# Coelom and Atrium in Herdamania

Due to overdevelopment of the atrium or peribranchial cavity, the true coelom in Herdmania is absent except in certain doubtful derivatives, like the pericardial cavity, gonad, etc. Like that of Ascidia, the space between the pharynx and the mantle is occupied by the atrium.

The atrium is divided into right and left halves due to the attachment of the pharynx with the mantle on the ventral and dorsal sides. However, both the halves are continuous dorsally and open to the exterior through the atriopore.

# Locomotion in Herdamania

Herdmania, in adult stage, is sessile. The visible movement is observed during the contraction of the body for the squirting out of water through the oral and atrial funnels. This movement is caused by three sets of special muscles.

**These are divided into the:**

(a) Oral muscle group,

(b) Atrial muscle group and

(c) Trio-oral muscle group.

Both the oral and atrial muscle groups surrounding the funnels are formed of annular muscles and the longitudinal muscles. The annular muscles are composed of strong circular muscles and sphincter muscles (oral and atrial sphincters).

The longitudinal muscles are more extensively developed than the annular muscles. The atrio-oral muscle group is composed of one muscle band running between the oral and atrial funnels and two pairs of muscles situated one pair on each side of the neural gland.

These muscles extend longitudinally from one funnel to the other. The contraction of the body is caused by the longitudinal muscles while that of the funnels is effected by the annular muscles.

# Digestive and Respiratory Systems of Herdamania

The digestive tract starts from the oral funnel. It has a tubular cavity containing the mouth at the basal end . The base of the funnel is provided with a circlet of tentacles. The tentacles are extensively branched delicate structures and form a sort of strainer to prevent the entry of larger particles into the pharyngeal cavity.

The tentacles are richly supplied with nerves, the presence of which led many workers to suggest that these are also testing organs. The tentacles are broadly divided into four varieties depending on size.

Although the number, size and shape of the tentacles show individual variation, the typical tentacular formula stands as: 8 large (5 mm in length), 8 median (2.5 mm long), 16 small (1.5 mm in length) and 32 minute (0.5 mm long). Each tentacle bears numerous paired lateral branches, called tentaculets which also carry small secondary branches. The secondary branches bear tertiary branches.

The mouth leads into a spacious sac-like pharynx or branchial sac which occupies the major part of the body. As stated earlier, the pharynx is enclosed by the atrium except the ventral and dorsal sides. The wall of the pharynx is perforated by numerous stigmata. The roof of the pharyngeal cavity is marked by the presence of a thin fold called dorsal lamina which is situated along the mid-dorsal line.

The free margin of the dorsal lamina produces 20-30 tentacle-like outgrowths, called languets. The dorsal lamina is lined outside by the non-ciliated cells while that of the languets are ciliated. The connective tissue core of both these structures contains blood sinuses. The endostyle runs as a shallow longitudinal groove running along the mid-ventral line of the pharynx.

It resembles closely that of Ascidia in structure, function and origin. At the anterior end of the pharyngeal cavity there are two pairs of ciliated bands (peripharyngeal bands) which are spaced by a peripharyngeal groove. The anterior pair of peripharyngeal bands unite to form a complete ring, while the posterior pair are interrupted to become continuous with the dorsal lamina and with the folded margins of the endostyle.

