Microbial Interactions

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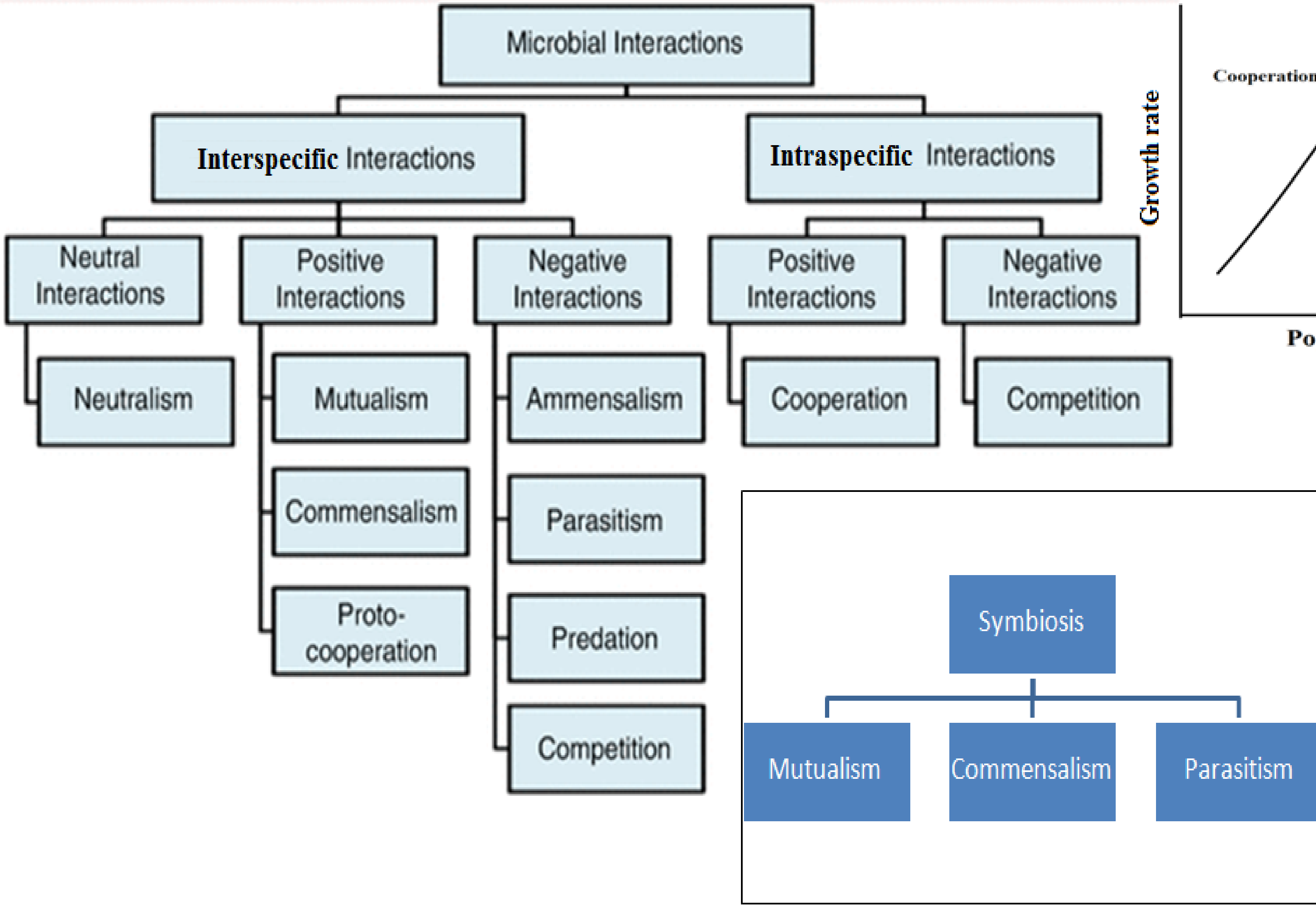
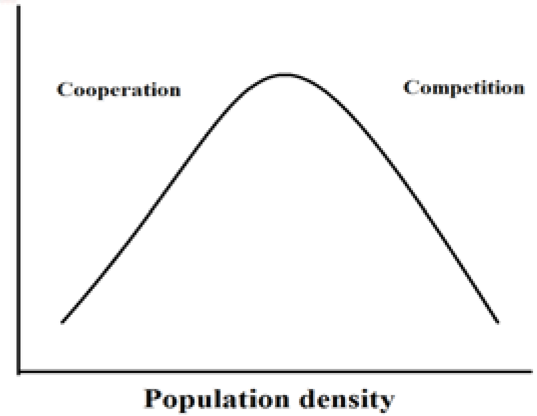
Types of microbial interactions



