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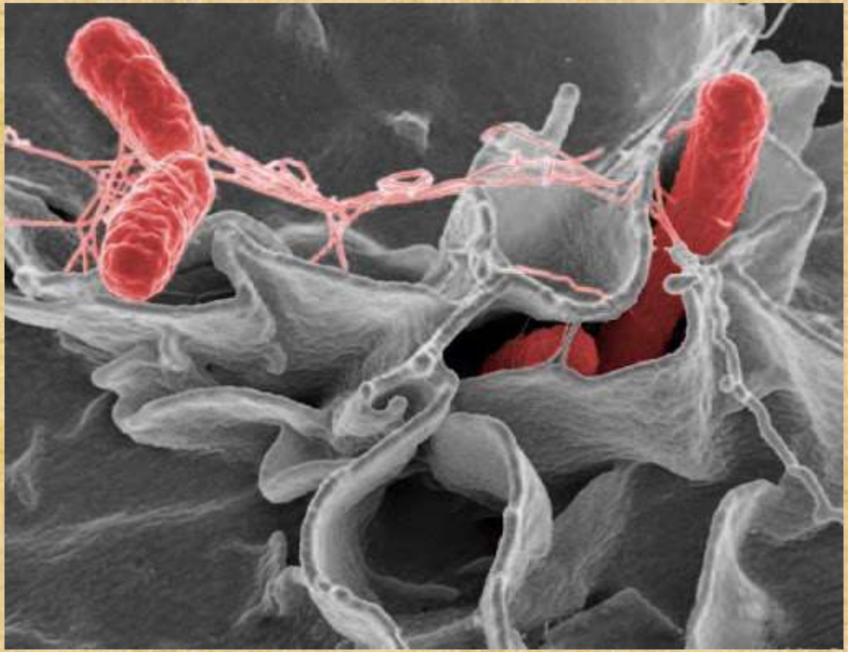

DEPARTMENT: MICROBIOLOGY (GENERAL)

SEMESTER : 5th (UG)

PAPER: MICROBIOLOGY

ENVIRONMENTAL MICROBIOLOGY

TOPIC : HOST-MICROORGANISM INTERACTIONS

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CONTENT INDEX

LEARNING OBJECTIVES

After completing this module, you would able to learn about-

- Compare and contrast different types of microbial interactions, including mutualism, cooperation, commensalism, predation, parasitism, amensalism, and competition

- Also get knowledge about at least one specific example of each of these types of interactions

- Microbial ecology examines the interrelationships between microorganisms and their living (biotic) and nonliving (abiotic) environments. Some of these interactions are beneficial- such as occurs in mutualism, synergism, commensalism. Other interactions-such as competition, parasitism and predation- are detrimental.

- **<u>The stable association of one organism with another is called symbiosis, regardless of whether the association is beneficial or has a negative impact</u>**.

- The smaller organism in a symbiotic relationship has always been called the **symbiont** and the larger organism the host, these organisms are now sometimes regarded as partners.

- Symbionts can live within the host as an **endosymbiont, or on the surface of** the host as an **ectosymbiont.** Finally, symbionts alter not only the health of their hosts, but their behavior, evolution, and reproductive success as well.

- All symbionts must undergo the process of host colonization, reproduction, and persistence within the host, as well as transmission to a new host. For example, **<u>host specificity can range from very narrow to very broad</u>**. Symbioses can range from those that are very stable (e.g., aphids and their bacterial mutualists), to interactions that are temporary, depending on the life cycle of the host or other variables.

CLASSIFICATION OF MICROBIAL INTERACTIONS:

Types of Interaction	Signs of Interaction Population A	 Population B	Effect of Interaction
Neutralism	0	0	Populations do not affect one another
Mutualism	+	+	Both are benefited
Commensalism	0	+	One population benefits, another unaffected
Synergism (Proto-cooperation)	+	+	Both populations are benefited from one another
Amensalism	0 or +	-	One population is unaffected while other is harmed.
Competition	-	-	Each population affected negatively
Parasitism	+	-	One population is benefited and the other population is harmed.
Predation	+	-	One population is benefited and the other population is harmed.

Note: 0, No effect ; +,Positive effect ; - Negative effect

Mutualism: Obligate Positive Interactions Between Host and Microbe

Mutualism (Latin *mutuus*, borrowed or reciprocal) defines the relationship in which some reciprocal benefit accrues to both partners. This is an obligatory relationship in which the mutualist and the host are dependent on each other. In many cases, the individual organisms will not survive when separated.

