// UNIT: 3 ENERGY FLOW IN THE ECOSYSTEM 02.08.2012

Energy is defined as the ability to do work. As per Einstein equation
$E = mc^2$,

where, E = Energy
m = Mass
c = Velocity of light

* The behaviour of energy in ecosystem can be conveniently termed the energy flow because of unidirectional energy transformations.

This equation implies that matter and energy are interchangeable. It is the flow of energy that drives the material cycles. Materials can be recycled but energy is non-recyclable. Units of energy are erg and calories (in ecology). Types:

1 Calorie = 4.18 J or 4.18×10^7 erg
= 1g H_2O Tem 14.5-15.5°C

Potential energy: energy at rest and available for work.
Kinetic energy: energy due to motion and results in work.

The flow of energy through the ecosystem is unidirectional and it follows two laws of thermodynamics i.e.

(i) I st Law of Conservation of Energy: Energy may be transformed from one form to another but is never created or destroyed.

(ii) II nd Law of Entropy: There is always a tendency for increase in entropy or degradation from a concentrated to a dispersed (random) form leading to dissipation of heat. No transformation is 100% efficient. Light energy fixed by green plants:

$6CO_2 + 18\,ATP + 12\,NADPH_2 \longrightarrow C_6H_{12}O_6 + 18\,ADP + 18\,Pi + 12\,NADP + 6H_2O$

* Out of this energy fixed by green plants some is released in respiration. As food it passes from plants through herbivores to carnivores.
* At each stage of food transfer potential energy is released causing further loss. Thus II nd Law of thermodynamics is followed.
* At each trophic level energy flow may follow 3 main paths:
  (i) To next trophic level
  (ii) Through death to decomposers
  (iii) Lost as heat by respiration.
* Energy flow at different trophic levels, follow a 10% rule i.e only about 10% energy is stored in successive higher trophic levels. Major part of energy is lost as heat or other metabolic activity of the organisms.
* Shorter the food chain, greater would be the available food energy. Hence, there remains limited number of links in a food chain.

ENERGY FLOW MODELS :→ (a) Single Channel Model:

