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nucleic acid, naturally occurring chemical compound that serves as the main information-carrying molecule of the cell and that directs the process of protein synthesis, thereby determining the inherited characteristics of every living thing. Nucleic acids are further defined by their ability to be broken down to yield phosphoric acid, sugars, and a mixture of organic bases (purines and pyrimidines).The two main classes of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA is the master blueprint for life and constitutes the genetic material in all free-living organisms and most viruses. RNA is the genetic material of certain viruses, but it is also found in all living cells, where it plays an important role in certain processes, such as the making of proteins. Nucleic acids are polynucleotides—that is, long chainlike molecules composed of a series of nearly identical building blocks called nucleotides. Each nucleotide consists of a nitrogen-containing aromatic base attached to a pentose (five-carbon) sugar, which is in turn attached to a phosphate group. Each nucleic acid contains four of five possible nitrogen-containing bases: adenine (A), guanine (G), cytosine (C), thymine (T), and uracil (U). A and G are categorized as purines, and C, T, and U are collectively called pyrimidines. All nucleic acids contain the bases A, C, and G, T, however, is found only in DNA, while U is found in RNA. The pentose sugar in DNA (2'-deoxyribose) differs from the sugar in RNA (ribose) by the absence of a hydroxyl group (—OH) on the 2' carbon of the sugar ring. Without an attached phosphate group, the sugar attached to one of the bases is known as a nucleoside. The phosphate group connects successive sugar residues by bridging the 5'-hydroxyl group on one sugar to the 3'-hydroxyl group of the next sugar in the chain. These nucleoside linkages are called phosphodiester bonds and are the same in RNA and DNA. Nucleotides are synthesized from readily available precursors in the cell. The ribose phosphate portion of both purine and pyrimidine nucleotides is synthesized from glucose via the pentose phosphate pathway. The six-atom pyrimidine ring is synthesized first and subsequently attached to the ribose phosphate. The two rings in purines are synthesized while attached to the ribose phosphate during the assembly of adenine or guanine nucleosides. In both cases the end product is a nucleotide carrying a phosphate attached to the 5' carbon on the sugar. Finally, a specialized enzyme called a kinase adds two phosphate groups using adenosine triphosphate (ATP) as the phosphate donor to form ribonucleoside triphosphate, the immediate precursor of RNA. For DNA, the 2'-hydroxyl group is removed from the ribonucleoside diphosphate to give deoxyribonucleoside diphosphate. An additional phosphate group from ATP is then added by another kinase to form a deoxyribonucleoside triphosphate, the immediate precursor of DNA. During normal cell metabolism, RNA is constantly being made and broken down. The purine and pyrimidine residues are reused by several salvage pathways to make more genetic material. Purine is salvaged in the form of the corresponding nucleotide, whereas pyrimidine is salvaged as the nucleoside. AnswerVerifiedHint: Nitrogen cycle is one of the biogeochemical cycles in which elementary nitrogen is circulated between the atmosphere and living organisms in various forms. There are various steps involved in the nitrogen cycle. These are- nitrogen fixation, ammonification, nitrification, assimilation and finally denitrification. Complete answer:The nitrogen fixation is the first step of the nitrogen cycle. During nitrogen fixation, the inert, unstable nitrogen is converted into ammonia or other forms, which is the usable form of nitrogen. In nature, nitrogen fixation occurs mainly by two processes. First is atmospheric nitrogen fixation and the other one is biological nitrogen fixation. However, most of the nitrogen fixation is done by bacteria. In atmospheric nitrogen fixation, the inert nitrogen is converted into nitrous oxide by lightning. The high temperature at the time of lightning the nitrogen is broken down and reacts with oxygen to form nitrous oxide. It is converted into nitrates when on reaction with alkalis present on the earth surface. The bacteria play an important