

UNIT 4.1 Contd.

Root nodule formation in Legumes

The majority of legumes is Symbiotic biological nitrogen fixers and contains symbiotic nitrogen fixing bacteria *Rhizobium*, within small, knob like protuberances called root nodules on their roots, producing nitrogen compounds that help the plant to grow and compete with other plants. Only a specific *Rhizobium* species infects a particular leguminous plant. When the legume plant dies, the fixed nitrogen is released, making it available to other plants; this helps to fertilize the soil. The root nodules vary in their shape and size. They may be spherical, elongated, flat and grooved or may have finger like projections. Their size varies from pin head to one centimeter in diameter and are brown, red or pink in colour. There may be hundreds of nodules on the roots of a single plant. Root nodules acts as a site of N₂ fixation in legumes.

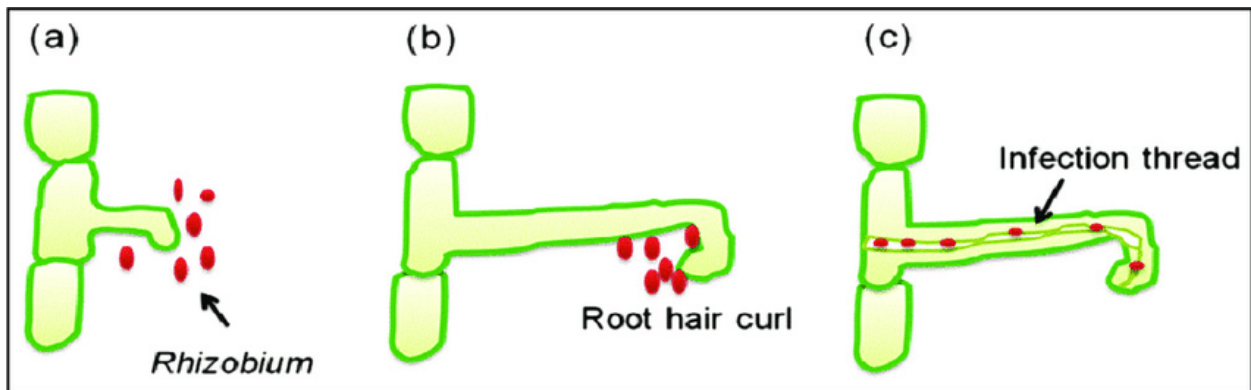
Depending upon growth, the genus *Rhizobium* has been divided into two major groups:

1. *Rhizobium*: It is a generic name which includes all fast growing species.
2. *Bradyrhizobium*: It is also a generic name which includes all slow growing species.

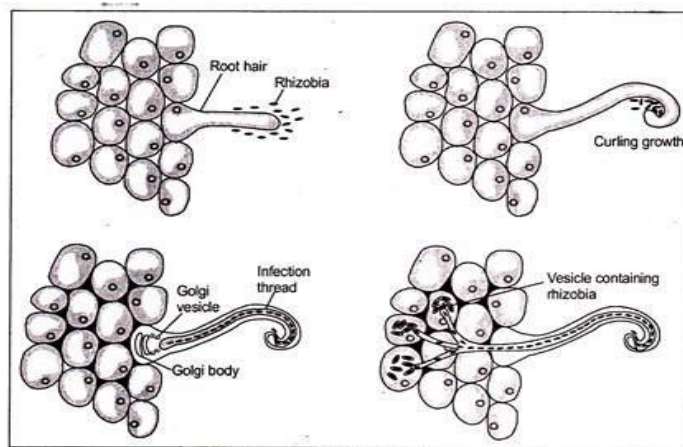
The Symbiotic nitrogen fixing leguminous bacteria (both the above genera) are gram negative, non-spore forming micro-aerobic and host specific.

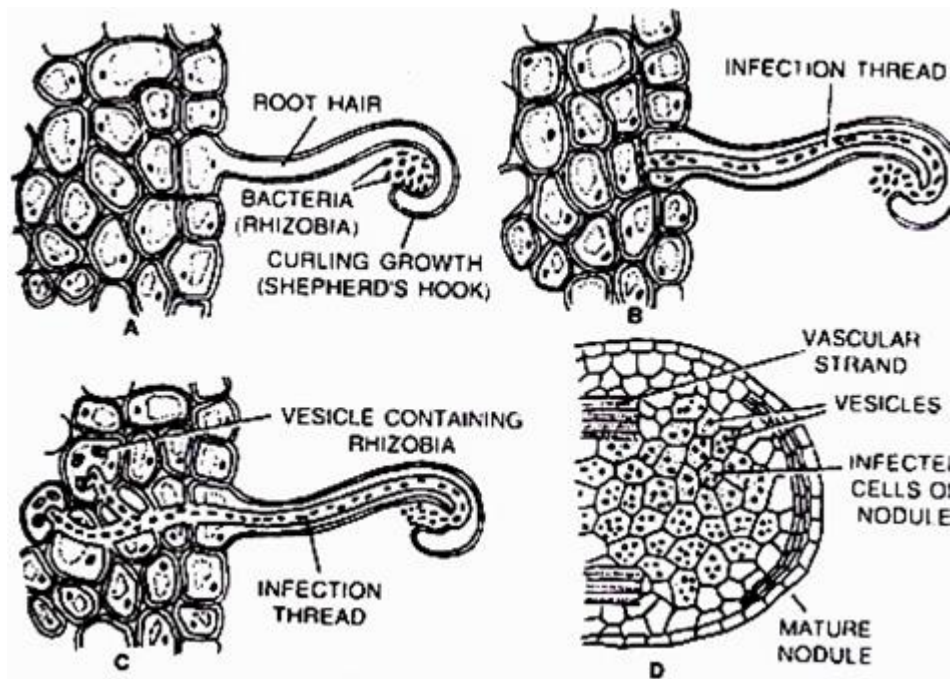
The root nodules in legume plants are produced due to infection of bacteria *Rhizobium*. This free living soil bacteria usually grows near the roots of the legumes and is unable to fix nitrogen in free condition. It fixes nitrogen only when it enters into the root and is present inside root-nodules. The roots of leguminous plants secrete some special types of lectins. The plant lectin of a given species can interact with polysaccharides of only a particular plant. The actual site, where the interaction takes place leading to the formation of nodules lies between the root tips and young root hair. The bacteria enter into the host through young root hairs. Prior to entry, it secretes some hormone like substances which causes deformation and curling of young root hairs. First a tubular infection thread is formed in the root hair cell and the bacteria enter into this thread, a new cell wall is formed which separates the bacteria from the contents of the host cells. The tubular infection thread contains mucopolysaccharides in which the bacteria get embedded and start multiplying. The infection threads containing bacteria and from root hair cell reaches to the cells of the inner layers of cortex where the bacteria are released. These bacterial cells induce the cortical cells to multiply which results in the formation of nodules on the surface of the roots. The bacterial cells also multiply and colonize inside the multiplying host cells. As the available space in the host cells is completely filled, the bacterial cells become dormant and are called bacteroids. The bacteroids usually occur inside the cytoplasm in groups. Each group of bacteroids is surrounded by a membrane called peribacteroid membrane. The space surrounded by peribacteroid membrane is called peribacteroid space. A red pigment **leghaemoglobin** is