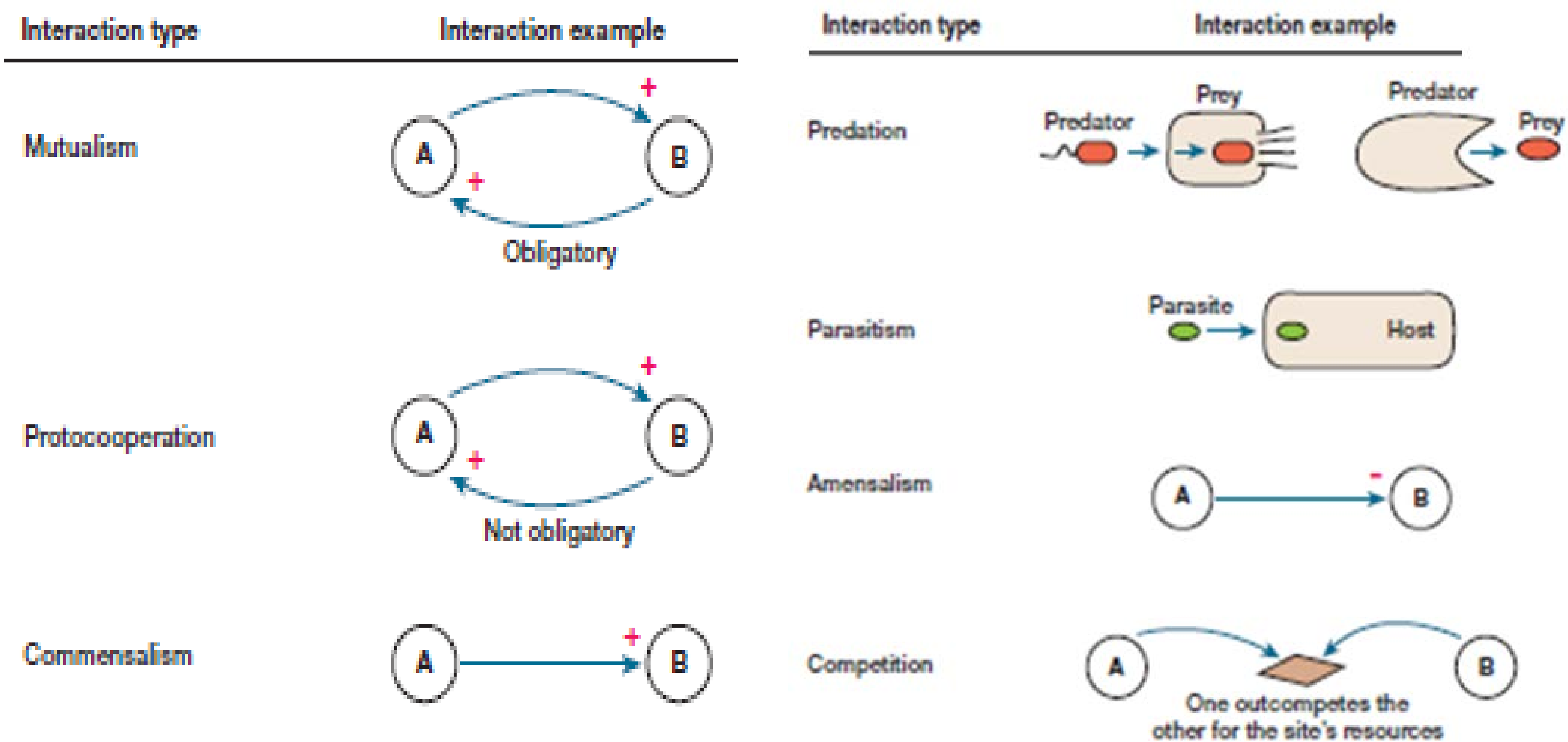


Types of interactions between microbial populations

Name of interaction	Effect of interaction: Population A	Effect of interaction: Population B
Neutralism	0	0
Commensalism	0	+
Synergism (protocooperation)	+	+
Mutualism	+	+
Competition	–	–
Amensalism	0 or +	–
Predation	+	–
Parasitism	+	–