role in the nitrogen fixation during the nitrogen cycle. In biological nitrogen fixation, the nitrogen fixing bacteria present in soil converts the nitrogen into ammonia. This ammonia is later converted into nitrites and then nitrates by other soil living bacteria. Biological nitrogen fixation is done by free-living bacteria and symbiotic bacteria. Example of free living bacteria that helps in nitrogen fixation is- Azotobacter. The symbiotic bacteria present in the roots of leguminous plants also helps in nitrogen fixation. Rhizobium is the most common bacteria which are known for nitrogen fixation. The nitrogen fixation by bacteria is important as it is the primary step in the nitrogen cycle. The conversion of nitrogen to plant usable form is essential for the growth and survival of plants. Note:All the nitrates are not used by the plants. Some of the nitrates are converted back into elementary nitrogen and released into the atmosphere. This process is called denitrification. The bacteria Pseudomonas and Clostridium help in the denitrification process. This is the last step of the nitrogen cycle. Various processes are responsible for recycling the chemicals necessary for life on Earth. The nitrogen cycle is the most complex of these. Carbon, sulfur and phosphorus are the other main cycles. In this article we explore how nitrogen is cycled and the important role of microbes in this cycle. Nitrogen is required by all living organisms for the synthesis of organic molecules such as amino acids, nucleic acids and proteins. The Earth's atmosphere contains almost 80% nitrogen gas. It cannot be used in this form by most living organisms until it has been fixed, that is reduced (combined with hydrogen), to ammonia. Green plants, the main producers of organic matter, use this supply of fixed nitrogen to make proteins that enter and pass through the food chain. Micro-organisms (the decomposers) break down the proteins in excretions and dead organisms, releasing ammonium ions. These two processes form part of the nitrogen cycle. The nitrogen cycle is the movement of nitrogen between the earth and the atmosphere. It consists of a series of processes that convert nitrogen gas to organic substances and these back to nitrogen in nature. It is a continuous cycle maintained by the decomposers and other bacteria. The nitrogen cycle can be broken down into four types of reaction and micro-organisms play roles in all of these (see Table 1). Nitrogen fixation Nitrogen gas is composed of two atoms of nitrogen linked by a very strong triple bond. This makes it chemically unreactive and large amounts of energy are required to break the bond. Nitrogen gas can be fixed in three ways. Atmospheric fixation. This occurs spontaneously by lightning; only a small amount (5–8%) is fixed this way. Lightning allows nitrogen and oxygen to combine to produce various oxides of nitrogen. These are carried by the rain into the soil where they can be used by plants. Industrial fixation. The Haber-Bosch process is used to make nitrogen-containing fertilizers. This is a very energy-inefficient process. Biological fixation. Nitrogen-fixing bacteria fix 60% of nitrogen gas in the atmosphere. Biological fixation The reduction of nitrogen gas to ammonia is energy-intensive. It requires 16 molecules of ATP and a complex set of enzymes to break the bonds so that the nitrogen can combine with hydrogen. Its reduction can be written as: N2 + 3H2→ 2NH3 Relatively few bacteria (the nitrogen-fixing bacteria) are able to carry out this reaction. Fixed nitrogen is made available to plants by the death and lysis of free-living nitrogen-fixing bacteria or from the symbiotic association of some nitrogen-fixing bacteria with plants. Table 1. Reactions of the nitrogen cycle. Reaction Micro-organism Conditions Process Nitrogen fixation Nitrogen-fixing bacteria, e.g. Rhizobium Aerobic/anaerobic The first step in the synthesis of virtually all nitrogenous compounds. Nitrogen gas is fixed into forms other organisms can use. Ammonification (decay) Ammonifying bacteria (decomposers) Aerobic/anaerobic The decomposers, certain soil bacteria and fungi, break down proteins in dead organisms and animal wastes, releasing ammonium ions which can be converted to other nitrogen compounds. Nitrification Nitrifying bacteria e.g. Nitrosomonas, Nitrobacter Aerobic Nitrification is a