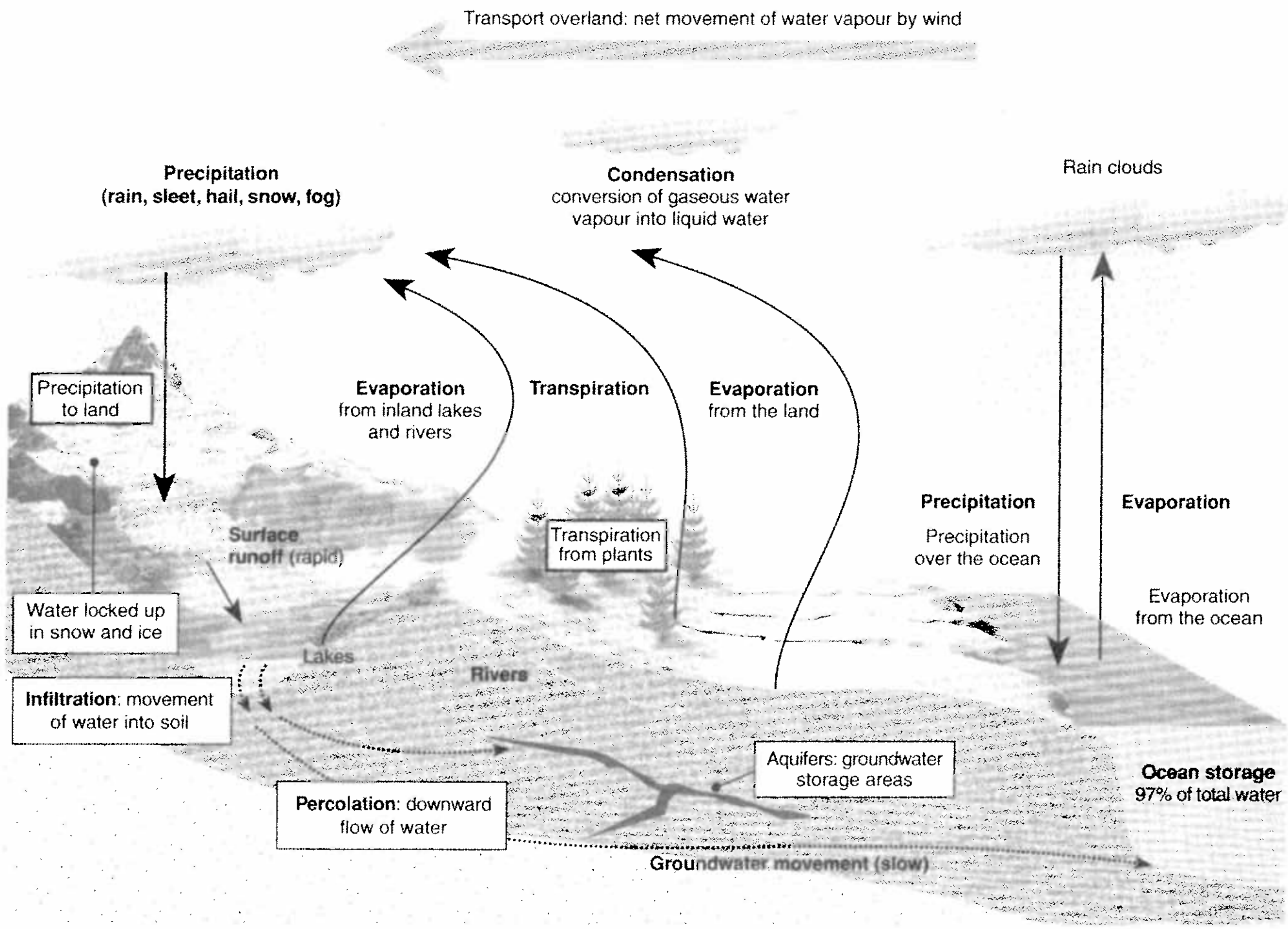
The Water Cycle

The hydrologic cycle (water cycle), collects, purifies, and distributes the Earth's fixed supply of water. The main processes in this water recycling are described below. Besides replenishing inland water supplies, rainwater causes erosion and is a major medium for transporting dissolved nutrients within and among ecosystems. On a global scale, evaporation (conversion of water to gaseous water vapour) exceeds precipitation (rain, snow etc.) over the oceans. This results in a net movement of water vapour (carried by winds) over the land. On land, precipitation exceeds evaporation. Some of this precipitation becomes locked up in snow and ice, for varying lengths of time. Most forms surface and groundwater systems that flow back to the sea, completing the