❖ **Mutualism** is a biological interaction between two species wherein **both the species benefit from each other.**

❖ Mutualistic relationship are viewed as **obligatory**, allowing populations to unite and establish essentiallly single unit populations that can occupy habitats unfavourable for the existence of either population alone.

❖Examples- **Lichens** are formed by a mutualistic relationship between some heterotrophic fungi (mycobiont) and their photosynthetic algal or cyanobacterial partners (phycobiont).

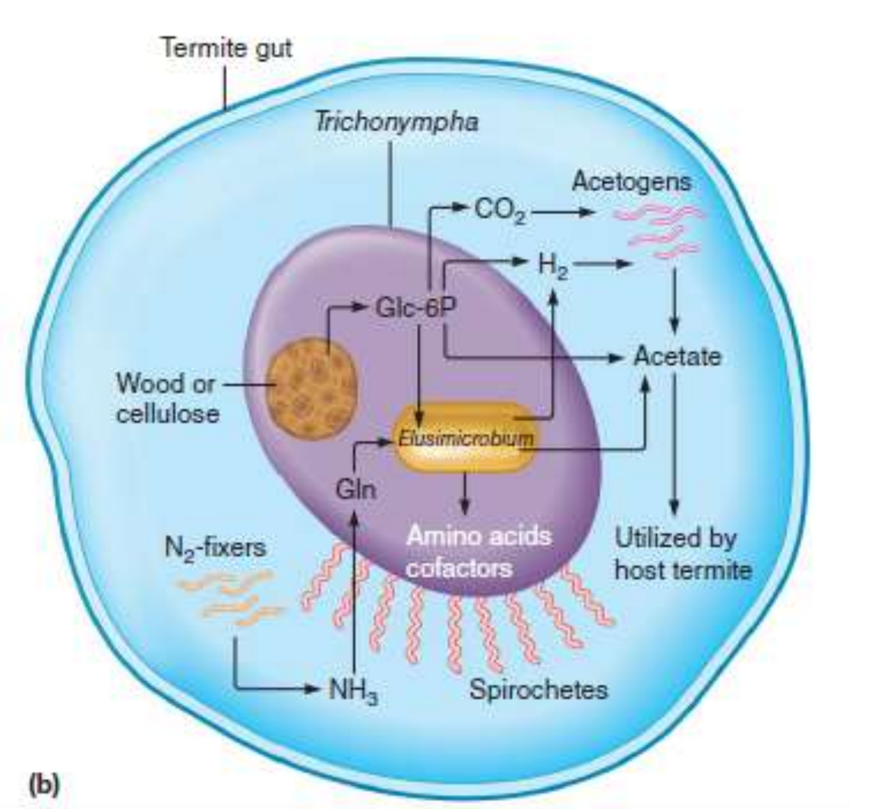
❖ **Where are they grow**? Lichens can grow in habitats, such as on rock surfaces, where neither of them can survive alone. Most lichens are resistant to extremes of temperature and desiccation.

❖**How they act**? The phycobiont utilizes light energy and atmospheric CO_2 to produce the organic matter consumed by the mycobiont. Whereas mycobiont provides physical protection for the lichen and produces organic acids that can solubilize rock minerals , making essential nutrients available to the lichen.

❖Most termite-associated protists are members of the *Excavata* supergroup and as such are quite ancient, possessing hydrogenosomes rather than mitochondria. **These protists ferment cellulose to acetate, CO_2, and H_2.**

❖**Acetate is the termite's preferred carbon source, and termites rely on bacterial symbionts to convert the CO_2, and H_2 released by the protists to acetate by the reductive acetyl-CoA pathway. In addition, termites harbor methanogenic archaea that use these substrates to form CH_4, which is excreted**.

❖Some termite **protists also harbor endosymbionts (i.e., endosymbionts of endosymbionts). For instance, the protist *Trichonympha* sp. relies on a bacterial endosymbiont in the new genus *Elusimicrobium* to convert glutamine to other amino acids and nitrogenous compounds**. In exchange, the protist supplies *Elusimicrobium sp.* with glucose 6-phosphate, which can directly enter glycolysis. In addition, **motility is often provided by spirochetes that cover the protist surface. Motility is essential to prevent protist expulsion by the termite gut and to acquire food.**