two-step process. Ammonia or ammonium ions are oxidized first to nitrites and then to nitrates, which is the form most usable by plant. Denitrification Denitrifying bacteria Anaerobic Nitrates are reduced to nitrogen gas, returning nitrogen to the air and completing the cycle. Types of nitrogen-fixing bacteria Some nitrogen-fixing bacteria are free-living in the soil, fixing nitrogen independently of other organisms, e.g. Azotobacter (aerobic) and Clostridium (anaerobic). Other nitrogen-fixing bacteria form symbiotic associations with plants. Root-nodulated legumes, such as peas and beans, with e.g. Rhizobium. Free-living rhizobia invade the legume through an infection thread formed in the root hair of the plant. The infection thread is constructed by the root cells, not the bacteria, and is formed only in response to infection. The infection thread grows through the root hair cells and penetrates other root cells nearby, often with branching of the thread. The root cells then proliferate to form a root nodule. Within a week of infection, small nodules are visible to the naked eye. Each root nodule is packed with thousands of living Rhizobium bacteria (known as bacteroids). Root-nodulated non-legumes, a diverse group of woody species such as alder, with e.g. Frankia. These filamentous bacteria infect the roots of plants forming actinorhizal root nodules. Azolla (tiny free-floating water ferns) with e.g. Anabaena azollae. This is a cyanobacterium that infects new leaves of Azollas as they develop from the stem. Strings of Anabaena get caught in tiny leaf hairs that grow from a dimple on the developing leaf. The dimple grows larger into a pouch-like structure that eventually closes up, locking the Anabaena inside the leaf. Adapting to their environment Nitrogen-fixing bacteria contain an enzyme complex called nitrogenase which catalyses the conversion of nitrogen gas to ammonia. It supplies hydrogen ions as well as energy from ATP. The nitrogenase enzyme is sensitive to oxygen, becoming inactivated when exposed to it. This is not a problem with the free-living anaerobic bacteria such as Clostridium. Free-living aerobic bacteria have a variety of different mechanisms for protecting the nitrogenase complex, including high rates of metabolism and physical barriers. Azotobacter overcome this problem by having the highest rate of respiration of any organism, thus maintaining a low level of oxygen in their cells. Rhizobium contains leghaemoglobin. This functions similarly to haemoglobin, i.e. it binds to oxygen. This provides sufficient oxygen for the metabolic functions of the bacteroids, but prevents the accumulation of free oxygen that would destroy the activity of nitrogenase. Frankia and Anabaena are able to exclude oxygen by carrying out the fixation in specialized structures known, respectively, as a vesicle and a heterocyst. The thick walls of the vesicle and heterocyst form an oxygen diffusion barrier. Nitrification This is the oxidation of ammonium compounds to nitrites and then to nitrates by the nitrifying bacteria. During these oxidation reactions energy is released. The nitrifying bacteria are chemoautotrophs and are able to use this source of energy to produce organic compounds from inorganic ones (photo-autotrophs use light energy to produce organic compounds from inorganic ones). Nitrification is a two-step process. Bacteria of the genus Nitrosomonas convert ammonium ions to nitrites (NO2−). (Nitrite is toxic to plants and animals at high concentrations.) Bacteria of the genus Nitrobacter convert nitrites to nitrates (NO3−). The nitrates can then be taken in by plants. Nitrification occurs in well-drained and aerated soils at neutral pH. Denitrification This is the conversion of nitrates into primarily nitrogen gas, but also nitrous oxide gas by the denitrifying bacteria, e.g. Pseudomonas. Denitrifying bacteria transform nitrate in extremely wet soils and swampy grounds where there is very little oxygen, i.e. the conditions are anaerobic. The bacteria get the oxygen they need for respiration from the breakdown of nitrates. The gases that are formed escape into the atmosphere completing the nitrogen cycle. This can be a harmful process as fixed nitrogen is removed from the soil making it less fertile. Ammonification (decay) This is the conversion of organic forms of nitrogen (e.g. in dead organisms and