0 = no effect
+ = positive effect
– = negative effect

Types of interactions between microbial populations



Mutualism

- Mutualism is most commonly defined as interactions between individuals of different species that benefit both of them.
- However, mutualism can be more precisely defined as an interaction between individuals of different species that results in positive (beneficial) effects on per capita reproduction and/or survival of the interacting populations.
- The degree of dependency of each mutualist upon the other ranges from obligate to facultative; hence, they can be:
  - obligate–obligate interactions
  - obligate–facultative interaction
  - facultative–facultative interactions
- Facultative mutualists are ones whose populations persist in the absence of a mutualist, whereas obligate mutualists are ones whose populations go extinct in the absence of a mutualist.

...Mutualism

- Interactions between algae and fungi that comprise lichens, interaction between rhizobia and legumes in root nodule (obligate mutualist, both members can not live freely in that environment thus can be considered as mutualistic symbiosis.
- Beneficial rhizobacteria and plants mutualism, plant–pollinator mutualisms (facultative mutualist as both partner species are free-living) can not considered as symbiosis.
- The term mutualism is not synonymous with symbiosis. Mutualistic interactions need not necessarily be symbiotic. (Symbiosis is along term intimate, close association between species).

Examples of mutualism

- **Lichens:** They are the association of specific fungi and algae.
  - In lichen, fungal partner is called **mycobiont** and algal partner is called Phycobiont is member of cyanobacteria ad green algae (*Trabauxua*).
  - Because phycobionts are photoautotrophs, the fungus get its organic carbon directly from algal partner, in turn fungi protects the phycobiont from extreme conditions and also provide water and minerals to algae.
  - Lichen are able to colonies habitat that do not permit the growth of other organisms.
  - Most lichens are resistant to high temperature and drying
- **Paramecium-Chlorella:** *Paramecium* (protozoa) can host *Chlorella* (algae) within its cytoplasm.
  - The algae *Chlorella* provide the protozoan partner with organism carbon and O_2, in turn protozoa provide protection, mortility, CO_2 and other growth factors.
  - The presence of *Chlorella* within *Paramecium* helps to survive protozoa in anaerobic condition as long as there is sufficient light.
- **Protozoan-termite:** Protozoan-termite relationship is the classical example of mutualism in which flagellated protozoan lives in the gut of termites.
  - Theses flagellated protozoan feeds on diet of carbohydrates acquired as cellulose or lignin by their host termites, metabolize into acetic acid which is utilized by termites.

Commensalism

- The word “commensalism” is derived from the word “commensal”, meaning “eating at the same table”.
- In commensalism, one interacting organism derives benefit from the association while the other partner remains unaffected.
- It is an unidirectional association and if the commensal is separated from the host, they can survive.

Examples of commensalism

- *E. coli* is a facultative anaerobe that uses oxygen and lower the O_2 concentration in gut which creates suitable environment for obligate anaerobes such as *Bacteroides*. *E. coli* is a host which remains unaffected by *Bacteroides*.

- *Flavobacterium* excrete cystine which is used by *Legionella pneumophila* and survive in aquatic habitat.

- Association of *Nitrosomonas* and *Nitrobacter* in Nitrification: *Nitrosomonas* oxidize Ammonia into Nitrite and finally *Nitrobacter* uses nitrite to obtain energy and oxidize it into Nitrate.

- In Swiss-type cheeses, propionic acid bacteria make use of lactic acid produced by LAB which acts as a starter.