Termites are another terrific model system for the study of endosymbiosis. Some termites harbor protist, bacterial, and archaeal endosymbionts and eat only wood. **The main structural polysaccharides of wood are cellulose (an unbranched glucose polymer) and hemicellulose (a smaller, branched glucose polymer), which combine with lignin to form lignocellulose. A diet of wood poses two problems for the termite: how to degrade polysaccharides that may possess as many as 15,000 glucose monomers and where to get organic nitrogen needed for nucleotide and protein synthesis.** Although these **termites produce a cellulolytic enzyme**, only their mutualistic protists can complete lignocellulose degradation. **Nitrogen- fixing bacteria that live in the termite gut solve the problem of obtaining organic nitrogen.**

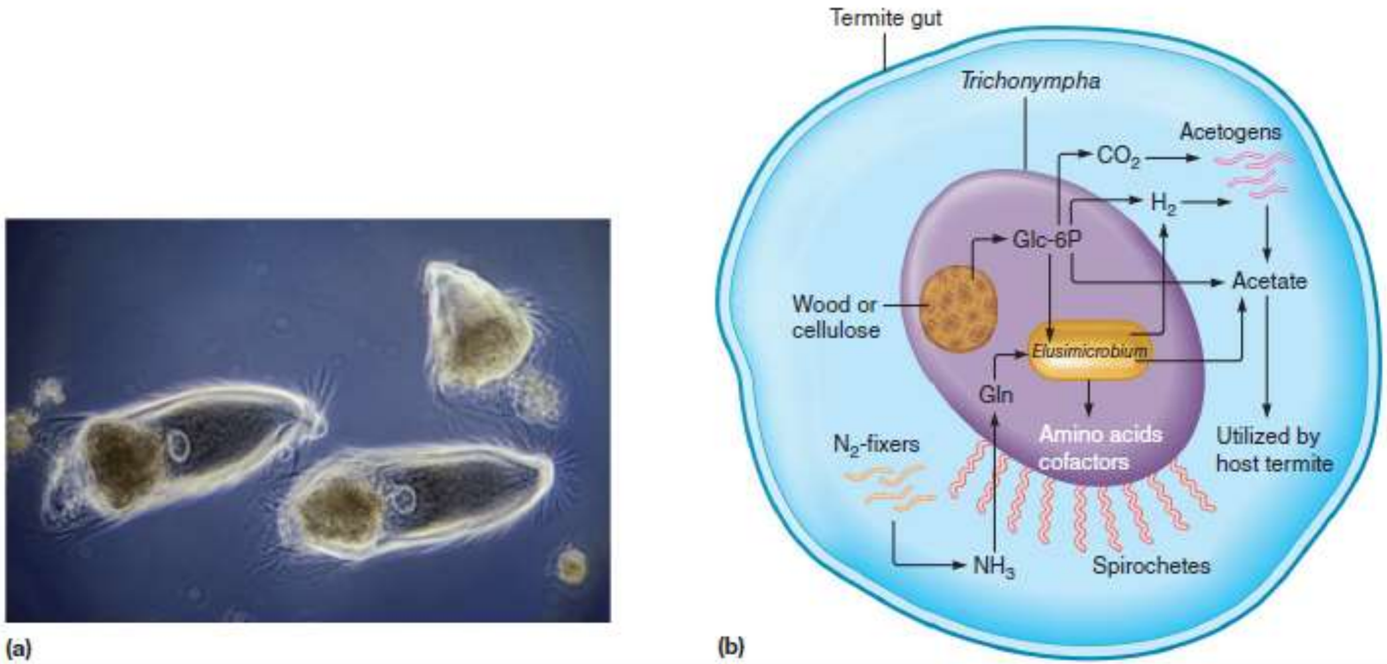


Figure 32.2 Mutualism. (a) Light micrograph of *Trichonympha* sp., a multiflagellated protozoan from the termite's gut (×135). The ability of *Trichonympha* to break down cellulose allows termites to use wood as a food source. (b) Proposed interaction between the termite endosymbiotic protist *Trichonympha* and its bacterial endosymbiont *Elusimicrobium* sp.. Within the termite gut, bacteria convert N_2 to ammonia, which is taken up and converted to glutamine (Gln) by *Trichonympha* sp. The protist relies on *Elusimicrobium* sp. to convert Gln to other amino acids, which are released with other cofactors that the protist cannot synthesize. Both the protist and *Elusimicrobium* sp. ferment glucose to acetate, H_2, and CO_2. These products are exported by the protist and made available to the termite, which also relies on free-swimming gut bacteria to boost acetate levels through reductive acetogenesis (*see figure 20.3*).