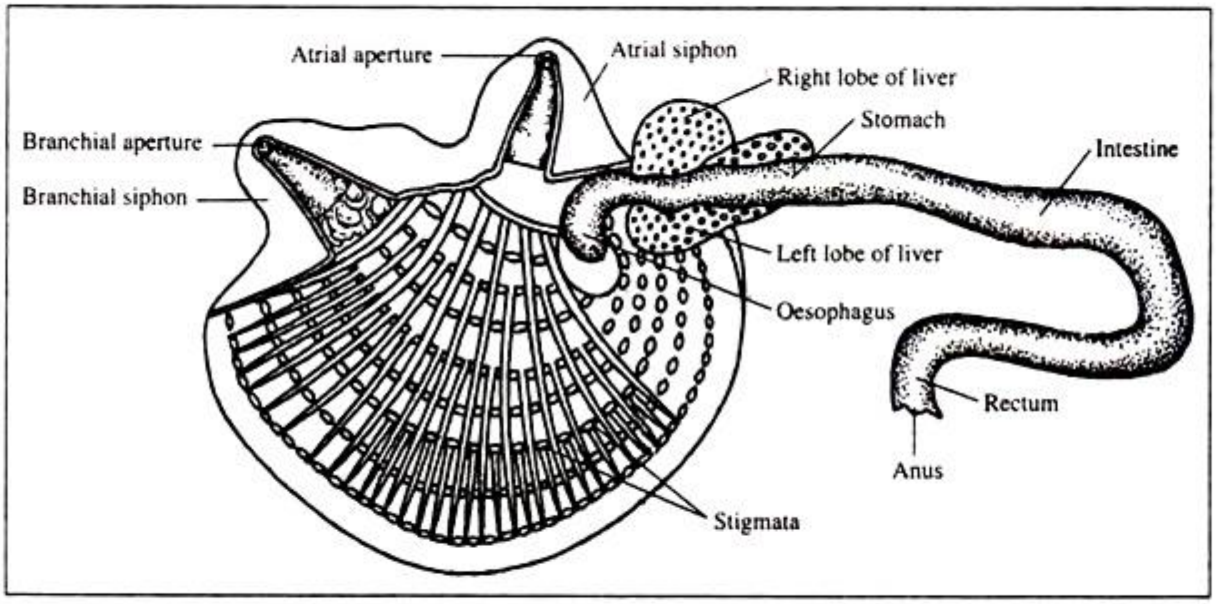



Fig. 3.6 : Digestive system of *Herdmania*.

Both the peripharyngeal bands and groove are lined by tall ciliated cells. The inner wall of the pharynx becomes folded longitudinally to increase the surface area. The inner cavity of the pharynx is lined by non-ciliated cells while the cells in the region of the stigmata are tall and ciliated.

The pharynx is supplied by two sets of blood vessels. The inner side of the pharynx is supplied by internal longitudinal vessels and the outer side by the external transverse vessels. These two types of vessels are so arranged that they cross one another at right-angles.

As a consequence, many square areas are produced which are bounded by transverse and longitudinal vessels. Such areas are often designated as the stigmatic areas. About 5-6 stigmata are present in each stigmatic area. Many small transverse blood vessels traverse the stigmatic areas.

The pharynx leads into a very short curved tube called oesophagus. The opening of the oesophagus is guarded by two semicircular folds. These folds are produced by the modification of the posterior most part of the pharynx.

The stomach is not so much dilated as seen in Ascidia. The stomach leads into the intestine which forms a single loop. The distal limb of the loop is called rectum which opens through the anus into the atrial funnel.

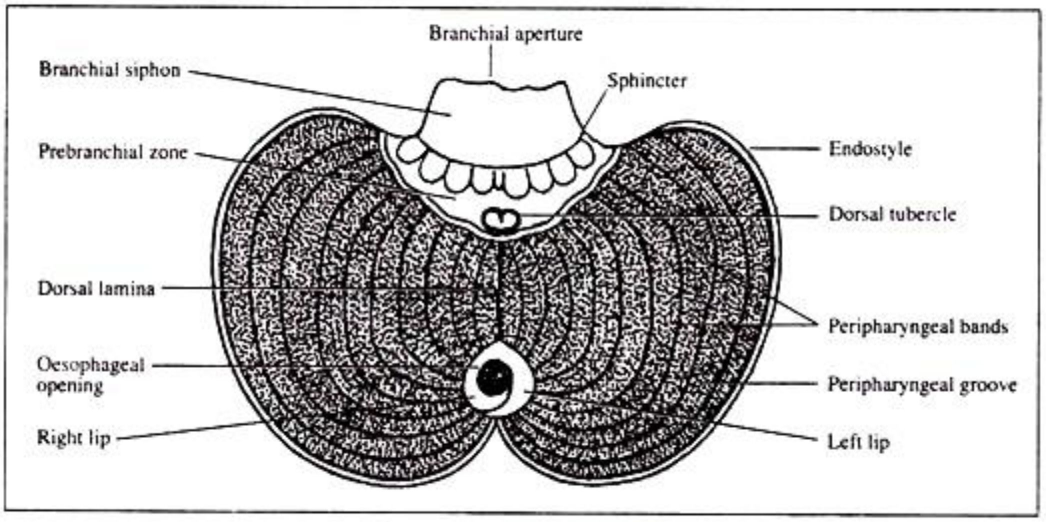


Fig. 3.7 : Pharynx of *Herdmania*.

**Digestive glands:**
A large digestive gland with two unequal lobes (liver) .is present in Herdmania. This gland is closely associated with the stomach. The liver is composed of an accumulation of a large number of caeca embedded in a ground substance.

This is made up of connective tissues and blood sinuses. The products of the liver are poured into the stomach by eleven independent ducts. Each duct is formed by the union of many ductules coming from the caeca.

The other digestive gland is the pyloric gland. It is an extensively branched structure and composed of numerous tubules. This gland remains in close contact with the stomach and intestine. The tubules unite to form a number of ducts which, ultimately open into the middle part of the intestine by a single opening.

The exact function of the pyloric gland is not properly known. It acts as a pancreas and also as an excretory organ.

The mechanism of food collection, digestion and respiration is similar to those of Ascidia. Only striking difference in the digestive system is the presence of a well-developed liver in Herdmania which is lacking in Ascidia. The digestive enzymes secreted by the distal parts of the liver-tubules are poured into the stomach.