Proto-cooperation (Synergism)

- Protocooperation is a class of interaction where participating partners benefit; however, the association is not obligatory and both populations can survive on their own.
- Nevertheless, such association provides a mutual benefit to the interacting partners.
- It is not at all necessary for protocooperation to occur; growth and survival is possible in the absence of the interaction.
- Some examples of synergistic interaction include:
  - formation of a product where none of the population can function on its own: eg., pathway completion (syntrophy)
  - Interactions among yogurt bacteria (eg. *Streptococcus, Lactobacillus* sp.) are also often referred to as synergism or protocooperation, interactions in which enhanced growth rate is the main mutual benefit.

Ammensalism/ Antagonism

- Simply stated, ‘amensalism’ is the term used to describe the (0,–) term in the familiar two-species-interaction matrix.
- When one microbial population produces substances that is inhibitory to other microbial population then this inter population relationship is known as Ammensalism or Antagonism.
- It is a negative relationship.
- This chemical inhibition is known as antibiosis.

Examples of antagonism (amensalism)

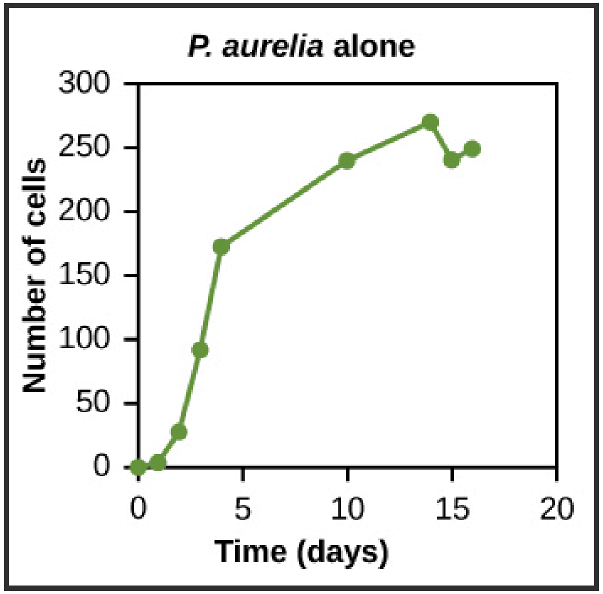
- Lactic acid produced by many normal floras in vaginal tract is inhibitory to many pathogenic organisms such as *Candida albicans*.
- Fatty acid produced by skin flora inhibits many pathogenic bacteria in skin.
- *Thiobacillus thioxidant* produces sulfuric acid by oxidation of sulfur which is responsible to lowering of pH in the culture media which inhibits the growth of most other bacteria.