Ruminant Animal- Microorganism Symbiosis

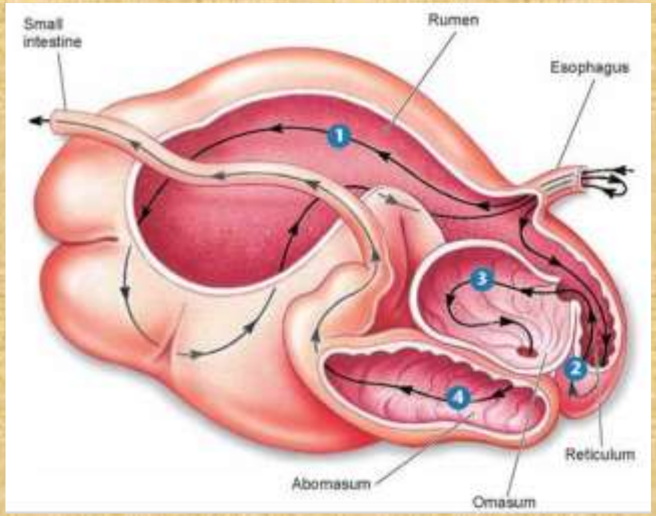
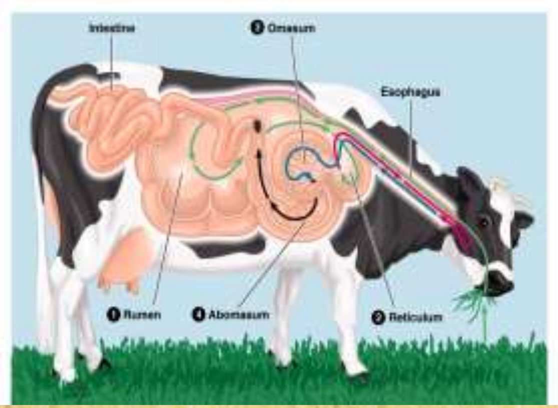


Fig 1: Four chambered Stomach of Ruminants

- ❑Animals such as cows and camels, establish mutualistic relationships with microbial populations.
- ❑They **do not** produce **cellulase enzyme** themselves, instead they depend on microbial populations for the degradation of the cellulosic materials they consume.
- ❑ Their stomach is divided into **four chamber-** 1) **Rumen**, 2) **Reticulum**, 3) **Omasum** and 4) **Abomasum**
- ❑ The microbial populations are maintained in the large first chamber called **rumen**, it provides a stable, constant-temperature (38°C-42°C), anaerobic environment for the establishment of mutualistic associations with microbial populations.
- ❑ Microbial populations within rumen **convert cellulose, starch and other polysaccharides** to **carbon dioxide, hydrogen gas, methane and low molecular weight organic acids.**
- ❑ The overall equation for the fermentation that occurs in the rumen- 57.5 ($C_6H_{12}O_6$) $\longrightarrow$ 65 Acetate+ 20 Propionate+ 15 Butyrate+ 60 CO_2+ 35 CH_4+ 25 H_2O
- ❑ Although hydrogen is produced by many of the fermentative bacteria in the rumen such as *Ruminococcus sp.* , it does not accumulate because of its rapid utilisation by methonogenic bacteria such as *Methanospirillum sp*.



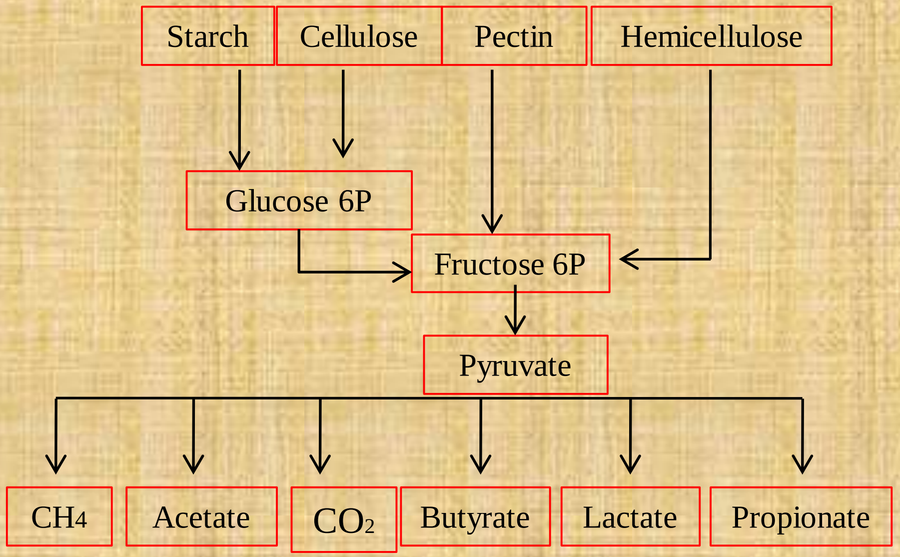


Fig 2: Microbial Metabolism in the rumen.

