humans and prostistans:** Humans habour several species of commensal protistans such as Entamoeba gingivalis which lives in the mouth where it feeds on bacteria, food particles and dead epithelial cells but never harm healthy tissues. Adult tape worms though generally regarded as parasites may not have known ill effects on their hosts [62].

4.2 TYPES OF COMMENSALISM

Facultative commensalism: This is a situation where the commensal may not necessarily participate in the relationship to live eg stalked ciliates of the genus verticella are frequently found on small crustaceans but they can survive equally on sticks on the same pond.

Obligate commensalism: This is a situation where the commensals necessarily need each other to survive eg some related ciliates such as Epistylis spp cannot survive without the presence of other organisms especially crustaceans.

4.3 PHORESIS

This is the relationship in which two organisms are simply "travelling together" and there is no physiological or biochemical dependence on the part of each participant. The two organisms are known as phoronts. Usually the smaller organism is usually carried by the larger organism (the host). Examples of phoresic relationship include:

a) Bacteria on the hairs of a fly
b) Fungous spores on the feet of beetle
c) Mites on insects such as beetles, flies or bees.
d) Pseudo scorpions on mammals [63]
e) Millipedes on birds [64].
f) The Dermatollia hominis larvae usually live beneath the skin of warm blooded animals including man. The eggs are usually carried by other insects such as mosquitoes and are deposited on the host's skin as the mosquito perches to feed. The eggs quickly hatch and the larvae burrow their way into the skin.

Like commensalism, phoresis can be facultative or obligate depending on the existing environmental conditions.

4.4 OTHER RELATIONSHIPS

INQUILINISM

This is a type of relationship where one organism uses the other as a permanent housing or place of abode. Examples include:

a) Epiphytic plants (eg Orchids) that grow on trees [65].

b) Birds that live in holes in trees.

METABIOSIS

This is a relationship in which one organism creates or prepares a suitable environment for the other. Examples include:

a) Maggots which feast and develop in corpses
b) Hermit crabs which use gastropod shells to protect their bodies

AMENSALISM

This is the type of relationship that exists where one species is inhibited or completely obliterated and the other is not affected. This type of relationship is common in the natural world. An example is a sapling growing under the shadow of a mature tree. The mature tree usually robs the sapling of necessary sunlight and other nutrient (eg rain water). The mature tree remains unaffected while the sapling dwindles and dies. The mature tree will even make use of nutrients arising from the decaying sapling.

SYNNECROSIS

This is a rare type of symbiosis in which the interaction between species is detrimental to both organisms involved. [9]. It is a temporal condition since the interaction will eventually lead to death of the two partners. Consequently, evolution selects against synnecrosis hence it is uncommon in life and the term is rarely used. [66].

CONCLUSION

Host parasite relationships occur as a result of prolonged evolutionary associations between organisms ie organisms developing or living with each other in the same environment for a long time. The extent of association determines the type of relationship which may result.

REFERENCES

1. Larry S,R and Gerald D.S . Foundations of Parasitology (6th Edition). 2000.pp 4-7.
2. The New Oxford Advanced English Dictionary.
3. Liddel and Scott. Greek English Lexicon.
4. Wilkinson , 2001
5. Douglas,A. Symbiotic Interactions, Oxford (Oxfordshire): Oxford University press 1994, p 1
6. Douglas A.E. The Symbiotic Habitat, New Jersey; Princeton University Press 2010 pp 5-12
7. Martin, B.D; Schwab,E. "Symbiosis: Living together in chaos". Studies in the History of Biology 2012, 4(4):7-25
8. Ahmadjian and Paracer 2000, p12
9. Dorland (2007) "Symbiosis" Dorlands illustrated Medical Dictionary. Philadelphia Elsevier Health Sciences, . Credo reference web. 17 Sept 2012
10. Poulin R (1992) Evolutionary ecology of parasites. From individual to communities. Chapman & Hall, London

11. Tripet F, Jacot A, Richner H (2002a) Larval competition affects the life histories and dispersal behavior of an avian ectoparasite. Ecology 83:935–945