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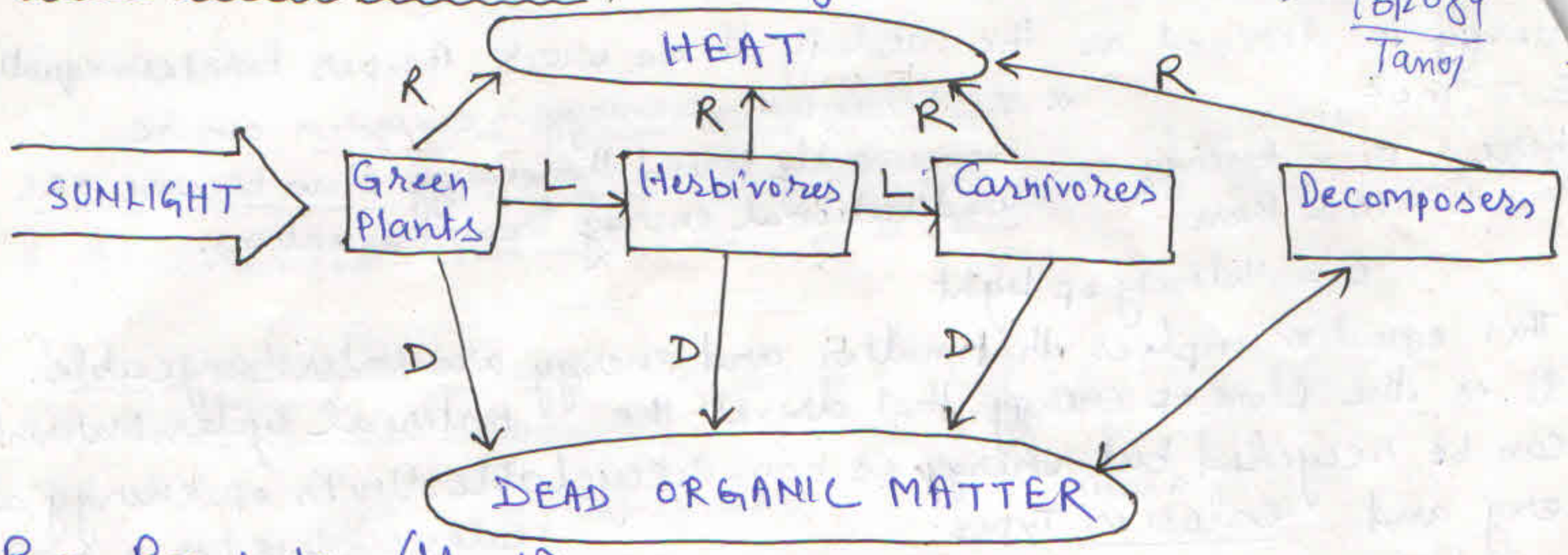
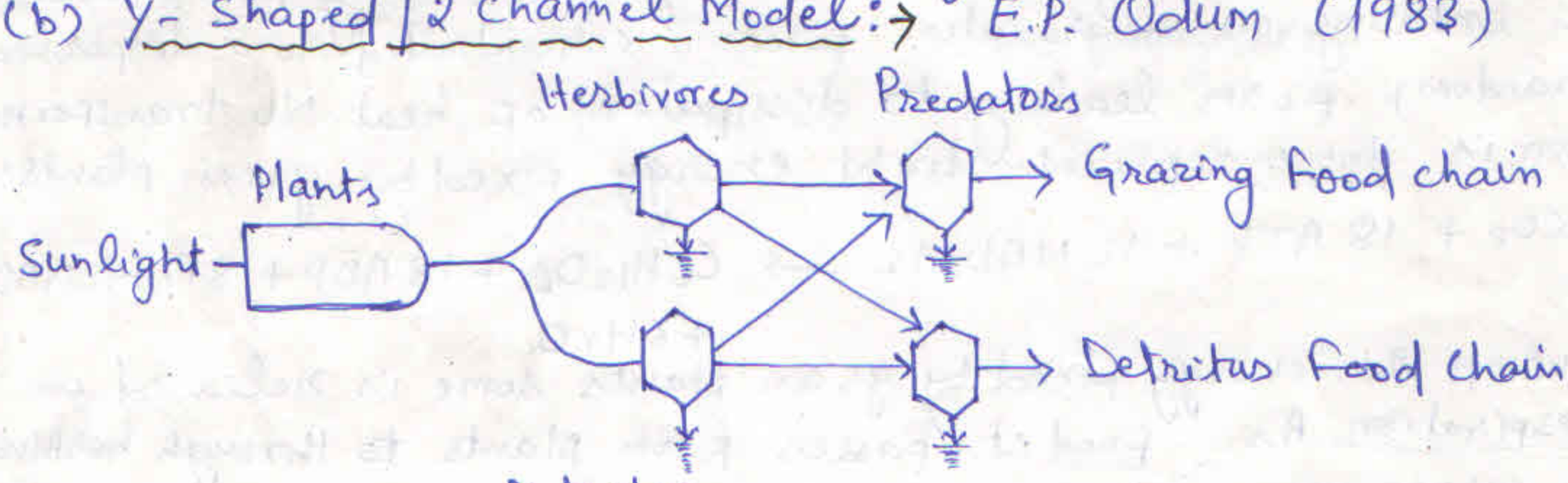


R = Respiration (Heat)
L = Chemical energy of live organisms.
D = " " " dead organisms.