- ❑ The organic acids produced by the microbial populations are absorbed into the bloodstream of the animal, where they are **oxidised aerobically to produce ATP** needed to **meet the animal's energy requirements**.

- ❑ Because the rumen is anaerobic, most of the caloric content of the ingested plants is maintained in the fatty acid transferred to the blood stream of the animal.

- ❑ although both animal and microbial populations benefit from this relationship, there is a delicate balance among the individual populations within the complex microbial community in the rumen, with each population contributing metabolically to the conversion of substrate to fermentation products.

- ❑ The population balances can be upset by sudden diet changes in ruminants, leading to a condition of bloat caused by excessive gas formation. Restoration of the metabolic balance among microbial populations restores the healthy state of the animal.

What is Commensalism?

- **Commensalism** (Latin *Com*, together, and *mensa*, table; means **"to eat the same table"**) is a relationship in which **one symbiont, the commensal benefits while the host is neither harmed nor affected**.

- A **commensal** species **benefits from** another species by **obtaining locomotion, shelter, food or support from the host species**, which neither benefits nor is harmed.

- The term was coined in **1876 by Belgian palentologist and zoologist Pierre-Joseph Van Beneden**.

- This is an **unidirectional process**. **The spatial proximity of the two partners permits the commensal to feed on substances captured or ingested by the host, and the commensal often obtains shelter by living either on or in the host.**

- The commensal is not directly dependent on the host's metabolism, so when it is separated from the host experimentally, it can survive without the addition of factors of host origin i.e. **it is a non-obligatory relationship**.

Examples of Commensalism

Barnacles have the benefit of moving through waters attached to the whale.

Titan triggerfish creates feeding opportunities for smaller fish by moving large rocks too big for them to shift themselves

Cattle Egrets- These birds live near cattle because when the cattle graze, their movements stir up insects. The birds have their insects and the cattle are unaffected

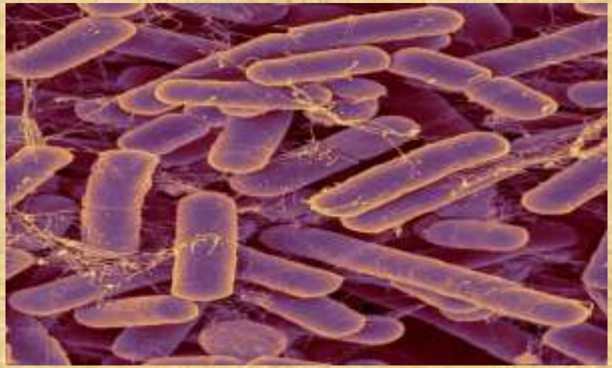
Tree frog – the frog uses plants or trees for protection from the rain

Remora fish have a disk on their heads that makes them able to attach to larger animals, such as sharks mantas and whales. When the larger animal feeds, the remora detaches itself to eat the extra food

Nurse plants are larger plants that offer protection to seedlings from the weather and herbivores, giving them an opportunity to grow

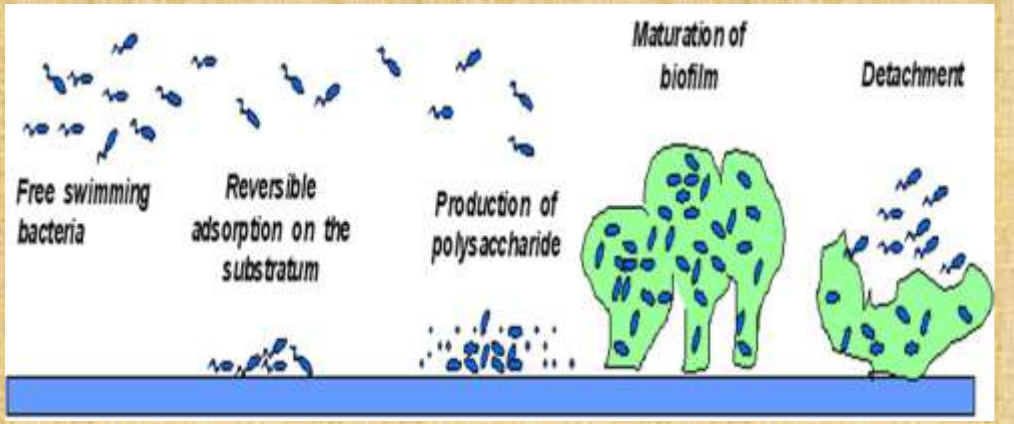
Golden jackals, once they have been expelled from a pack, will trail a tiger to feed on the remains of its kills

Goby fish live on other sea animals, changing color to blend in with the host, thus gaining protection from predators.