their excretions) into inorganic nitrogen. A wide range of soil fungi and bacteria, called the decomposers, carry out the ammonification process. The decomposers consume the organic matter, and the nitrogen contained in the dead organism is converted to ammonium ions. The ammonium is then converted to nitrates by the nitrifying bacteria. Practical – isolating microbes from root nodules Learning objectives To show the role of microbes in the nitrogen cycle, how microbes can be grown from root nodules and an example of symbiosis. Materials Plant with root nodules, e.g. clover, peas Mannitol yeast extract agar plate (Recipe: Suspend 10 g agar in 1 litre water. Heat to dissolve. Add 0.5 g K2HPO4, 0.2 g MgSO4.7H2O, 0.2 g NaCl, 0.2 g CaCl2.6H2O, 10 g mannitol and 0.4 g yeast extract. Dispense and sterilize by autoclaving.) Sterile distilled water in beaker (covered) 70% (v/v) industrial denatured alcohol in a small beaker or glass Petri dish covered in foil (caution: flammable, keep covered and away from lit Bunsen burner) 5 sterile Petri dishes Bunsen burner Pasteur pipettes: 1 sterile, 1 non-sterile Sterile glass rod Scalpel Metal forceps (can be pre-sterilized by autoclaving) Wire loop Beaker of disinfectant Discard pot Marker pen Adhesive tape Recommendations Advance planning is necessary to obtain suitable plant material. Clover (obtain seeds from school science suppliers or plants from a field or lawn) is recommended as the nodules are relatively soft. Potato dextrose agar supplemented with 0.25 g yeast extract per litre may be used instead of mannitol yeast extract agar. The plates should be incubated preferably at 20–25°C or at room temperature for 2–3 days. If the nodules are cleaned well in the alcohol, a population of predominantly Rhizobium should result. Students should be informed that they are using sterile apparatus so that any bacteria that do grow on their plates are likely to have come from the root nodules. 1% bleach solution can be used instead of alcohol to clean the nodules. The colonies of Rhizobium are off-white with a sticky appearance. Colonies of other colours are not Rhizobium; they may be either intracellular contaminants from the nodule or soil microbes that have survived the washing and alcohol treatment. Procedure Choose a length of root that has nodules and cut off a portion about 1 cm long using a scalpel. Hold the portion of root by forceps and wash free of soil using tap water. Transfer several drops of 70% (v/v) industrial denatured alcohol by Pasteur pipette fitted with a teat to a sterile Petri dish. The pipette need not be sterile for this operation; put the pipette into a discard pot. Transfer the washed portion of the root to the alcohol in the Petri dish with forceps and leave immersed for 1–2 minutes to sterilize it. Use aseptic technique from this stage forward. Transfer sufficient sterile water to cover the base of another Petri dish using a sterile Pasteur pipette fitted with a teat. If it is necessary to re-use the pipette, keep it sterile, e.g. by resting under the lid of a sterile Petri dish base. Use sterile forceps or sterilize them by dipping in alcohol (keeping the points facing downward) and passing quickly through the Bunsen burner flame, allow to cool and use to transfer the portion of root to the sterile water in the Petri dish to rinse off the alcohol. Repeat this operation at least twice more with fresh sterile water. If using alcohol take care to keep the pot well away from the Bunsen burner flame. Transfer a few drops of sterile water to a sterile Petri dish and add the portion of root using sterile metal forceps. Macerate the nodules using a sterile glass rod (or forceps) to produce a milky fluid. Label the base of a mannitol yeast extract agar plate with your name, the date and MYEA. Sterilize a wire loop by flaming, cool it, take a loopful of the nodule macerate and streak it out on the plate as shown here: Reflame the loop. Tape the lid on the plate, invert it and incubate for 3–4 days. Dispose of contaminated materials appropriately. Next lesson... Examine the MYEA plate without removing the lid, noting the appearance of any colonies growing on the agar. Reproduced from our education resource, Practical Microbiology for Secondary Schools. This publication and its companion Basic Practical Microbiology (which contains details of how to carry out a risk