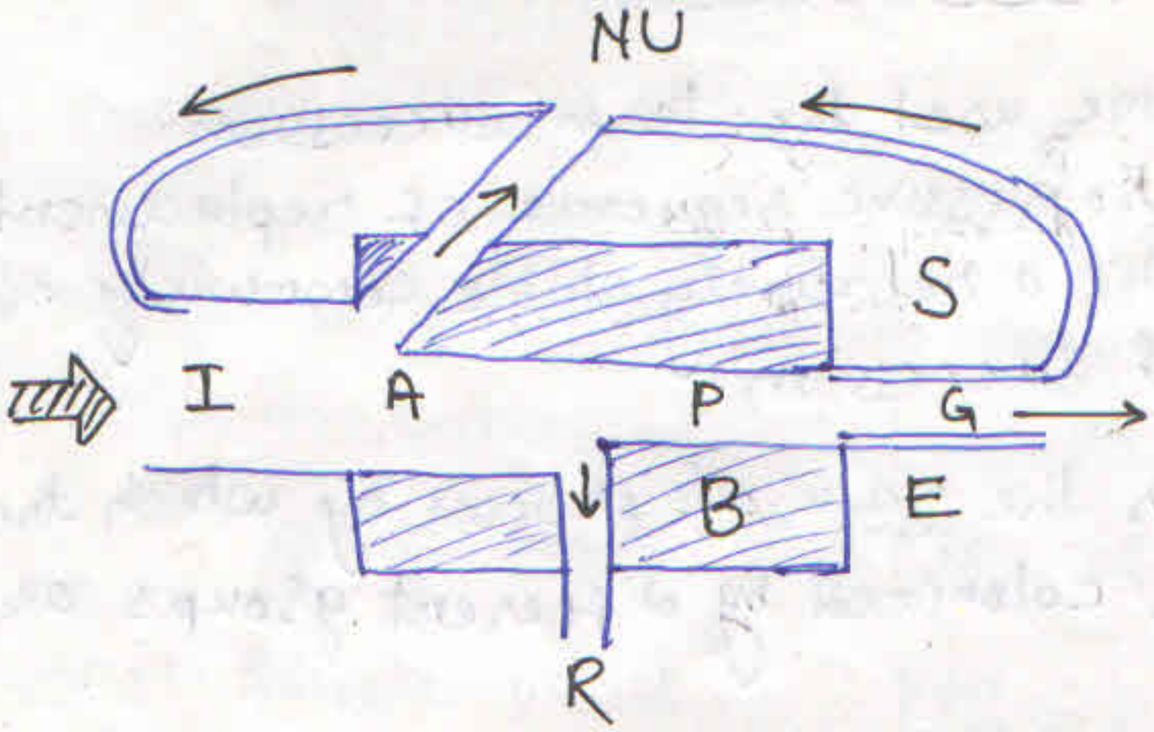
Energy enters from outside (sunlight) and passes through each trophic level, some energy is released as heat by respiration (R), some is transferred to next trophic level (L) and some to decomposers through death and excrement (D).

(b) Y- Shaped / 2 channel Model :→ E.P. Odum (1983)



* One arm represents grazing and other detritus F. Chain. They are sharply separated. However, under natural conditions, they are not completely isolated from one another e.g. dead animal / faeces of grazing animals, a part of G.F. Chain, become incorporated in D.F. Chain.
→ More realistic and practical.
→ Confirms basic stratified structure of ecosystems.

(c) Universal Model :→



I = Input / ingested energy
NU = Not used
A = Assimilated energy
P = Production
R = Respiration
B = Biomass
G = Growth
S = Stored energy
E = Excreted energy.
A = P + R

* The energy used for all the plant life processes is derived from solar radiation. (Electromagnetic radiation)

ECOLOGICAL SUCCESSION

Hult. (1885) for the first time used the term succession.
The process of orderly and progressive sequence of replacement of one community by another until a relatively stable community occupies the area is called ecological succession.

Clements (1916): defined it as the natural process by which the same locality becomes successively colonized by different groups or communities of plants.

Odum (1969): called it the process of ecosystem development.
i) Orderly and directional process. Thus predictable.
ii) Species/community structure changes.
iii) Community controlled.
iv) Culminates in a stabilized ecosystem.

Sere :→ The whole sequence of communities that replace one another in a given area and terminate in a final stable community i.e. climax.

Seral Stages :→ The developmental stages in the process of plant succession. (Developmental stages | pioneer stages).

Pioneers :→ The first organisms that invade a bare area are called pioneers.

Climax :→ The terminal stabilized system.

Species replacement occurs because populations tend to modify the physical environment, making conditions favourable for other populations until an equilibrium between biotic and abiotic is achieved.

Causes of Succession :→

① Initial causes :→ may be biotic or abiotic. e.g. erosion and deposit, wind, fire etc. They may destroy the existing populatio in an area.

② Ecesis or Continuing Causes :→ migration, aggregation an stabilization.

③ Stabilizing Causes : climate is the chief cause of stabilization

Trends of Succession :→

① Change in species composition.
② Increase in diversity of species.
③ Progressive increase in biomass.
④ Shift in community metabolism:

Young pond = P/R > 1

Stable pond = P/R = 1 or P/R < 1
(Heterotrophic succession)

Types of Succession :→

① Primary succession :→ When a community starts from the primitive substratum (e.g. a newly exposed rock/sand surface or a lava flow) unoccupied by any other community, the process is called as P. succession. The organisms establishing there are called as pioneers or primary community.