Many obligate anaerobes, such as *Bacteroides* species, can live in the human gastrointestinal tract (GI tract) because facultative anaerobes such as *Escherichia coli*, have removed the molecular oxygen which favors the growth of anaerobic bacteria.

Biofilm formation: The colonization of newly exposed surface by one type of microorganism (an initial colonizer, produce extracellular polymers that facilitate attachment and matrix formation) makes it possible for other microorganisms to attach to the microbially modified surface. Microorganisms that form biofilms include bacteria, fungi and protists.



What is Synergism or Proto-cooperation?

❑ **Synergism or proto-cooperation between two populations indicates that both populations benefits from the relationship but that the association is not obligatory that means both populations are capable of surviving independently.**

❑ **Each gains an advantage** from the **synergistic relationship**.

❑ Synergistic relationship are loose in that one member population can readily be replaced by another.

❑ **Syntrophism:** It is a type of synergism in which **two populations supply each other's nutritional needs**. The **term syntrophic means eating together.** Syntrophism is sometimes called ***cross-feeding*** **because two microbial populations may complete a metabolic pathway that neither organism is capable of carrying out alone.**

❑ **Example of Syntrophism:**

1) ***Lactobacillus arabinosus*** **and** ***Enterococcus faecalis*** **can establish a syngergistic relationship based on the mutual exchange of required growth factors**. ***L. arabinosus*** requires phenylalanine for growth, which is produced by ***E. faecalis***. ***E. faecalis*** requires folic acid for growth, which is produced by ***L. arabinosus***. In a minimal medium, both population can grow together but neither population can grow alone.

2) **Syntrophism is very important in methanogenesis**. When fermentative bacteria produce low molecular fatty acids (Propionic acid, butyric acid etc.) that can be degraded by anaerobic bacteria such as δ-proteobacteria in the genus ***Syntrophobacter*** and ***Syntrophomonas*** to produce molecular hydrogen. The products acetate, CO_2 and H_2 are used by methanogenic archaea (***Methanospirillum spp***.) to produce methane (CH_4). The oxidation of organic substrate, which results in the generation of H_2 quickly consumed by methanogens, the reaction becomes thermodynamically favorable. Thus increasing the growth rate if ***Syntrophobacte***r and ***Syntrophomonas.***

- **Rhizosphere Effect:** Synergistic interactions **between plants and microorganisms** are important in **providing the nutritional requirements of both members**. Within the **rhizosphere**, which is the soil region in close contact with plant roots, **plant roots exert a direct influence on the soil bacteria. This influence is known as rhizosphere effect.** Microbial populations in the rhizosphere have an important influence on the growth of the plant.

Microbial populations in the rhizosphere may benefit the plant by-

1) **Removing hydrogen sulfide, which is toxic to the plant roots**
2) **Increasing solubilization of mineral nutrients (Phosphate, iron, manganese, calcium)** needed by the plant for growth
3) **Synthesizing vitamins, amino acids, auxins and gibberellins** that stimulate plant growth and
4) Antagonizing potential plant pathogens through **competition and the production of antibiotics and allelopathic substances**.

What is Amensalism?

❖ **Amensalism or antagonism**, occurs **when one population produces a substance inhibitory to another population.**

❖ This is a **unidirectional process** based on the release of a specific compound by one organism that **has a negative effect** on another.

❖The first population gains a competitive edge as a result of its ability to inhibit the growth of competitive populations.

Examples of Amensalism

✓ A classic example of amensalism is the **microbial production of antibiotics** that can give the antibiotic producing population an advantage while inhibit or kill the other susceptible microorganisms. Example- Bread mold *Penicillium* produces antibiotic penicillin that kills gram positive bacteria.

✓The **production of lactic acid by *Streptococcus* and *Lactobacillus* species** similarly precludes the invasion of that food by other bacterial species. Lactic acid also acts as a food preservative.