assessment) are available free to School Members. Please contact {email protected}. Daniel Burdass is Head of Communications Nitrogen is a component of proteins and nucleic acids and is essential to life on Earth. Although nitrogen is abundant in the atmosphere, most organisms cannot use it in that form. Nitrogen-fixing bacteria accomplish more than 90 percent of all nitrogen fixation and thus play an important role in the nitrogen cycle. Because of these bacteria, legumes have the nitrogen necessary to make lots of proteins, which, in turn, is why beans are such a good source of dietary protein for humans and other animals. Additionally, legumes and certain cereal grasses are often grown as green manures and for crop rotation on farms as an organic source of nitrogen for other crops. Key Points Bacteria, such as cyanobacteria, convert nitrogen into nitrogen gas via nitrogen fixation. Nitrogen fixation occurs in three steps: ammonification, nitrification, and denitrification. Human activity can release nitrogen into the environment by the combustion of fossil fuels and by the use of artificial fertilizers in agriculture. Atmospheric nitrogen is responsible for acid rain, the release of greenhouse gasses, and eutrophication. Nitrogen fixation can be performed by marine bacteria; nitrogen falls to the ocean floor as sediment and is then moved to land, becoming incorporated into terrestrial rock. Key Terms denitrification: process of converting nitrates into nitrogen gas, especially by the action of bacteria nitrification: the conversion of ammonium into nitrites (NO2−) by nitrifying bacteria ammonification: the formation of ammonia or its compounds from nitrogenous compounds, especially as a result of bacterial decomposition All organisms require nitrogen because it is an important component of nucleic acids, proteins, and other organic molecules. Getting nitrogen into the living world is difficult. Plants and phytoplankton are not equipped to incorporate nitrogen from the atmosphere (which exists as tightly-bonded, triple-covalent N2), even though this molecule comprises approximately 78 percent of the atmosphere. Nitrogen enters the living world through nitrogen fixation (Figure 1(1-2)), the process of converting nitrogen gas into ammonia (NH3), which spontaneously becomes ammonium (NH4+). Ammonium is found in bodies of water and in the soil (Figure 1(1-2)). Figure 1(PageIndex(1)): Nitrogen enters the living world from the atmosphere through nitrogen-fixing bacteria. This nitrogen and nitrogenous waste from animals is then processed back into gaseous nitrogen by soil bacteria, which also supply terrestrial food webs with the organic nitrogen they need (credit: "shipworms" (wood-eating bivalves). Although the first stable product of the process is ammonia, this is quickly incorporated into protein and other organic nitrogen compounds. Figure 1(PageIndex(3)): Nitrogen-fixing bacteria live in the spherical nodules of this soybean root. Image by United Soybean Board is licensed under CC BY 2.0 Organic nitrogen is especially important to the study of ecosystem dynamics since many ecosystem processes, such as primary production and decomposition, are limited by the available supply of nitrogen. Plants and other producers directly use ammonium and nitrates to make organic molecules through the process of assimilation (Figure 1(PageIndex(2))). This nitrogen is now available to consumers. Consumers excrete organic nitrogen compounds that return to the environment. Additionally dead organisms at each trophic level contain organic nitrogen. As shown in Figure 1(PageIndex(2)), the nitrogen that enters living systems by nitrogen fixation is eventually converted from organic nitrogen back into nitrogen gas by bacteria. This process occurs in three steps in terrestrial systems: ammonification, nitrification, and denitrification. First, the ammonification or nitrogen mineralization process converts nitrogenous waste from living organisms or the remains of dead organisms into ammonium (NH4+) by certain bacteria and fungi. Second, this ammonium is then converted to nitrites (NO2−) and then nitrates (NO3−) by nitrifying bacteria and archaea, such as Nitrosomonas or Nitrobacter, through the process of nitrification. In addition, both soil and the ocean contain archaeal microbes, assigned to the Crenarchaeota, that convert ammonia