major part of the cycle. Living organisms, particularly plants, participate to varying degrees in the water cycle. Over the sea, most of the water vapour is due to evaporation alone. However on land, about 90% of the vapour results from plant transpiration. Animals (particularly humans) intervene in the cycle by utilising the resource for their own needs.



1. Identify two ways in which water returns to the oceans from the land:

   (a) ______________________ (b) ______________________

2. Briefly describe three ways in which humans may intervene in the water cycle, and the effects of these interventions:

   (a) ______________________

   (b) ______________________

   (c) ______________________

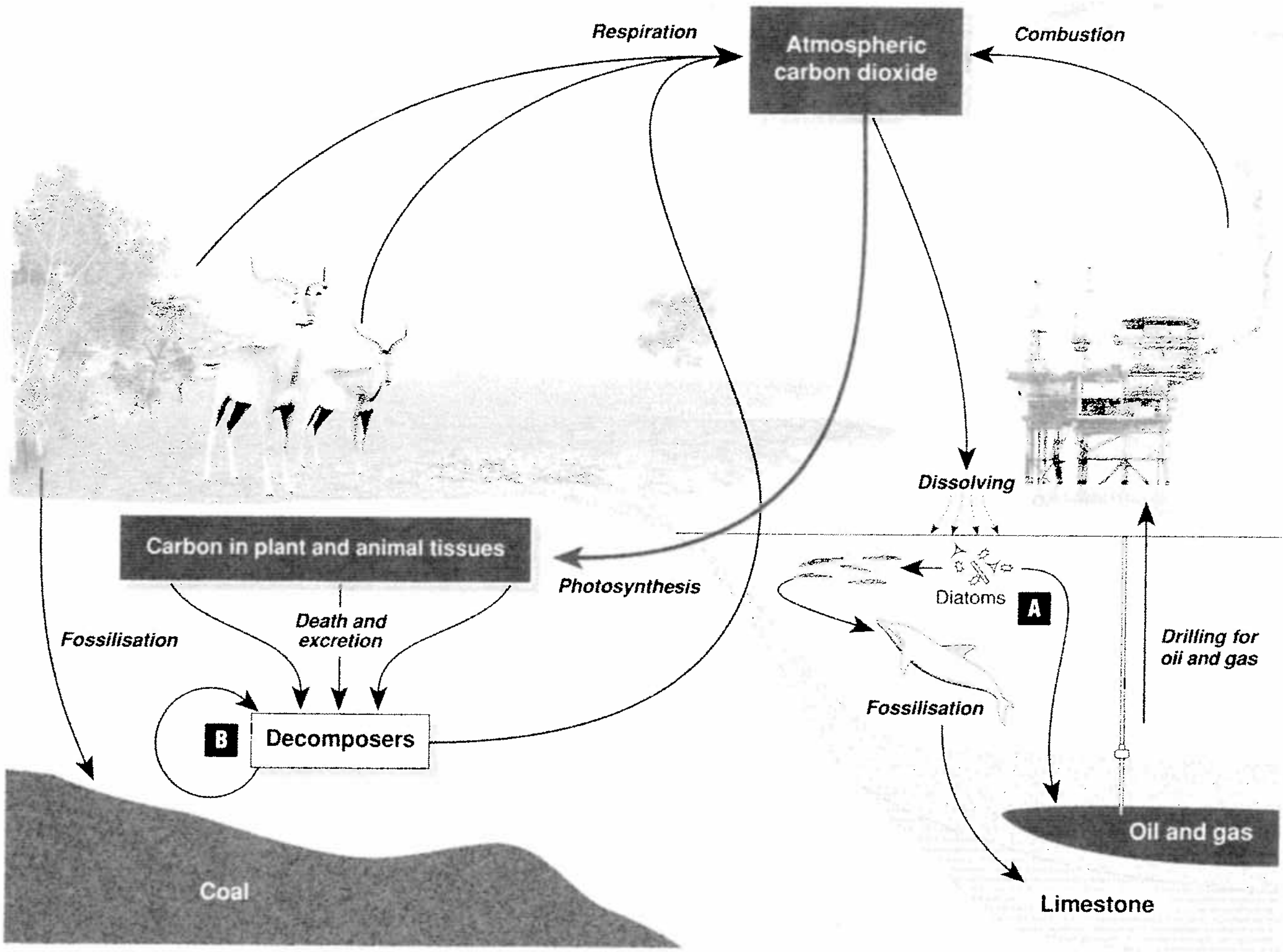
3. Identify the main reservoir for water on Earth: ______________________