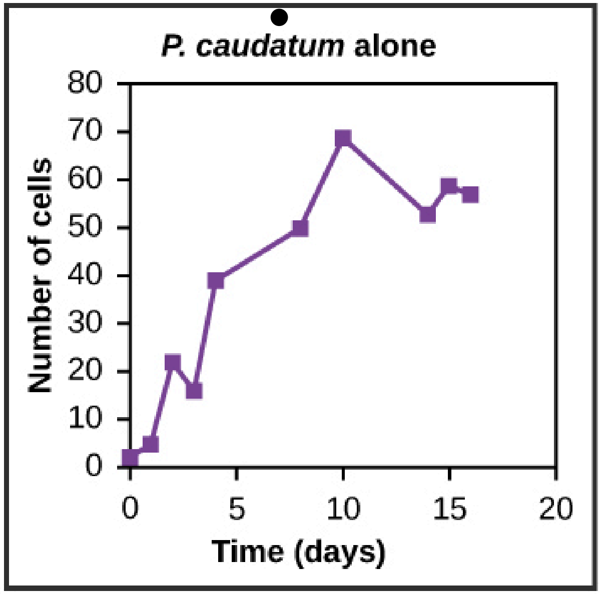
Competition

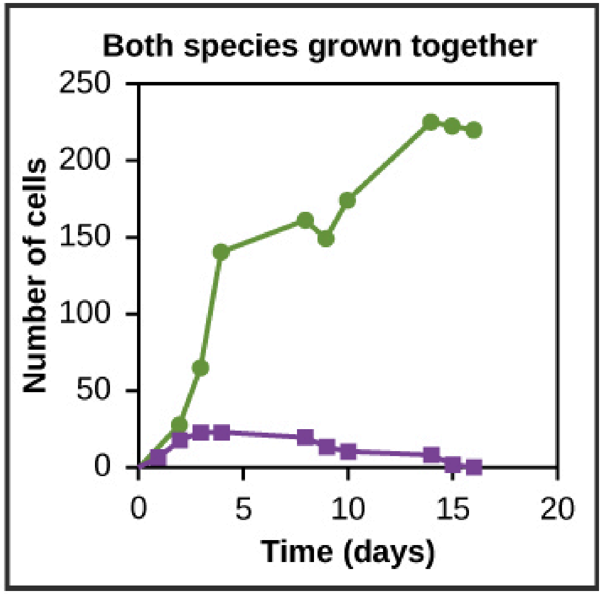
- The competition represents a negative relationship between two microbial population in which both the population are adversely affected with respect to their survival and growth.
- Competition occurs when both population uses same resources such as same space or same nutrition, so, the microbial population achieve lower maximum density or growth rate.
- Microbial population competes for any growth limiting resources such as carbon source, nitrogen source, phosphorus, vitamins, growth factors etc.
- Competition inhibits both population from occupying exactly same ecological niche because one will win the competition and the other one is eliminated.
- The **competitive exclusion principle or Gause's principle** tells us that two species can't have exactly the same niche in a habitat and stably coexist. That's because species with identical niches also have identical needs, which means they would compete for precisely the same resources.

Example of competition

- *Paramecium aurelia* and *Paramecium caudatum*. When grown individually in the lab, both species thrive. But when they are grown in the same test tube (habitat) with a fixed amount of nutrients, both grow more poorly and *P. aurelia* eventually outcompetes *P. caudatum* for food, leading to *P. caudatum*'s extinction.







...Competition

- Competitive exclusion may be avoided if one or both of the competing species evolves to use a different resource, occupy a different area of the habitat, or feed during a different time of day.
- This is called **resource partitioning**, and it helps the species coexist because there is less direct competition between them.

Parasitism

- It is a relationship in which one population (parasite) get benefited and derive its nutrition from other population (host) in the association which is harmed.
- The host-parasite relationship is characterized by a relatively a long period of contact which may be physical or metabolic.
- Some parasite lives outside host cell, known as ectoparasite while other parasite lives inside host cell, known as endoparasite.

Examples of parasitism

- Parasitic fungi include *Rhizophydium sphaerocarpum* with the alga *Spyrogyra.*
- *Rhizoctonia solani* is a parasite of *Mucor* and *Pythium,* which is important in biocontrol processes, the use of one microorganism to control another.
- Viruses are obligate intracellular parasite that exhibit great host specificity.
  - There are may viruses that are parasite to bacteria (bacteriophage), fungi, algae, protozoa etc.
  - Bacteriophages are the commonly known examples of microbial parasitism in nature.