to nitrites. They are more abundant than the nitrifying bacteria and may turn out to play an important role in the nitrogen cycle. Like ammonium, nitrites and nitrates are found in water and the soil. Some nitrates are converted back into nitrogen gas, which is released into the atmosphere. The process, called denitrification, is conducted by bacteria, such as Pseudomonas and Clostridium, which use nitrate when decomposing organic matter in the absence of oxygen. In the process of denitrification several intermediates are formed and may be released to the atmosphere including nitric oxide (NO) and nitrous oxide (N2O, a greenhouse gas). Under anaerobic conditions in marine and freshwater systems other species of bacteria are able to oxidize ammonia with nitrite forming nitrogen gas in a process called anammox (anaerobic ammonia oxidation). In marine ecosystems, nitrogen compounds created by bacteria, or through decomposition, collects in ocean floor sediments. It can then be moved to land in geologic time by uplift of Earth's crust and thereby incorporated into terrestrial rock. Although the movement of nitrogen from rock directly into living systems has been traditionally seen as insignificant compared with nitrogen fixed from the atmosphere, a recent study showed that this process may indeed be significant and should be included in any study of the global nitrogen cycle (Morford et al., 2011). Human activity can release nitrogen into the environment by two primary means: the combustion of fossil fuels, which releases different nitrogen oxides, and by the use of artificial fertilizers (which contain nitrogen and phosphorus compounds) in agriculture, which are then washed into lakes, streams, and rivers by surface runoff. Humans are also increasing the amount of reactive nitrogen in the environment by the cultivation of nitrogen fixing crops, such as soybeans. If the nitrogen fixation from leguminous crops (e.g. beans, alfalfa) is included, then the anthropogenic flux of nitrogen from the atmosphere to the land exceeds natural fluxes to the land. Atmospheric nitrogen (other than N2) is associated with several effects on Earth's ecosystems including the production of acid deposition (as nitric acid, HNO3), also known as acid rain. Acid deposition damages healthy trees, destroys aquatic systems and erodes building materials such as marble and limestone. Like carbon dioxide, nitrous oxide (N2O) is a greenhouse gas, potentially causing climate change when released during denitrification. Humans are primarily dependent on the nitrogen cycle as a supporting ecosystem service for crop and forest productivity. Nitrogen fertilizers are added to enhance the growth of many crops and plantations (figure 1(PageIndex(4))). The enhanced use of fertilizers in agriculture was a key feature of the green revolution that boosted global crop yields in the 1970s. The industrial production of nitrogen-rich fertilizers has increased substantially over time and now matches more than half of the input to the land from biological nitrogen fixation (90 megatons = 1 million tons of nitrogen each year). If the nitrogen fixation from legume crops is included, then the anthropogenic flux of nitrogen from the atmosphere to the land exceeds natural fluxes to the land. Fertilizers are washed into lakes, streams, and rivers by surface runoff, resulting in saltwater and freshwater eutrophication, a process whereby nutrient runoff causes the overgrowth of algae, the depletion of oxygen, and death of aquatic fauna. Excess nitrates in water supplies have also been linked to human health problems. Figure 1(PageIndex(4))). Fertilizer containing nitrogen is conventionally applied at large scales in agriculture. Image by Bob Nichols, USDA National Resources Conservation Service is available in the public domain. Efforts to reduce nitrogen pollution focus on increasing the efficiency of synthetic fertilizer use, altering feeding of animals to reduce nitrogen content in their excreta, and better processing of livestock waste and sewage sludge to reduce ammonia release. At the same time, increasing demand for food production from a growing global population with a greater appetite for meat is driving greater total fertilizer use, so there is no guarantee that better practices will lead to a reduction in the overall amount of nitrogen