4. Identify the main reservoirs for fresh water: ______________________

5. Describe the important role of plants in the cycling of water through ecosystems: ______________________

The Carbon Cycle

Carbon is an essential element in living systems, providing the chemical framework to form the molecules that make up living organisms (e.g. proteins, carbohydrates, fats, and nucleic acids). Carbon also makes up approximately 0.03% of the atmosphere as the gas carbon dioxide (CO_2), and it is present in the ocean as carbonate and bicarbonate, and in rocks such as limestone. Carbon cycles between the living (biotic) and non-living (abiotic) environment: it is fixed in the process of photosynthesis and returned to the atmosphere in respiration. Carbon may remain locked up in biotic or abiotic systems for long periods of time as, for example, in the wood of trees or in fossil fuels such as coal or oil. Human activity has disturbed the balance of the carbon cycle (the global carbon budget) through activities such as combustion (e.g. the burning of wood and **fossil fuels**) and deforestation.



1. In the diagram above, add arrows and labels to show the following activities:

   (a) Dissolving of limestone by acid rain
   (b) Release of carbon from the marine food chain
   (c) Mining and burning of coal
   (d) Burning of plant material.

2. Describe the **biological origin** of the following geological deposits:

   (a) Coal: ______________________________

   (b) Oil: ______________________________

   (c) Limestone: ______________________________

3. Describe the two processes that release carbon into the atmosphere: ______________________________

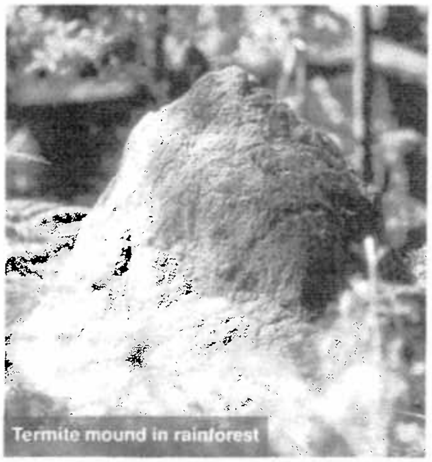
   ____

   ____

4. Name the four geological reservoirs (sinks), in the diagram above, that can act as a source of carbon:

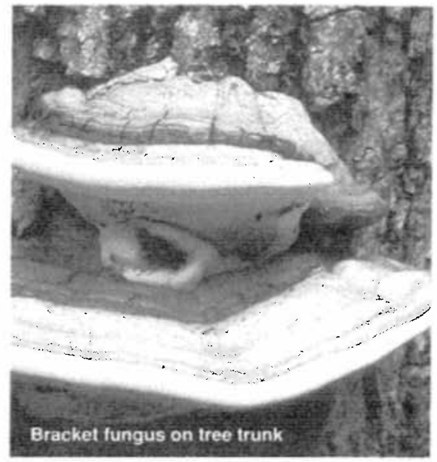
   (a) ______________ (c) ______________

   (b) ______________ (d) ______________



Termites: These insects play an important role in nutrient recycling. With the aid of symbiotic protozoans and bacteria in their guts, they can digest the tough cellulose of woody tissues in trees. Termites fulfill a vital function in breaking down the endless rain of debris in tropical rainforests.