The digestive enzymes are the amylase, protease, lipase, invertase, lactase and maltase. The liver stores carbohydrates in the form of starch. The exact relationship of the liver of Herdmania with that of vertebrates has not been experimentally established.

The respiratory system in Herdmania is more efficient than that of Ascidia. The pharynx is a highly vascular structure, and the inter-stigmatic and intra-stigmatic blood vessels help in the exchange of respiratory gases.

The presence of internal foldings increases the surface area of the pharynx. Besides the pharynx, the test also acts as an accessory respiratory organ. It is richly supplied with blood vessels and vascular ampullae.

## Circulatory System of Herdamania

The circulatory system is highly developed in Herdmania. Due to extensive vascularization of the test, the circulatory system is modified. The blood contains a few colourless amoeboid and plenty of pigmented corpuscles. Six types of corpuscles are claimed to be present in Herdmania. The pigment present in the corpuscles is either orange or yellowish-green or yellow or brown. Red colour is absent.

The heart is a cylindrical tube-like structure enclosed by tubular pericardium. The heart is attached to one side of the pericardium by a thin connective tissue bridge. It is situated ventral to the right gonad as an obliquely placed tube at about the middle of the endostyle.

The heart is a highly contractile tube though the pericardial wall is non-contractile. The wall of the heart is composed of a thin outer striated muscle layer which encloses an epithelial layer. The heart contracts and dilates with the activity of the heart muscles. The wave of contractions of the heart is alternately reversed as seen in other ascidians.

The larger blood vessels have definite wall while the small ones lack definite wall and these are mere sinuses (haemocoel). Originating from the heart, a larger vessel extends anteriorly as well as posteriorly below the whole length of the endostyle.

This is the strongest vessel in Herdmania and is called ventral or sub-endostyle vessel. The ventral vessel, throughout its course, gives paired transverse vessels to the pharynx and a stout ventral test vessel to the test. The latter originates just from the point of origin of the ventral vessel from the- heart.

Another large blood vessel located dorsal to the dorsal lamina is the dorsal vessel which receives transverse vessels from the pharynx along its course and anteriorly sends branches to the neural gland. Originating from the dorsal vessels there is a small branchio-visceral vessel.

This vessel bifurcates into right and left vessels on the respective sides of the pharynx. The left one is the ventrointestinal vessel supplying blood to the oesophagus, stomach and left lobe of liver while the right oesophageal vessel supplies the right lobe of liver and oesophagus.

From the dorsal side of the heart a cardio-visceral vessel emerges out. This vessel immediately divides into two branches. One of the branches is the hepatic vessel ramifying within the liver and the other vessel immediately bifurcates to form a slender test vessel and a stout oesophageal vessel.

The cardio-visceral vessel, after sending these branches, gives off one dorsal, a median and a ventral vessel. The dorsal branch ends in a ring-like sub-tentacular vessel. It encircles the base of the atrial funnel and sends branches to the wall of the funnel. The median branch ends in the left gonad. The ventral branch divides into dorsointestinal vessel and a sub-intestinal test vessel.

The pharynx and the test are supplied by many blood vessels from different sources. The anterior part of the pharynx is provided with peripharyngeal vessel which originates from the ventral vessel. The internal longitudinal blood vessels of the pharynx originate from the peripharyngeal vessel.

Thus the circulatory system in Herdmania is very well-developed and the course of circulation, like other Ascidians, is periodically changed by reversion of peristalsis. This phenomenon of reversal of peristalsis is not observed in any other animal except in certain larval insects.

## Excretory System of Herdamania

The neural gland in Herdmania is regarded as the excretory organ. It is an oval- shaped gland situated dorsal to the nerve ganglion. But in Ascidia its position is ventral. This gland is composed of branched tubules and many desquamated cells containing dark granules (probably the excretory products) are found in the cavity of the gland.

The actual homology of the gland is much disputed. Julin (1893) and Metcalf (1901) regarded this gland to be homologous with the hypophysis of the vertebrates. Georges (1971) assumes that the gland influences the process of reproduction and Godeaux (1964) claims the phagocytotic activity of the gland. But Das (1936) strongly inclines to think that the neural gland, at least in Herdmania, is an excretory organ.

## Nervous System of Herdamania

The nervous system, in adults, is represented by an elongated solid nerve ganglion, called brain or cerebral ganglion. It is situated ventral to the neural gland. From the anterior end of the ganglion, three nerves emerge to innervate the oral funnel. The nerve ganglion gives off posteriorly two nerves to the atrial funnel.

## Sense Organs of Herdamania

Definite organs of special sense are absent, but several structures function as the sensory receptors.

a. Receptor cells – Many receptor cells (receive contact stimuli) are present throughout the test except at the vascular areas.

b. The epithelial cells covering the vascular ampullae of the test are tactile receptors.

c. The pigmented spots or ocelli located in the margins of the oral and atrial funnels are the photoreceptors.

d. The oral tentacles are able to test water that is drawn in through the oral funnel.