② Secondary Succession :→ When a community starts on a previously built substratum with already existing living matter, the process is called as secondary succession. The existing community might have disappeared due to sudden environmental changes. (Climatic factors change, fire, wind, biotic intervention etc.

③ Hydrosere / Hydrarch : starting in regions where water is in plenty i.e. ponds, lakes, streams, swamps, bogs etc.

④ Mesarch : where adequate moisture conditions are present.

⑤ Xerosere / Xerarch : Occuring in dry areas with minimal moisture contents e.g. dry deserts, rocks etc.

⑥ Lithosere : on rocks

⑦ Psammosere : on sand

⑧ Halosere : in saline water/soil.

HYDROSERE OR HYDRARCH

The process of succession of plants, in particular, is called as sere. Sere originating in water is known as hydrosere. The successive stages of developnent in a water body can be identified as follows:

① PIONEER STAGE: It is the Ist stage in succession. Newly formed, man-made ponds and lakes gets occupied by phytoplanktons e.g algae, blue-green algae, diatoms and bacteria. Upon death they settle to bottom forming a layer known as muck.

② Rooted Submerged stage: After death, phytoplanktons get mixed with the silt, brought by rain water, forming a soft mud at pond bottom. Since light can reach the bottom of pond, rooted submerged hydrophytes e.g. hydrilla, Vallisneria, Utricularia etc. start growing. Their growth decreases water level making the pond shallower. This change in habitat causes their replacement by plants having floating leaves.

③ Rooted Floating Stage: Hydrophytes with large floating leaves on water surface colonize the habitat with their rhizomes. Some free floating species i.e. Azolla, Pistia, Lemna etc. also becomes associated.

Their growth further decreases water level and make pond more shallow. Their death and decomposition enrich the substratum.

④ Reed-Swamp or Amphibious Stage: This community possesses rooted plants having shoots exposed to air e.g. Typha, Sagittaria etc. With well developed rhizomes they promote formation of a very dense vegetation.

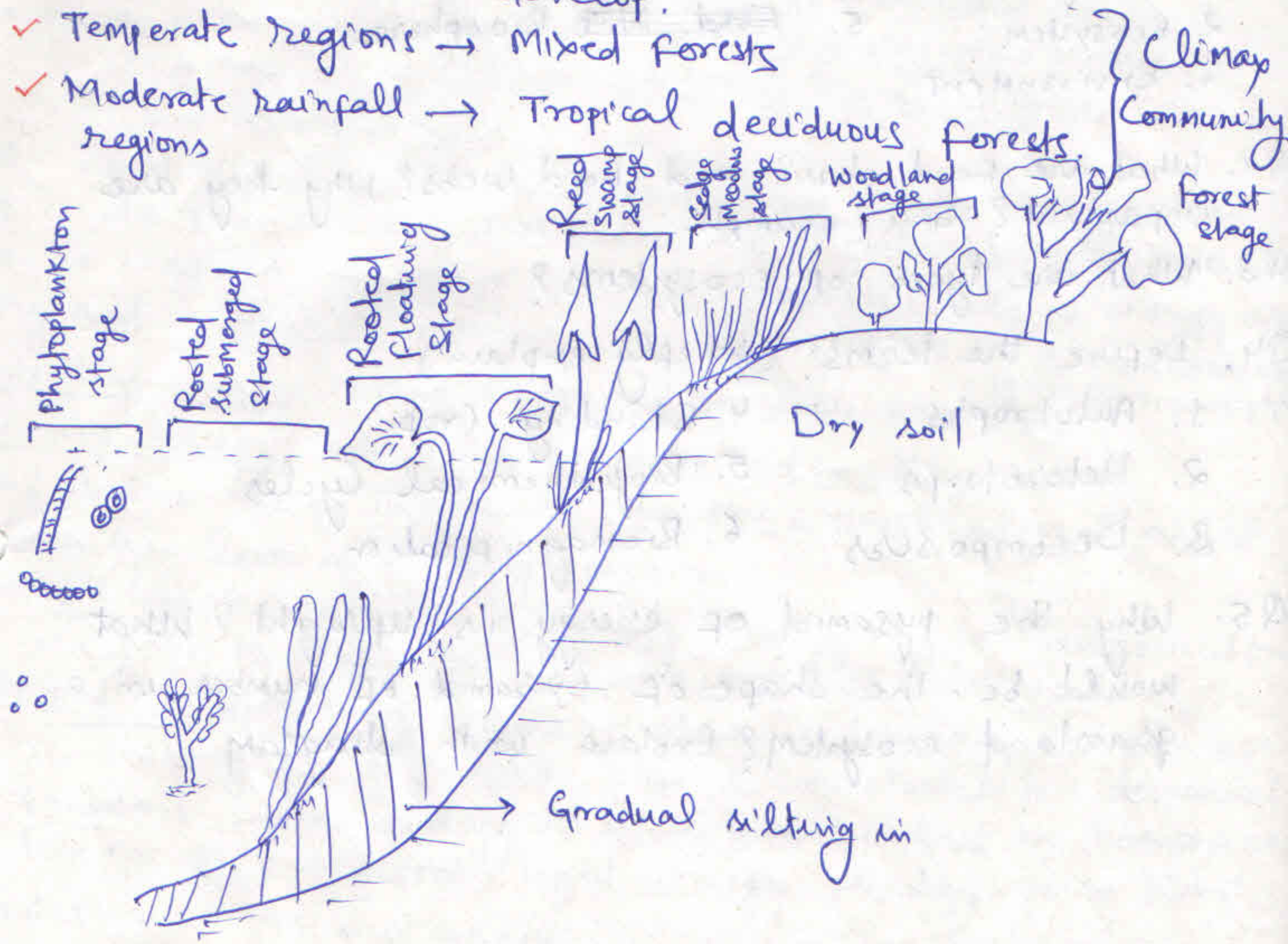
⑤ Sedge-Meadow Stage: Substratum change and reduction in water level causes colonization by species e.g. Carex, Juncus etc.