pollution. Morford, S. L., Houlton, B. Z., & Dahlgren, R. A. (2011). Increased forest ecosystem carbon and nitrogen storage from nitrogen-rich bedrock. Nature, 477(7362), 78–81. Editors: Peggy Yang and Angela Lin Similar to the water cycle, nitrogen also cycles in nature with the help of different types of bacteria. About 78% of the air in the Earth's atmosphere is made up of nitrogen meaning that it is very abundant. With the help of the nitrogen cycle, nitrogen can exist in soil, water, and the air. It is the nutrient that plants need to make chlorophyll and capture sunlight. Nitrogen is also needed for proteins, DNA, and amino acids. Too much nitrogen can have side effects as well. Nitrogen-based fertilizer can cause nitrogen pollution in our water ecosystems. Even though we have a lot of nitrogen, much of it is in the gaseous form (N2) which cannot be used by living organisms. That is where the nitrogen cycle comes in to convert this unusable form of nitrogen into something usable. Nitrogen fixation, nitrification, and denitrification are the three main processes in the nitrogen cycle. All of the bacteria used in the nitrogen cycle contain special enzymes that allow them to do their role in the cycle. Nitrogen-fixing bacteria convert nitrogen gas to ammonium and/or nitrate which can be used by plants. This type of bacteria can be found in soil or nodes in the roots of legumes. Bacillus, clostridium, rhizobium, and azotobacter are all examples of nitrogen-fixing bacteria. A special enzyme in these bacteria called nitrogenase allows for the conversion to ammonium, which is a nutrient used by plants. Bacteria play a big role in the nitrogen cycle. Nitrifying bacteria can either convert ammonium to nitrite through oxidation or convert nitrite to nitrate. Through this oxidation process, energy is obtained for nitrifying bacteria. Special enzymes, monooxygenase and nitrite oxidoreductase in the bacteria allows the nitrification process to occur. The process of denitrification completes the cycle where nitrates are converted back to nitrogen gas. Although nitrate and nitrite are essential nutrients to maintain the well-being of plants, there can be an excess of nitrate in the soil. Denitrifying bacteria are necessary to prevent the accumulation of nitrogen in the water. By releasing the nitrogen as gas, it can re-enter the soil and be reused by plants. The nitrogen cycle is not complete without denitrifying bacteria. Some examples include the pseudomonas family denitrificans. These bacteria have the enzymes nitric oxide reductase, nitrite reductase, and nitrate reductase. The nitrogen cycle is dependent on bacteria to convert and recycle all forms of nitrogen. "Denitrifying Bacteria." Encyclopedia Britannica, Encyclopædia Britannica, Inc., www.britannica.com/science/denitrifying-bacteria. "Nitrifying Bacteria." Nitrifying Bacteria - an Overview | ScienceDirect Topics, www.sciencedirect.com/topics/agricultural-and-biological-sciences/nitrifying-bacteria#:~:text=Nitrifying%20bacteria%20possess%20specific%20enzymes,hydroxylamine%2C%20respective%20nitrite%20to%20nitrate. "Nitrogen-Fixing Bacteria." Encyclopædia Britannica, Encyclopædia Britannica, Inc., www.britannica.com/science/nitrogen-fixing-bacteria. The series of processes by which nitrogen and its different forms are circulated and interconverted in nature with the help of living organisms is called the nitrogen cycle. It shows the path that nitrogen follows through the biogeochemical cycle using its storage reservoirs, such as the atmosphere, living organisms, and soil. Nitrogen Cycle Diagram The entire process of the Nitrogen Cycle, one of the important biogeochemical cycle takes place in five stages: 1) Nitrogen Fixation by Bacteria - Converting inert atmospheric nitrogen (N2)into biologically available forms such as ammonia (NH3), nitrates, or nitrites 2) Nitrification by Bacteria - Converting ammonia to nitrite and then to nitrate 3) Assimilation by Plants - Absorbing nitrogen from the soil and incorporating them in the plant and animal bodies 4) Ammonification by Decomposers - Converting the dead organic nitrogen of plants or animals back into ammonia 5) Denitrification by Denitrifiers - Reducingnitrates or nitrites and releasing gaseous nitrogen What role do bacteria play in the nitrogen cycle? Nitrogen fixation - Performed by two different groups of bacteria - a) symbiotic