Dung beetles: Beetles play a major role in the decomposition of animal dung. Some beetles merely eat the dung, but true dung beetles, such as the scarabs and *Geotrupes*, bury the dung and lay their eggs in it to provide food for the beetle grubs during their development.



Fungi: Together with decomposing bacteria, fungi perform an important role in breaking down dead plant matter in the leaf litter of forests. Some mycorrhizal fungi have been found to link up to the root systems of trees where an exchange of nutrients occurs (a mutualistic relationship).

5. Explain what would happen to the carbon cycle if there were no decomposers present in an ecosystem:

6. Study the diagram on the previous page and identify the processes represented at the points labelled [**A**] and [**B**]:

   (a) Process carried out by the diatoms at label **A**:

   (b) Process carried out by the decomposers at label **B**:

7. Explain how each of the three organisms listed below has a role to play in the carbon cycle:

   (a) Dung beetles:

   (b) Termites:

   (c) Fungi:

8. In natural circumstances, accumulated reserves of carbon such as peat, coal and oil represent a **sink** or natural diversion from the cycle. Eventually the carbon in these sinks returns to the cycle through the action of geological processes which return deposits to the surface for oxidation.

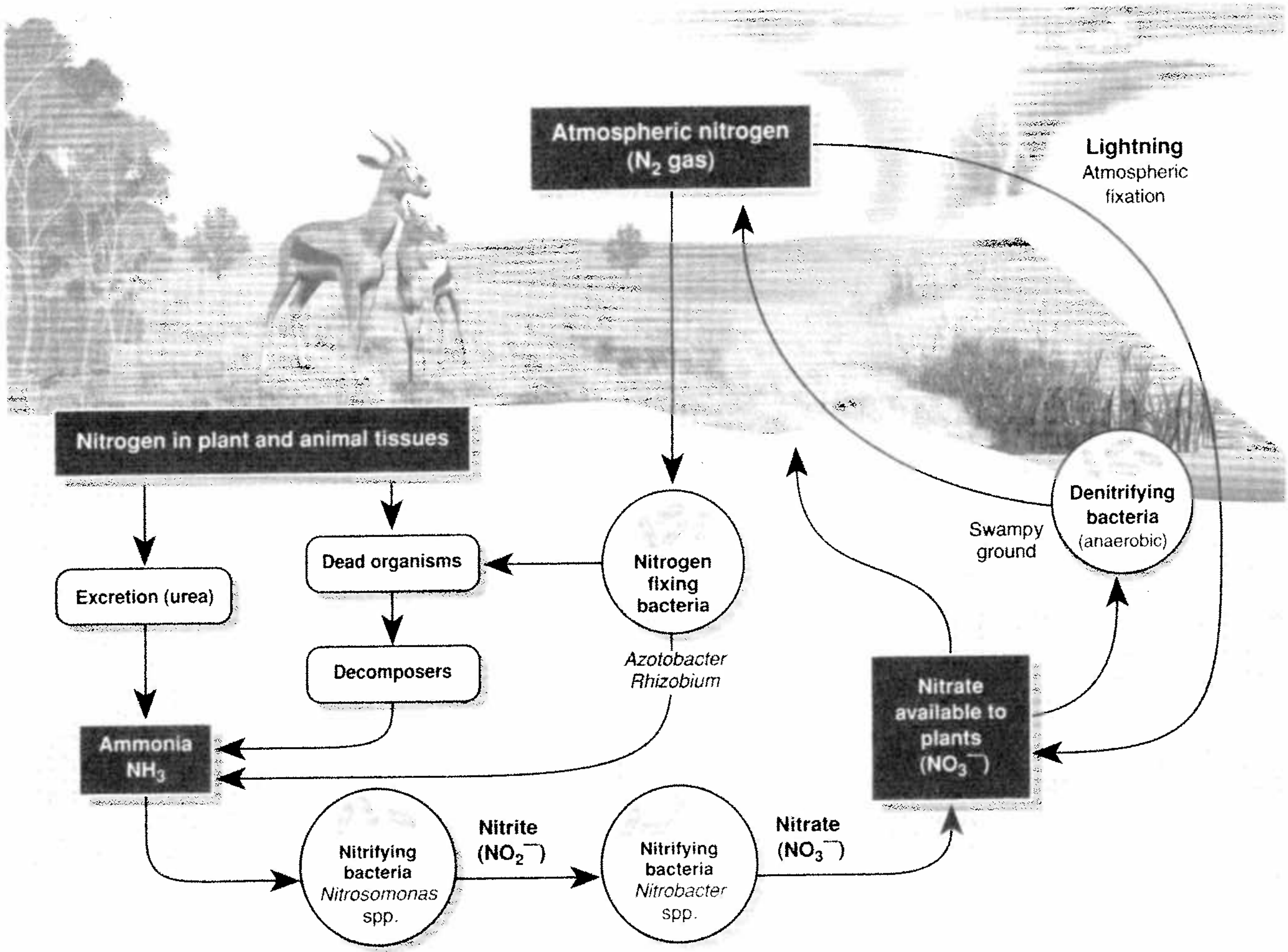
   (a) Describe what effect human activity is having on the amount of carbon stored in sinks:

   (b) Explain two global effects arising from this activity:

   (c) Suggest what could be done to prevent or alleviate these effects:

The Nitrogen Cycle

Nitrogen is a crucial element for all living things, forming an essential part of the structure of proteins and nucleic acids. The Earth's atmosphere is about 80% nitrogen gas (N_2), but molecular nitrogen is so stable that it is only rarely available directly to organisms and is often in short supply in biological systems. Bacteria play an important role in transferring nitrogen between the biotic and abiotic environments. Some bacteria are able to fix atmospheric nitrogen, while others convert ammonia to nitrate and thus make it available for incorporation into plant and animal tissues. Nitrogen-fixing bacteria are found living freely in the soil *(Azotobacter)* and living symbiotically with some plants in root nodules *(Rhizobium)*. Lightning discharges also cause the oxidation of nitrogen gas to nitrate which ends up in the soil. Denitrifying bacteria reverse this activity and return fixed nitrogen to the atmosphere. Humans intervene in the nitrogen cycle by producing, and applying to the land, large amounts of nitrogen fertiliser. Some applied fertiliser is from organic sources (e.g. green crops and manures) but much is inorganic, produced from atmospheric nitrogen using an energy-expensive industrial process. Overuse of nitrogen fertilisers may lead to pollution of water supplies, particularly where land clearance increases the amount of leaching and runoff into ground and surface waters.



1. Describe five instances in the nitrogen cycle where **bacterial** action is important. Include the name of each of the processes and the changes to the form of nitrogen involved:

(a) ______________________________

____

(b) ______________________________

____

(c) ______________________________

____

(d) ______________________________

____

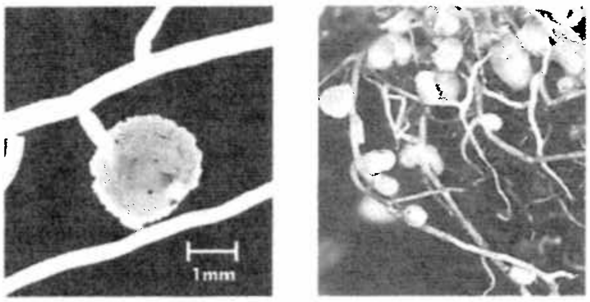
(e) ______________________________

____

Nitrogen Fixation in Root Nodules

Root nodules are a root **symbiosis** between a higher plant and a bacterium. The bacteria fix atmospheric nitrogen and are extremely important to the nutrition of many plants, including the economically important legume family. Root nodules are extensions of the root tissue caused by entry of a bacterium. In legumes, this bacterium is *Rhizobium*. Other bacterial genera are involved in the root nodule symbioses in non-legume species.

The bacteria in these symbioses live in the nodule where they fix atmospheric nitrogen and provide the plant with most, or all, of its nitrogen requirements. In return, they have access to a rich supply of carbohydrate. The fixation of atmospheric nitrogen to ammonia occurs within the nodule, using the enzyme **nitrogenase**. Nitrogenase is inhibited by oxygen and the nodule provides a low O_2 environment in which fixation can occur.