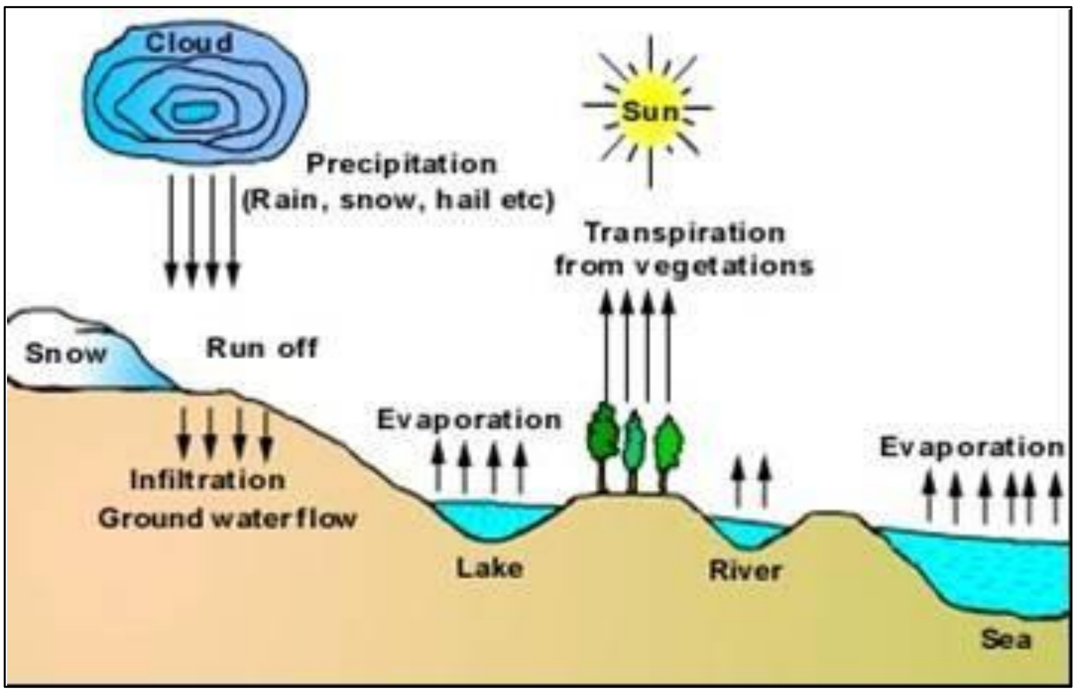
e. The dorsal tubercle is regarded to be either an olfactory or gustatory organ. The dorsal tubercle is composed of two conical elevations. Each conical elevation is produced by a conical lobe which becomes spirally coiled. The dorsal tubercle is situated near the junction of the peripharyngeal bands with the dorsal lamina.

# Life on Earth – Biogeochemical Cycles (Section - II)

BSc. Part I Zoology (Hons) Paper II

## Matter and cycles of matter

Biogeochemical cycles describe the circulation of matter, particularly plant and animal nutrients, through ecosystems. These cycles are ultimately powered by solar energy, fine-tuned and directed by energy expended by organisms. In a sense, the solar-energy-powered hydrologic cycle acts as an endless conveyer belt to move materials essential for life through ecosystems.