filled outside the peribacteroid space in the cytosol of the nodule cells. It means that the dormant bacteroids float in this red pigment. Leghaemoglobin is a proteinaceous pigment, and the characteristic red, pink or brown colour of the nodules is due to this pigment. It has the ability to combine very rapidly with O_2 thus acts as a very efficient scavenger. It protects the key enzyme nitrogenase, against oxidative inactivation and at the same time allows the bacteroids to carry on oxidative ATP generation which is essential for nitrogen fixation. The pigment is a symbiotic compound is made up of apoprotein part and heme molecule. The apoprotein part is synthesized under the genetic direction of the plant and heme part under rhizobial gene. Recent studies have shown that leghaemoglobin is not essential requirement but plays a helpful role in enhancing the efficiency of nitrogen fixation in leguminous plants. Nodules establish a direct vascular connection with the host for exchange of nutrients. A special vascular system develops in the host, supplying product of photosynthesis to the nodule tissue and carry away fixed nitrogenous compounds to other parts of the plant.



Formation of infection thread





Formation of root nodules

Some important Questions

Q: Do Legumes add nitrogen to soil?

Legumes, with the proper **soil bacteria**, convert **nitrogen** gas from the air to a plant available form. Therefore, they **do not** need **nitrogen** fertilization, and can even **add nitrogen** to the **soil**. "Much of the **nitrogen** benefit of **legumes** comes from the plant residue - shoots and roots.

Q: What does Rhizobium do in leguminous plants?

Rhizobia are nitrogen-fixing bacteria which invade root hairs of **leguminous plants** and induce, in a specific manner, the formation of root nodules in which they fix nitrogen. The early steps of the symbiosis **can** be considered as a reciprocal molecular communication between the two partners.

Q: How root nodules are formed

Legumes release compounds called flavonoids from their roots, which trigger the production of nod factors by the bacteria. When the nod factor is sensed by the root, a number of biochemical and morphological changes happen: cell division is triggered in the root to create the nodule, and the root hair growth is redirected to wind around the bacteria multiple times until it fully encapsulates one or more bacteria. The bacteria encapsulated divide multiple times, forming a micro colony. From this

micro colony, the bacteria enter the developing nodule through a structure called an infection thread, which grows through the root hair into the basal part of the epidermis cell, and onwards into the root cortex; they are then surrounded by a plant-derived membrane and differentiate into bacteroids that fix nitrogen.

Q: What are the steps involved in formation of a root nodule?

Multiple interactions are involved in the formation of root nodules:

- 1) The *Rhizobium* bacteria divide and form colonies. These get attached to the root hairs and epidermal cells.
- 2) The root hairs get curled and are invaded by the bacteria.
- 3) This invasion is followed by the formation of an infection thread that carries the bacteria into the cortex of the root. The bacteria get modified into rod-shaped bacteroids

Q: What is root nodule formation?

Root nodules are found in plants of Leguminosae It is **formed** due to the symbiotic association between the leguminous plant and the host-specific bacteria called the *Rhizobium*.

Q: How are nodules formed in leguminous plants?

Rhizobium is a certain bacteria that show symbiotic association with the root **nodules** of **leguminous plants** to help fix nitrogen present in the air. This causes the cortex and the pericycle to divide and **form** root **nodules** and the bacteria to move towards the vascular bundles and help in the exchange of nutrients.

Reference /Syllabus Books(For material & diadrams)

1. Plant Physiology by H. S. Srivastava(Rastogo Publlication)
2. A Text Book of Plant Physiology by S. K. Verma (S. Chand & Company Ltd.)
3. Plant Physiology and Metabolism by Dr. H.N. Srivastava (Pradeep Publicationsp
4. Plant Physiology and Metabolism by Dr. Kamaljit& co-workers (S. Vinesh & Co.)