nitrogen fixers like Rhizobium, which keep a close association with the host leguminous plant, and b) free-living, non-symbiotic bacteria like Azotobacter. Both these group of bacteria use specific enzymes to complete the biological nitrogen fixation process by the following reaction - N2 + 8 H+ + 8 e− → 2 NH3 + H2 Nitrification - Performed by nitrifying bacteria in two steps - 1) Ammonia-oxidizing bacteria such as Nitrosomonas species perform oxidation of ammonia to nitrite by the following reaction - 2NH4+ + 3O2 + 8 e− → 2 NO2− + 4H2 + 2H2O 2) Nitrite-oxidizing bacteria such as Nitrobacter species perform oxidation of nitrite (NO2−) to nitrate (NO3−) by the following reaction - 2 NO3− + O2 → 2 NO3- Plants help in the assimilation of nitrogen when they absorb it from the soil in the form of ammonia, nitrite ions, nitrate ions or ammonium ions to form plant and animal proteins. In leguminous plants such as pea and bean, the symbiotic association with Rhizobium helps to assimilate nitrogen directly in the form of ammonium ions. Detritus feeders or decomposers such as fungi and bacteria present in the soil convert the dead organic matter of plants or animals back into ammonia (NH3) or ammonium ions (NH4+). Denitrifiers such as Clostridium and Pseudomonas helps in the reduction ofnitrates (NO3) or nitrites (NO2), resulting in the escape of gaseous nitrogen which again returns to the cycle. Lightning with thunderstorm serves as an important source of fixing nitrogen in the atmosphere apart from bacteria mediated nitrogen fixation. Here the energy of lightning breaks atmospheric nitrogen into nitrogen oxides which can then be utilized by plants for assimilation. Allowing plants and animals to use nitrogen by converting atmospheric nitrogen to a more chemically available form such as ammonium (NH4+), nitrate (NO3−) or organic nitrogen Enriching the soil through the formation of Nitrates and nitrites which are essential for the cultivationhelping in the synthesis of some biomolecules such as amino acids, nucleic acids, and chlorophyll, the building blocks of lifeDecomposing dead plant and animal matter by decomposers which cleans up the environment Human activities release excess nitrogen into the environment, eventually disturbing the balance of nitrogen in its different reservoirs in two possible ways: Burning of Fossil FuelUse of Nitrogen-Containing Fertilizers Burning fossil fuels like coal, petroleum, and natural gas releases excess nitrogen into the environment that accumulates over time. An increase in the concentration of nitrogen is found to affect the climate of the earth by gradually increasing its temperature, causing greenhouse effect and global warming. When artificial fertilizers containing nitrogen as one of the components are washed away from the agricultural fields, it contaminates the nearby water bodies and also the groundwater making it more difficult for the plants to absorb the nitrogen both for the terrestrial and aquatic plants. Since nitrogen fixation by plants is affected, it affects the nitrogen cycle. Article was last reviewed on Tuesday, February 25, 2020 Gallaway, J. N. et al. Year 2020: Consequences of population growth and development on deposition of oxidized nitrogen. Ambio 23, 120–123 (1994). Howarth, R. W. Coastal nitrogen pollution: a review of sources and trends globally and regionally. Harmful Algae 8, 14–20. (2008). Johnson, P. T. J. et al. Linking environmental nutrient enrichment and disease emergence in humans and wildlife. 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Nitrogenase gene diversity and microbial community structure: a cross-system comparison. Environmental Microbiology 5, 539–554 (2003). Fertiliser design and environmental impact of fertilisers Bacteria play a crucial role in the nitrogen cycle because they facilitate the conversion of nitrogen into different forms that can be used by plants and animals. For example, nitrogen-fixing bacteria convert atmospheric nitrogen (N2) into ammonia (NH3), which plants can absorb and use. Other bacteria convert ammonia into nitrites (NO2-) and then into nitrates (NO3-), which are also absorbable by plants. Finally, denitrifying bacteria convert nitrates back into nitrogen gas, completing the cycle. Without these bacteria, the nitrogen in the atmosphere would not be accessible to most life forms.Analogy / Example