Predation

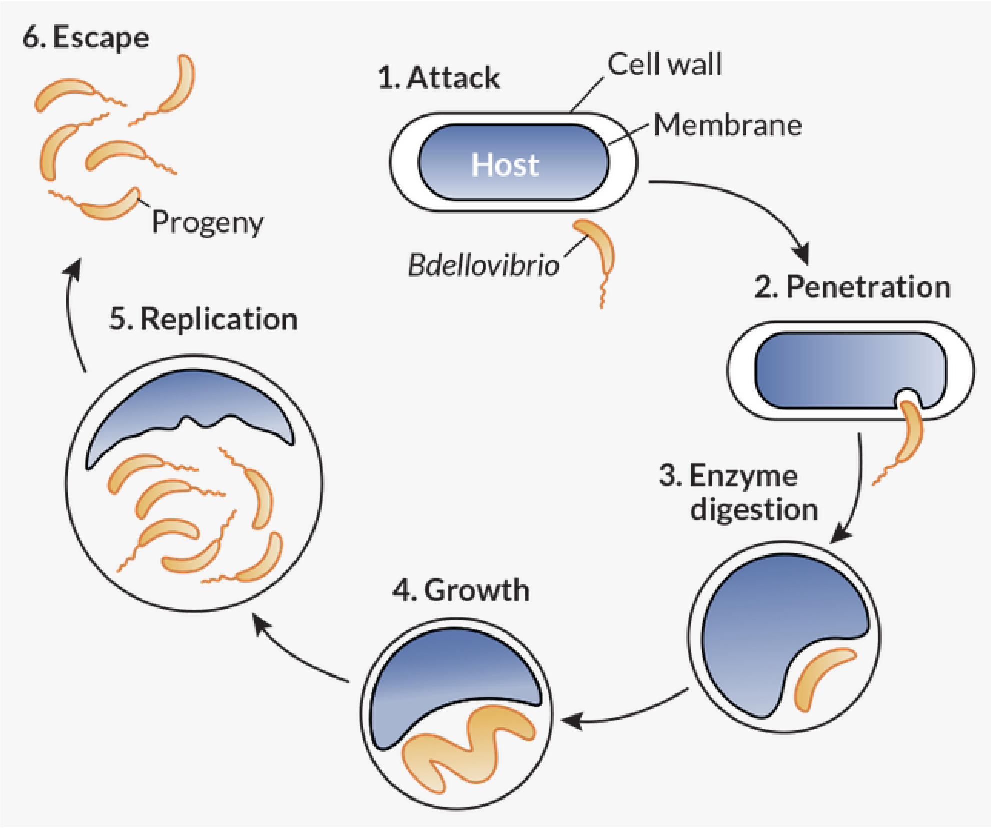
- It is a wide spread phenomenon when one organism (predator) engulf or attack other organism (prey).

Or

- The prey-predator relationships where predator (hunter) feeds on its prey (hunted).
- Normally predator-prey interaction is of short duration.