* Mat like vegetation forms on entire pond.
* High transpiration rate causes rapid loss of water.
* Marshy vegetation starts disappearing.

⑥ Wood land stage: Dry soil is invaded by shrubs like Salix and trees eg Populus. Soil accumulate humus with rich flora of micro-organisms. Soil mineralization favours growth of other species.

⑦ Forest Stage: Woodland community is rapidly invaded by several trees. In tropical climates with heavy rainfall, tropical rain forests develop.

- ✓ Temperate regions → Mixed forests
- ✓ Moderate rainfall → Tropical deciduous forests.



LITHOSERE - A XEROSERE ON ROCK

07.08.2012

* This originates on bare rock surface.
* System lack organic matter and is deficient in water.
* Minerals present in disintegrated unweathered state.
* Pioneer community: lichens.

① CRUSTOSE LICHEN STAGE ⇒ Lichens like Rhizocarpon, Rinodina etc. survive and cause weathering of rocks by producing acids. Dead lichens get mixed with small rock particles.

② FOLIOSE LICHEN STAGE: Communities like Parmelia and Dermatocarpon possessing large leaf like thalli grow on substratum partially built by crustose lichens.
- ✓* They can absorb and retain waters.
- ✓* Accumulate dust particles.
- ✓* Humus forms.
- ✓* Weathered rocks get mixed with humus forming soil.

③ MOSS STAGE:- Soil formation promotes growth of xerophytic mosses e.g. Polytrichum. They compete and outnumber lichens. Death and decaying of lichens enrich soil with organic matter.

④ HERBS STAGE:- Soil formation and habitat change favours growth of annual herbs, followed by biennials and perennials. Their death and decay further enriches soil and favours rock weathering.
* Habitat now gets occupied by rooted grasses i.e. Poa grass.

⑤ SHRUB STAGE: Shrubs eg. Phytocarpus soon outnumber the herbs. Later shrubs are replaced by trees (climax comm.)

⑥ FOREST STAGE: Rock weathering and humus formation in soil favours growth of trees i.e. xerophytic to mesophytic vegetation. Thus a forest community is formed.

Climax Community:- A final, terminal and more or less stabilized community that has reached to an equilibrium with the environmental conditions is called a climax community.

H2
i) Bikash Kumar - 1105
ii) Prakash Roshaan - 1106
iii) Gaurav Kumar Singh - 962

BIOGEOCHEMICAL CYCLES

Bio = Living organisms (biotic communities)

Geo = Rocks, soil, air, water (abiotic environment)

Vernadskii (1929): coined the term.