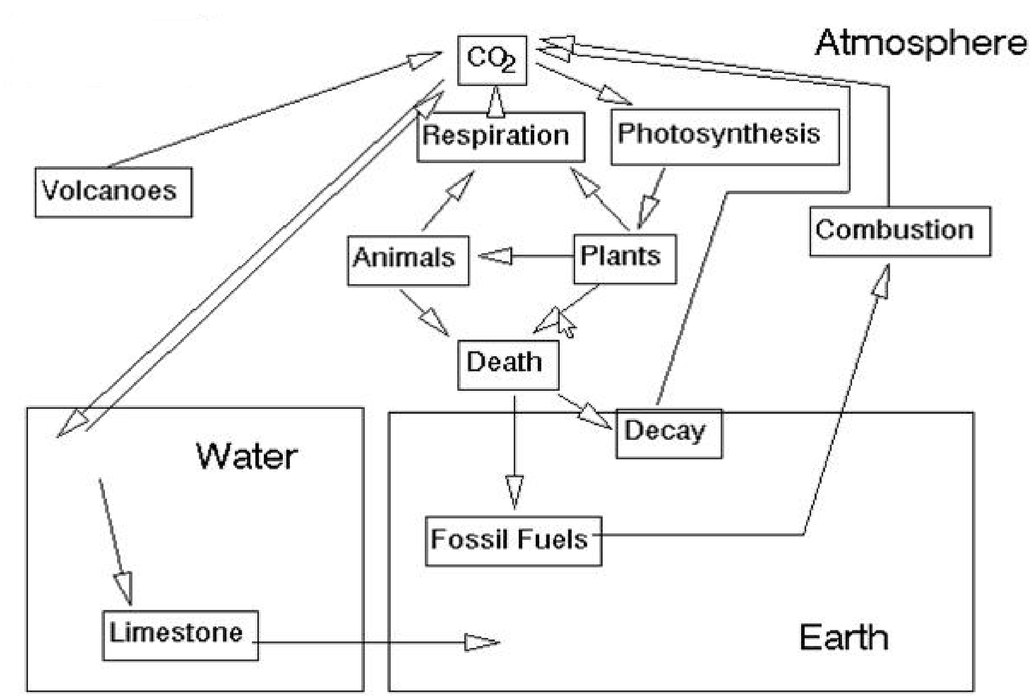



Most biogeochemical cycles can be described as elemental cycles involving nutrient elements such as carbon, oxygen, nitrogen, sulfur and phosphorus. Many are gaseous cycles in which the element in question spends part of the cycle in the atmosphere – $O_2$ for oxygen, $N_2$ for nitrogen, $CO_2$ for carbon. Others, notably the phosphorus cycle, do not have a gaseous component and are called sedimentary cycles. All sedimentary cycles involve salt solutions or soil solutions that contain dissolved substances leached from weathered minerals that may be deposited as mineral formations or organisms as nutrients may take them up. The sulfur cycle, which may have $H_2S$ or $SO_2$ in the gaseous phase or minerals ($CaSO_4$ $2H_2O$) in the solid phase, is a combination of gaseous and sedimentary cycles.

**Carbon Cycle**

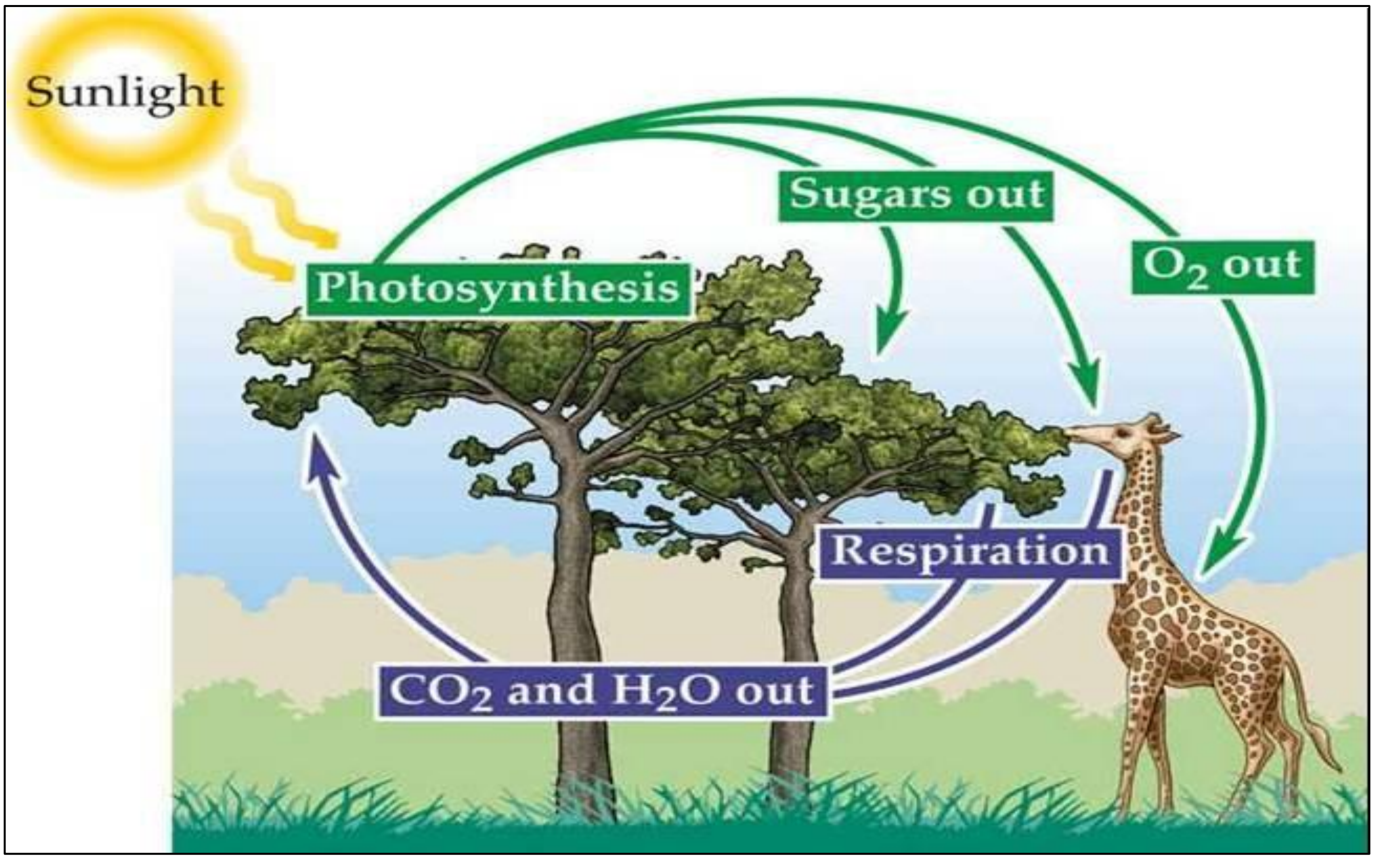
Carbon, the basic building block of life molecules, is circulated through the carbon cycle. This cycle shows that carbon may be present as gaseous atmospheric $CO_2$, dissolved in groundwater as $HCO_3$ or molecular $CO_2$ (aq), in underlying rock strata as limestone ($CaCO_3$), and as organic matter, represented in a simplified manner as ($CH_2O$). Photosynthesis fixes inorganic carbon as biological carbon, which is a constituent of all life molecules.