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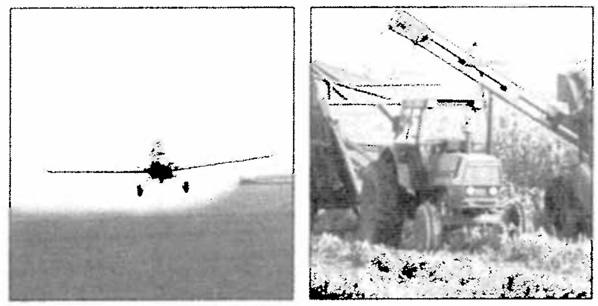
Two examples of legume nodules caused by *Rhizobium*. The photographs above show the size of a single nodule (left), and the nodules forming clusters around the roots of *Acacia* (right).

Human Intervention in the Nitrogen Cycle

Until about sixty years ago, microbial nitrogen fixation (left) was the only mechanism by which nitrogen could be made available to plants. However, during WW II, Fritz Haber developed the **Haber process** whereby nitrogen and hydrogen gas are combined to form gaseous ammonia. The ammonia is converted into ammonium salts and sold as inorganic fertiliser. Its application has revolutionised agriculture by increasing crop yields.

As well as adding nitrogen fertilisers to the land, humans use anaerobic bacteria to break down livestock wastes and release NH_3 into the soil. They also intervene in the nitrogen cycle by discharging **effluent** into waterways. Nitrogen is removed from the land through burning, which releases nitrogen oxides into the atmosphere. It is also lost by mining, harvesting crops, and irrigation, which leaches nitrate ions from the soil.



Two examples of human intervention in the nitrogen cycle. The photographs above show the aerial application of a commercial fertiliser (left), and the harvesting of an agricultural crop (right).