✓ **Chemicals produced by microbial populations**, including inorganic compounds such as oxygen, ammonia, mineral acids, hydrogen sulfide and organic compounds such as fatty acids, alcohols and antibiotics, permit the establishment of amensal relationship between microbial populations.

Competition: Microbes Vying for Common Goods

- **Competition** occurs when **two populations are striving for the same resource**. Often it focuses on a **nutrient present in limited concentrations, but it may also occur for other resources, including light and space**. **Both populations are harmed each other**.

- **If one of the two competing organisms can dominate the environment, whether by occupying the physical habitat or by consuming a limiting nutrient, it will overtake the other organism. This phenomenon was studied by E. F. Gause, who in 1934 described it as the competitive exclusion principle**.

- Competitive interactions tend to result in **ecological separation (exclusion) of closely related populations.**

- **Competitive exclusion prevents two populations from occupying the same ecological niche**, that is, they cannot play the same functional role at the same location. When two populations attempt to occupy the same niche, one will succeed and the other will fail.

- **Examples**: **In chemostat**, competition for a limiting nutrient may occur among microorganisms with transport systems of differing affinity. As a rule, the population with the higher growth rate under the given set of environmental conditions in the habitat will prevail over the population with the lower growth rate. If the dilution rate in the chemostat is changed, the previously slower-growing population may become dominant. **Spatial separation allows microorganisms to escape competitive pressures, permitting coexistence of competitive populations**.

Competitive exclusion most likely accounts, at least in part, for the phenomenon of colonization resistance- the capacity of **gut microflora** to prevent pathogen growth.

Predation: Microbes Harming Other Microbes

✓ **Predation among microbes involves a predator species that attack and kills its prey. The predator eats the prey.** Normally, predator-prey interactions are of short duration and the predator is larger than the prey, but this is not always the case.

✓**The predatory populations derive nutrition from the prey species and, clearly, the predator population exerts a negative influence on the consumed prey population.**

✓ **Example**: 1) In addition to ***bdellovibrios*** (δ-proteobacteria), members of the genera ***Vampirococcus*** and ***Daptobacter*** also kills their prey:

a) **Vampirococcus** cells attach to the outer menbrane of prey (***Chromatium sp***.) and secrete degradative enzymes, which result in the release of prey's cytoplasmic content.

b) In contrast, a **Daptobacter** cell penetrates the prey cell and consumes the cytoplasmic content directly.

c) After entry, the **bdellovibrio** cell takes control of the host cell and quickly inhibits host DNA, RNA and proteins synthesis, and disrupts the host's plasma membrane so that cytoplasmic contents leak out of the cell. Growing cells uses host amino acids as carbon nitrogen and energy source.

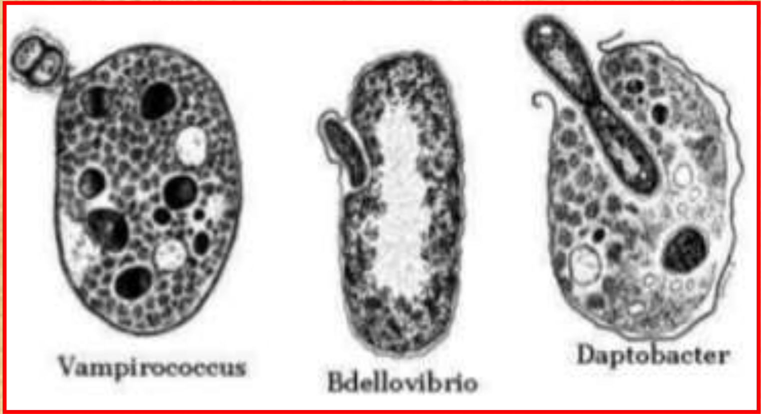


Fig 1: Examples of Predator Bacteria Found In Nature.

2) Some bacteria are **facultative predators**. Sometimes they consume organic matter released from dead organisms, whereas at other times, they actively prey on other microbes. **Two good examples are members of the γ-proteobacterial genus *Lysobacter* and the δ-proteobacterial genus *Myxococcus***. Both display what have been called **"wolf pack" predation** whereby populations of **cells use gliding motility to creep toward and cover their prey** while releasing an arsenal of degradative enzyme. ***Myxococcus xanthus*** formed fruiting body when its prey has been exhausted (Fig 2 & 3).