12. Tripet F, Richner H (1997) The coevolutionary potential of a ‘generalist’ parasite, the hen flea Ceratophyllus gallinae. Parasitology 115:419–427

13. Soler JJ, Møller AP, Soler M (1999) A comparative study of host selection in the European cuckoo Cuculus canorus. Oecologia 118:265–276

14. Johnson KP, Williams BL, Drown DM, Adams RJ, Clayton DH (2002) The population genetics of host specificity: genetic differentiation in dove lice (Insecta: Phthiraptera). Mol Ecol 11:25–38

15. Combes C (1991) Evolution of parasite life cycles. In: Toft CA, Aeschlimann A, Bolis L (eds) Parasite-host associations. Coexistence or conflict? Oxford University Press, London, pp 62–82

16. Thompson JN (1994) The coevolutionary process. University of Chicago Press, Chicago

17. Kawecki TJ (1998) Red queen meets Santa Rosalia—arms races and the evolution of host specialization in organisms with parasitic lifestyles. Am Nat 152:635–651

18. De Meus et al, 1998

19. Jaenike J (1990) Host specialization in phytophagous insects. Annu Rev Ecol Syst 21:243–273

20. Combes C (1995) Interactions durables: ecologie et évolution du parasitisme. Masson, Paris

21. Combes C (1997) Fitness of parasites—pathology and selection [Review]. Int J Parasitol 27:1–10

22. Norton DA, De Lange PJ (1999) Host specificity in parasitic mistletoes (Loranthaceae) in New Zealand. Funct Ecol 13:552–559

23. McCoy KD, Boulinier T, Tirard C, Michalakis Y (2001) Host specificity of a generalist parasite: genetic evidence of sympatric host races in the seabird tick Ixodes uriae. J Evol Biol 14:395–405

24. Giorgi MS, Arlettaz R, Christe P, Vogel P (2001) The energetic grooming costs imposed by a parasitic mite (Spinturnix myoti) upon its bat host (Myotis myotis). Proc R Soc Lond B Biol Sci 268:2071–2075

25. Norton DA, Carpenter MA (1998) Mistletoes as parasites: host specificity and speciation. Trends Ecol Evol 13:101–105

26. Timms R, Read AF (1999) What makes a specialist special? Trends Ecol Evol 14:333–334

27. Tompkins DM, Clayton DH (1999) Host resources govern the specificity of swiftlet lice: size matters. J Anim Ecol 68:489–500

28. Combes, 2005

29. Henry and Scott. Greek English Lexicon

30. Getz, W (2011).Biomass transformation webs provide a unified approach to consumer-resource modeling. Ecology Letters,doi:10.1111/j.1461-0248.2010.01566.x

31. Gardiner C.H, Koh D.S, Cardella T.A (1980). Micronema in man: Third fatal infection. Am J Trop Med Hyg 30:586-589

32. Thomas J, Karsten S, Simona B, Francesca B, and Emilio B (2010). “Corruption of ant acoustical signals by mimetic social parasites” Communicative and integrative Biology 3(2):169-171

33. Parasitism: Bullies of Wild Life, the Bird World Wild life Magazine, 1997.

34. O Brien T.G, (1998).”Parasitic nursing behavior in the wedge-capped capuchin monkey (Cebus olivaceus). Am J Primatology 16(4):341-344

35. Charles H, Godfray J (2004). "Parasitoids". Current Biology Magazine 14(12): R468

36. Bug Life, 2013"The differences between Parasites and Parasitoids". Bug Life. Retrieved 2010- 07-19

37. Larry G, and Mark Wheelis (1991). The Cartoon guide to Genetics. Harper Collins, 1991

38. Overview of Plants Diseases, 2013

39. Milan N,F, Cacso B.Z, Schlenke T.A (2012)." Alcohol Consumption as self medication against Blood- Bourne parasites in the Fruit fly". Current Biology 22(6):488-93

40. Price W.A (1980), Evolutionary Biology of Parasites. Princeton University Press, Princeton.

41. Wolff E.D.S, Steven W.S, John R.H, David J.V (2009). "Common Avian Infection Plagued the Tyrant Dinosaurs". In Hansen, Denis Marinus. PLoS ONE 4 (9):e7288.