An important aspect of the carbon cycle is that it is the cycle by which energy is transferred to biological systems. Organic or biological carbon, ($CH_2O$), is an energy-rich molecule that can react biochemically with molecular oxygen, $O_2$, to regenerate carbon dioxide and produce energy. This can occur in an organism as shown by the "decay" reaction or it may take place as combustion, such as when wood is burned.



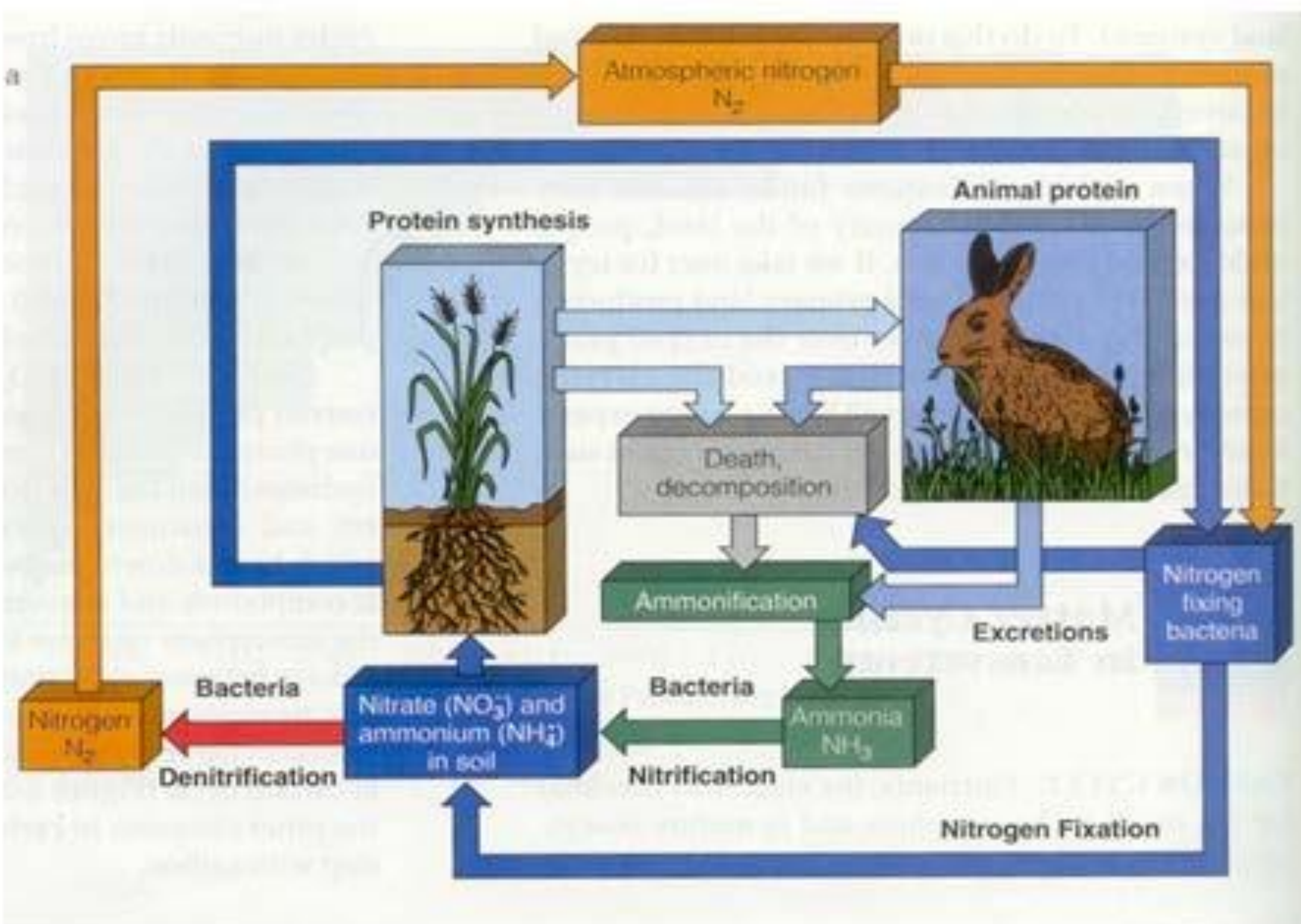
**Oxygen Cycle**

The oxygen cycle involves the interchange of oxygen between the elemental form of gaseous $O_2$ in the atmosphere and chemically bound O in $CO_2$, $H_2O$, and organic matter. Various energy-yielding processes, particularly combustion and metabolic processes in organisms chemically bind elemental oxygen. It is released during photosynthesis.