2. Identify three processes that **fix** atmospheric nitrogen:

   (a) ____________ (b) ____________ (c) ____________

3. Name the process that releases nitrogen gas into the atmosphere: ____________

4. Name the main geological reservoir that provides a source of nitrogen: ____________

5. State the form in which nitrogen is available to most plants: ____________

6. Name a vital organic compound that plants need nitrogen containing ions for: ____________

7. Describe how animals acquire the nitrogen they need: ____________

   ____

8. Explain why farmers may plough a crop of legumes into the ground rather than harvest it: ____________

   ____

9. Describe five ways in which humans may intervene in the nitrogen cycle and the effects of these interventions:

   (a) ____________

   ____

   (b) ____________

   ____

   (c) ____________

   ____

   (d) ____________

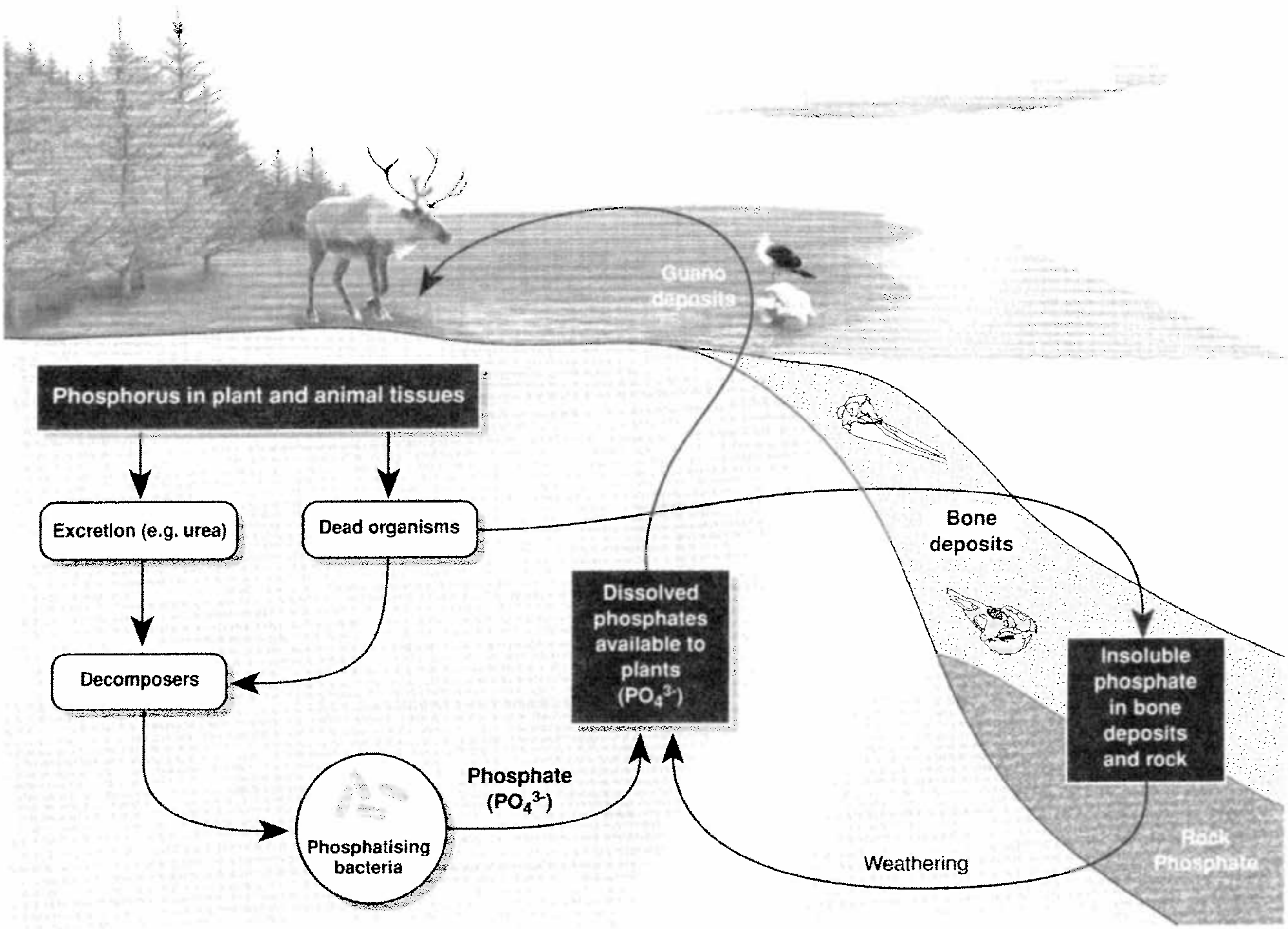
   ____

   (e) ____________

   ____

The Phosphorus Cycle

Phosphorus is an essential component of nucleic acids and ATP. Unlike carbon, phosphorus has no atmospheric component; cycling of phosphorus is very slow and tends to be local. Small losses from terrestrial systems by leaching are generally balanced by gains from weathering. In aquatic and terrestrial ecosystems, phosphorus is cycled through food webs. Bacterial decomposition breaks down the remains of dead organisms and excreted products. Phosphatising bacteria further break down these products and return phosphates to the soil. Phosphorus is lost from ecosystems through run-off, precipitation, and sedimentation. Sedimentation may lock phosphorus away but, in the much longer term, it can become available again through processes such as geological uplift. Some phosphorus returns to the land as **guano**; phosphate-rich manure (typically of fish eating birds). This return is small though compared with the phosphate transferred to the oceans each year by natural processes and human activity. Excess phosphorus entering water bodies through runoff is a major contributor to **eutrophication** and excessive algal and weed growth, primarily because phosphorus is often limiting in aquatic systems.



1. In the diagram, add an arrow and label to show where one human activity might intervene in the phosphorus cycle.

2. Identify two instances in the phosphorus cycle where bacterial action is important:

   (a) ______________________ (b) ______________________

3. Name two types of molecules found in living organisms which include phosphorus as a part of their structure:

   (a) ______________________ (b) ______________________

4. Name and describe the origin of three forms of inorganic phosphate making up the geological reservoir:

   (a) ______________________

   (b) ______________________

   (c) ______________________

5. Describe the processes that must occur in order to make rock phosphate available to plants again: ______________________

   ____

6. Identify one major difference between the phosphorus and carbon cycles: ______________________

   ____