42. Rook G.A.W.(2007). "The Hygiene hypothesis and the increasing prevalence of Chronic Inflammatory disorders". Trans Roy Soc Trop Med Hyg 101(11): 1072-4

43. Claude Combes (2005). The Art of being a parasite, Univ of Chicago Press, 2005

44. Lively M.M,and Dybdahyl M.F (2000). ‘ Parasite Adaptation to locally common Host Genotypes”. Nature, Vol 405. 8 June 2000.

45. Lafferty K.D, and Morris A.K (1996). Altered behavior of parasitized killifish increases susceptibility to predation by bird final hosts” Ecology 77.

46. Berdoy M, Webster J.P, Macdonald D.W (2000). Fatal attraction in rats infected with Toxoplasma gondii”. Proc Biol. Sci 267 (1452): 1591-4

47. Holts. 2010

48. Thomson J.N, (2005). The Geographic mosaic of coevolution. Chicago, IL:University of Chicago Press.

49. Brostein J.L, (1994). Our Current Understanding of mutualism. Quarterly Review of Biology 69(1):31-51

50. Begon M, Harper J.I, and Tronsend C.R (1996). Ecology, Individuals, populations and communities, (3rd ed). Blackwell Science Ltd, Cambridge Massachussetts, USA.

51. Ollerton J (2006). “Biological barter”. Patterns of Specialization comparedacross different mutualisms. Pp 411-435 in: Waser, N.M and Ollerton, J (Eds)-Plant Pollinator Interactions: From Specialization to generalization. University of Chicago Press.

52. Denis R.F and Kiers E.T (2004). Why are most rhizobia beneficial to their plant host, rather than parasitic? Microbes and infection 6(13): 1235-1239.

53. Soares M.C, Cote I.M, Cardoso S.C and Bshary R (2008) “The cleaning goby mutualism: a system without punishment, partner Switching or tactile stimulation”. J Zool 276 (3):306-312

54. Porat D and Chadwick-Furman N.E (2004). Effects of anemone fish on giant sea anemones: expansion behavior, growth, and survival. Hydrobiologia 530:513-520.

55. Porat D and Chadwick-Furman N.E (2005). Effects of anemone fish on giant sea anemones: ammonium uptake, zooxanthella content and tissue regeneration. Mar Freshw Behav- Phy, 38,, 43-51.

56. Piper R (2007). Extra ordinary Animalas: An Encyclopedia of Curious and unusual Animals, Greenwood Press.

57. Sears C.L (2005). “A dynamic partnership: celebrating our gut flora”. Anaerobe 11(5): 247-51

58. Lozsa and Apari, 2012

59. Mt. Pleasant J (2006). “ The Science behind the three sisters mound system: An agronomic assessment of an indigenous agricultural system in the North- east. In: John E Staller, Robert S Tykot and Bruce F BENZ. Histories of maize: multidisciplinary approach to the prehistory, linguistics, biogeography, domestication and evolution of maize, Amsterdam, pp529- 537

60. Gibbon J Whitefield, forwarded by Odum Eugene P (2010). Keeping all the pieces: Perspectives on Natural History and the environment. Athens, Georgia. University of Georgia Press, pp41-42.

61. Http/newsdiscovery.com/animals/whales-dolphin

62. Insler G.D, and Robberts L.S (1976). Hymenolepsis diminuita: Lack of pathogenecity in the healthy rat host. Exp Parasitology 39:351-357

63. Durden L.A (2001). " Pseudoscorpions associated with Mammals in Papua New Guinea" Biotropica 23(2):204-206

64. Tajovy Karel et al (2001). "Millipeds (Diplopoda) in Dogs Nest". Eur J Soil Biol Vol 37:321-323

65. Hogan C.M (2011). Commensalism. Topic Ed, M, Mcginley, Ed-in-chief C.J Cleveland. Encyclopedia of Earth. National Council for Science and the Environment. Washington D.C.

66. Lidicher W.Z (1979). A Clarification of Interaction in Ecological Systems". BioScience 29:475-477.