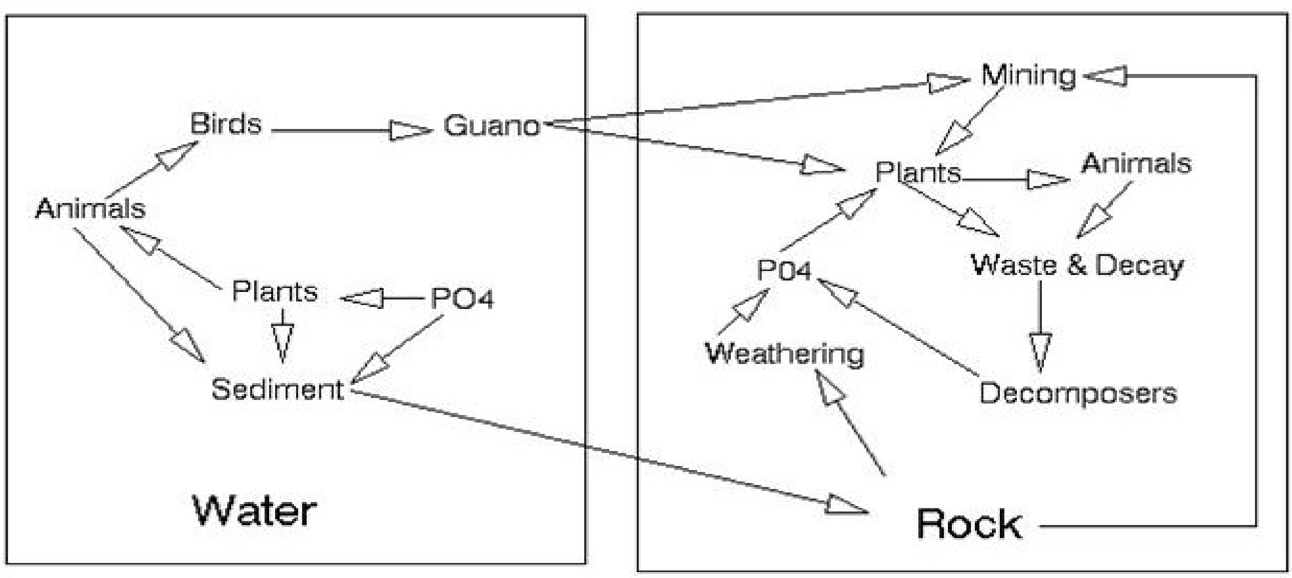
**Nitrogen Cycle**

Nitrogen, though constituting much less of biomass than carbon or oxygen, is an essential constituent of proteins. The atmosphere is 78% by volume elemental nitrogen, $N_2$ and constitutes an inexhaustible reservoir of this essential element. The $N_2$ molecule is very stable so that breaking it down to atoms that can be incorporated in inorganic and organic chemical forms of nitrogen is the limiting step in the nitrogen cycle. This does occur by highly energetic processes in lightning discharges such that nitrogen becomes chemically combined with hydrogen or oxygen as ammonia or nitrogen oxides. Elemental nitrogen is also incorporated into chemically bound forms or fixed by biochemical processes mediated by microorganisms. The biological nitrogen is returned to the inorganic form during the decay of biomass by a process called mineralization.