3) **Many protozoa prey on bacterial species sometimes refereed to as grazing**. Phagocytic capture of a rod shaped bacteria by the soil protozoan ***Vahlkampfia***. (Fig 4)

4) **Some fungi are able to trap and consume much larger nematodes**. Fungi capture nematode prey, including the production of networks of adhesive branches, stalk adhesive knobs and adhesive or constrictive rings. When a nematode attempts to move past such a predacious fungus, the fungus traps it.

Fig 2: **Wolf pack predation by *Myxococcus xanthus.*** A drop of ***Myxococcus xanthus*** cells is placed to the left of a colony of prey bacteria ***Escherichia Coli***. The ***E. coli*** cells lyse as ***Myxococcus xanthus*** glides over and consume them, thus the becomes clear.

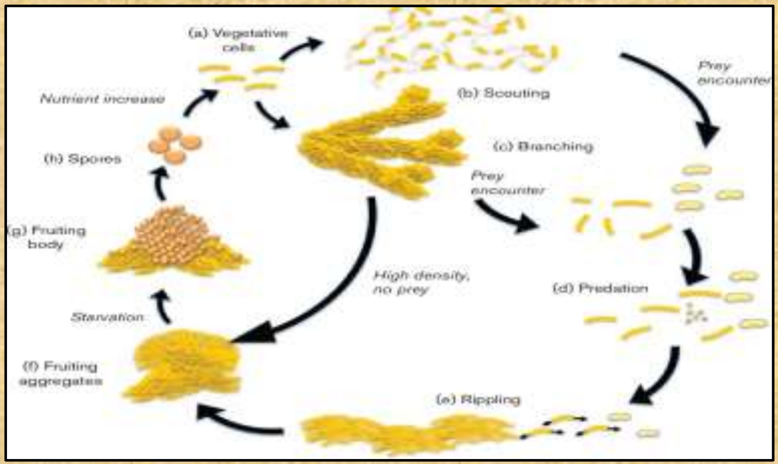


Fig 3: Life cycle of ***Myxococcus xanthus***.

Fig 4: Protozoa grazing on Bacteria.

Even violent movements by the nematode to escape the grasp of the fungi generally fail. The fungal hyphae penetrate and digest the nematode, consuming the animal (Fig 5).

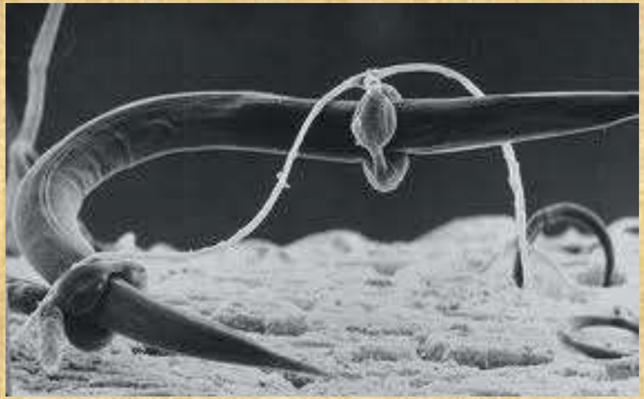


Fig 5: Predation- Nematode trapping Fungi.

Parasitism: Microbes Harm the Host

❖ **<u>In a relationship of parasitism, the parasite population is benefited and the host population is harmed</u>**. Parasitic relationships are characterised by a relatively long period of contact and the parasite is smaller than the host.

❖ In both parasitism and predation relationship one organism is benefited but other one is harmed. But there is some differences present between them: **<u>Parasite and host must coexist, at least temporarily, so the microbes has enough time to reproduce and colonise a new host. Coexistence may involve nutrient acquisition, physical maintenance in or on the host or both.</u>**

❖ Some microorganisms are **obligate parasites**, their existence depends on the successful establishment of a parasitic relationship with a host organism.

❖**For example**:

1) **viruses are obligate intracellular parasites, able to multiply only within suitable host cells.**
2) **Bacteriophage invade and multiply within bacterial cells, causing lysis and death of the bacteria. Viruses invade fungi, algae and protozoa.**
3) **Rickettsiae are obligate parasitic bacteria and sporozoans are obligately parasitic protozoa.**
4) **Many human diseases result from infection with microbial parasites.**

❖ There must be some **balance between host-parasite equilibrium**. If the balance favors the host (perhaps by strong immune defence or antimicrobial therapy), the parasite loses its habitat and may be unable to survive. On the other hand, if the equilibrium is shifted to favor the parasite, the host becomes ill, depending on the specific host-parasite relationship, may die.

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