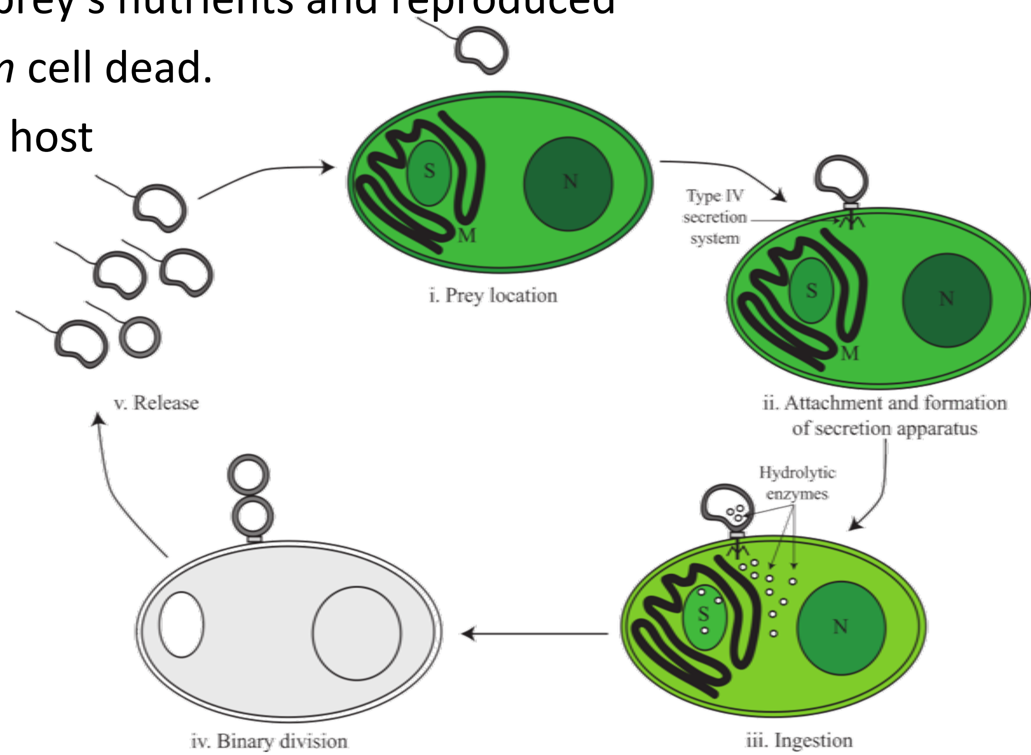
Examples of Predation

- Many protozoans can feed on various bacterial population which helps to maintain count of soil bacteria at optimum level.
- Predatory prokaryotes (*Bdellovibrio, Vampirococcus, Daptobacter*) are smaller than their prey, they cannot engulf, or phagocytize, the larger bacteria.
- *Bdellavibrio* is predatory to many Gram negative bacteria (*E.coli*) penetrate the outer membrane of its prey and enters periplasmic space but not inside host cytoplasm.



Examples of Predation

- ***Vampirococcus*** is a predatory Gram (-) bacteria lives in anaerobic, aquatic conditions.
- It attaches to the prey's cell membrane via a cytoplasmic bridge structure. At first, this attachment is reversible but soon becomes permanent.
- *Vampirococcus* then secretes hydrolytic enzymes into the *Chromatium* bacterium to digest and degrade the cytoplasm.
- The nutrients are directly transported into the predator cell.
- Once the prokaryote has used all the prey's nutrients and reproduced
- *Vampirococcus* leaves the *Chromatium* cell dead.
- ***Daptobacter*** penetrates a susceptible host and uses the cytoplasmic contents as a nutrient source.



Lotka–Volterra equations (Or) predator–prey equations

- Lotka-Volterra model is the simplest model of predator-prey interactions. The model was developed independently by Lotka (1925) and Volterra (1926):
- It has two variables (P, H) and several parameters:
  H = density of prey
  P = density of predators
  r = intrinsic rate of prey population increase
  a = predation rate coefficient
  b = reproduction rate of predators per 1 prey eaten
  m = predator mortality rate

$$\begin{cases} \dfrac{dH}{dt} = rH - aHP \\ \dfrac{dP}{dt} = bHP - mP \end{cases}$$

- With these two terms the equation above can be interpreted as follows:
  - the rate of change of the prey's population is given by its own growth rate minus the rate at which it is preyed upon.
  - the rate of change of the predator's population depends upon the rate at which it consumes prey, minus its intrinsic death rate.

Symbiosis

- Ecologists sometimes use the terms “mutualism” and “symbiosis” interchangeably, but this not exactly the case.
- **The main difference between symbiotic and mutualistic organisms is that some symbiotic organisms benefit, suffer or are unaffected by the relationship whereas mutualistic organisms are benefited.**
- The term symbiosis identifies an intimate, close association between species in which the large majority or entire life cycle of one species occurs within or in very close association with another.
- Often, one species (the symbiont) is not free-living, but inhabits the body of another species (the host).
- A mutualism can also be a symbiosis, and many symbioses are also mutualistic, but not all symbioses are mutualisms and not all mutualisms are symbioses.

Symbiosis

- Symbiotic relationships are categorized by the benefits and physical relationships experienced by each species.
- Common types of symbiosis are categorized by the degree to which each species benefits from the interaction:
  - Mutualism: both species benefit from the relationship. Eg. Lichen, rhizobia-legume (root nodule)
  - Commensalism: one species benefits and the other species is not affected. (eg. *E. coli* and *Bacteroides* in gut)
  - Parasitism: one species benefits at the expense of the second species. (eg. Bacteriophage)
- Symbiosis can also be characterized by an organism's physical relationship with its partner:
  - Endosymbiosis (gutless marine worms of the genus Riftia, which get nutrition from their endosymbiotic bacteria, lysogenic bacteriophage)
  - Ectosymbiosis (anaerobic sulfate-reducing chemolithoautotrophs that likely reduce sulfate with hydrogen produced by hydrogenosome-like organelles underlying the plasma membrane of the protist.)

Questions

- Write an essay on microbial interaction between species.
- Explain intra-species and interspecies microbial interaction with examples.
- Differentiate between mutualism and symbiosis
- Write short notes on:
  - Mutualism
  - Symbiosis
  - Commensalism
  - Parasitism
  - Predation
  - Competition
  - Competitive exclusion principle
  - Lotka–Volterra equations
  - predator–prey equations