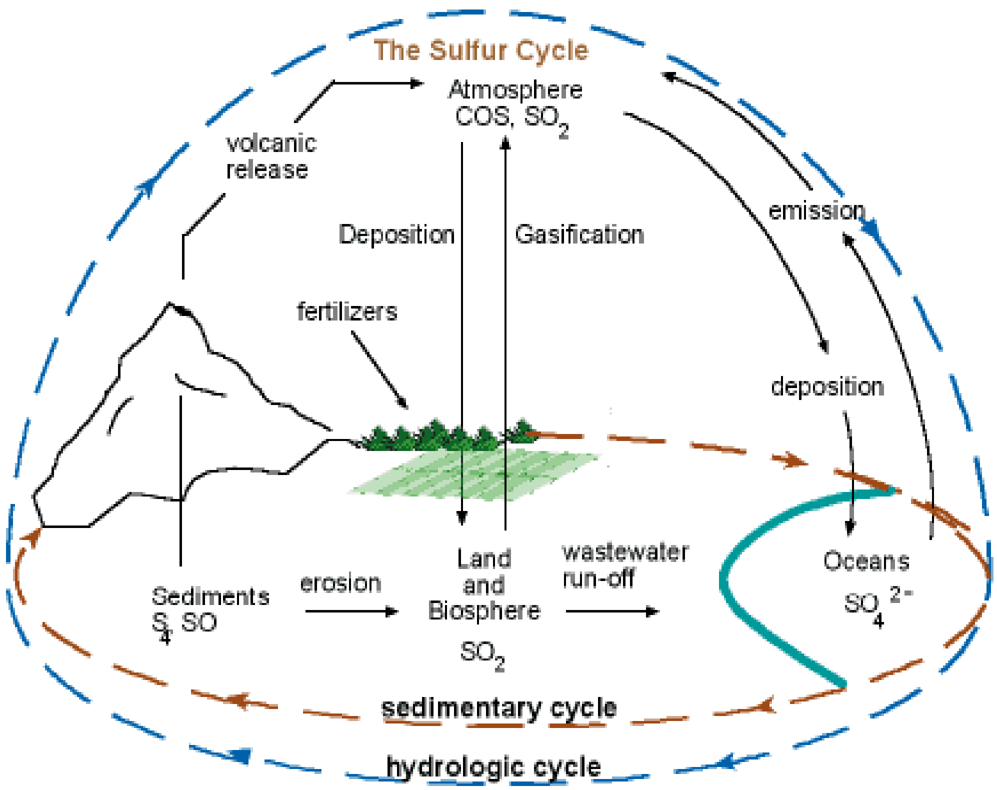
**Phosphorus cycle**

The phosphorus cycle is crucial because phosphorus is usually the limiting nutrient in ecosystems. There are no common stable gaseous forms of phosphorus, so the phosphorus cycle is strictly sedimentary. In the geosphere phosphorus is held largely in poorly soluble minerals, such as hydroxyapatite, a calcium salt. Soluble phosphorus from these minerals and other sources, such as fertilizers, is taken up by plants and incorporated into the nucleic acids of biomass. Mineralization of biomass by microbial decay returns phosphorus to the salt solution from which it may precipitate as mineral matter.



**Sulfur cycle**

The sulfur cycle is relatively complex. It involves several gaseous species, poorly soluble minerals, and several species in solution. It is involved with the oxygen cycle in that sulfur combines with oxygen to form gaseous sulfur di oxide ($SO_2$) an atmospheric pollutant, and soluble sulfate ion, ($SO_4^{2-}$). Among the significant species involved in the sulfur cycle are gaseous hydrogen sulfide, $H_2S$; mineral sulfides, such as PbS; sulfuric acid, $H_2SO_4$, the main constituent of acid rain; and biologically bound sulfur in sulfur-containing proteins.




It should be obvious that material cycles, often based on elemental cycles, are very important in the environment.

## Energy and cycles of energy

Biogeochemical cycles and virtually all other processes on Earth are drive by energy from the sun. The sun acts as a blackbody radiator with an effective surface temperature of 5780 K (Celsius degrees above absolute zero). It transmits energy to earth as electromagnetic radiation. The maximum energy flux of the incoming solar energy is at a wavelength of about 500 nanometers, which is in the visible region of the spectrum. A 1 square meter area perpendicular to the line of solar flux at the top of the atmosphere receives energy at a rate of 1,340 watts, sufficient, for example, to power an electric iron. This is called solar flux.

Energy in natural systems is transferred by heat, which is the form of energy that flows between two bodies as a result of their difference in temperature, or by work, which is transfer of energy that does not depend upon a temperature difference, as governed by the laws of thermodynamics. The first law of thermodynamics states that, although energy may be transferred or transformed, it is conserved and is not lost. Chemical energy in the food ingested by organisms is converted by metabolic processes to work or heat that can be utilized by the organisms, but there is no net gain or loss of energy overall. The second law of thermodynamics describes the tendency toward disorder in natural systems. It demonstrates that each time energy is transformed; some is lost in the sense that it cannot be utilized for work, so only a fraction of the energy that organisms derive from metabolizing food can be converted to work; the rest is dissipated as heat.

## Energy Flow and Photosynthesis

Whereas materials are recycled through ecosystems, the flow of useful energy may be viewed as essentially a one-way process. Incoming solar energy can be regarded as high-grade energy because it can cause useful reactions to occur, the most important of which in living systems is photosynthesis. Solar energy captured by green plants energizes chlorophyll, which in turn powers metabolic processes that produce carbohydrates from water and carbon dioxide. These carbohydrates represent stored chemical energy that can be converted to heat and work by metabolic reactions with oxygen in organisms. Ultimately, most of the energy is converted to low-grade heat, which is eventually re- radiated away from Earth by infrared radiation.