Definition:→ The cyclic movement of chemical elements of the biosphere between the organism and the environment are referred to as biog. cycles.

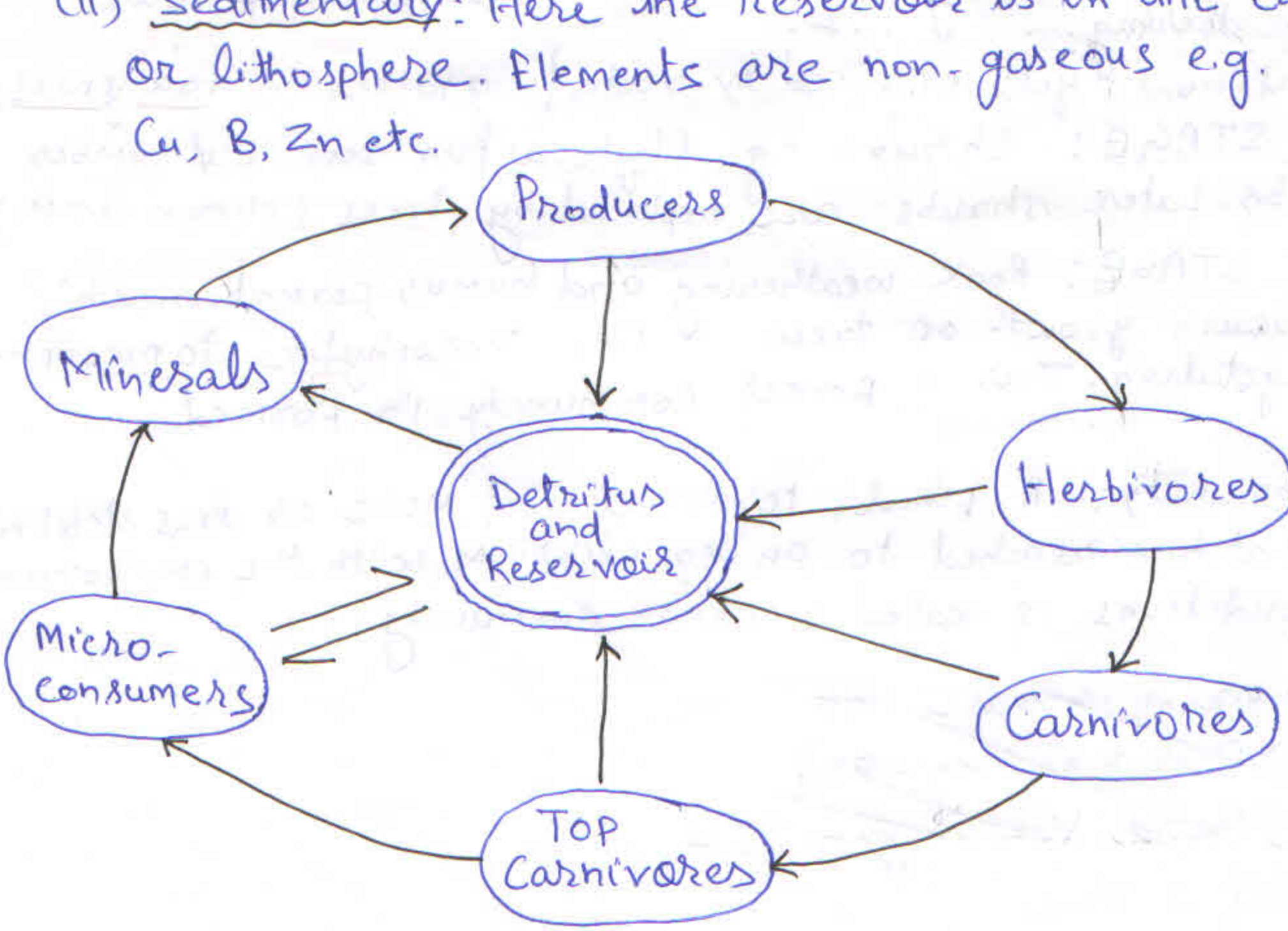
Significance:→

1. Elements again become available after use.
2. Nutrients remain continuously available to organisms.
3. Cycling prevents accumulation of elements which is deleterious to life.

Types:→

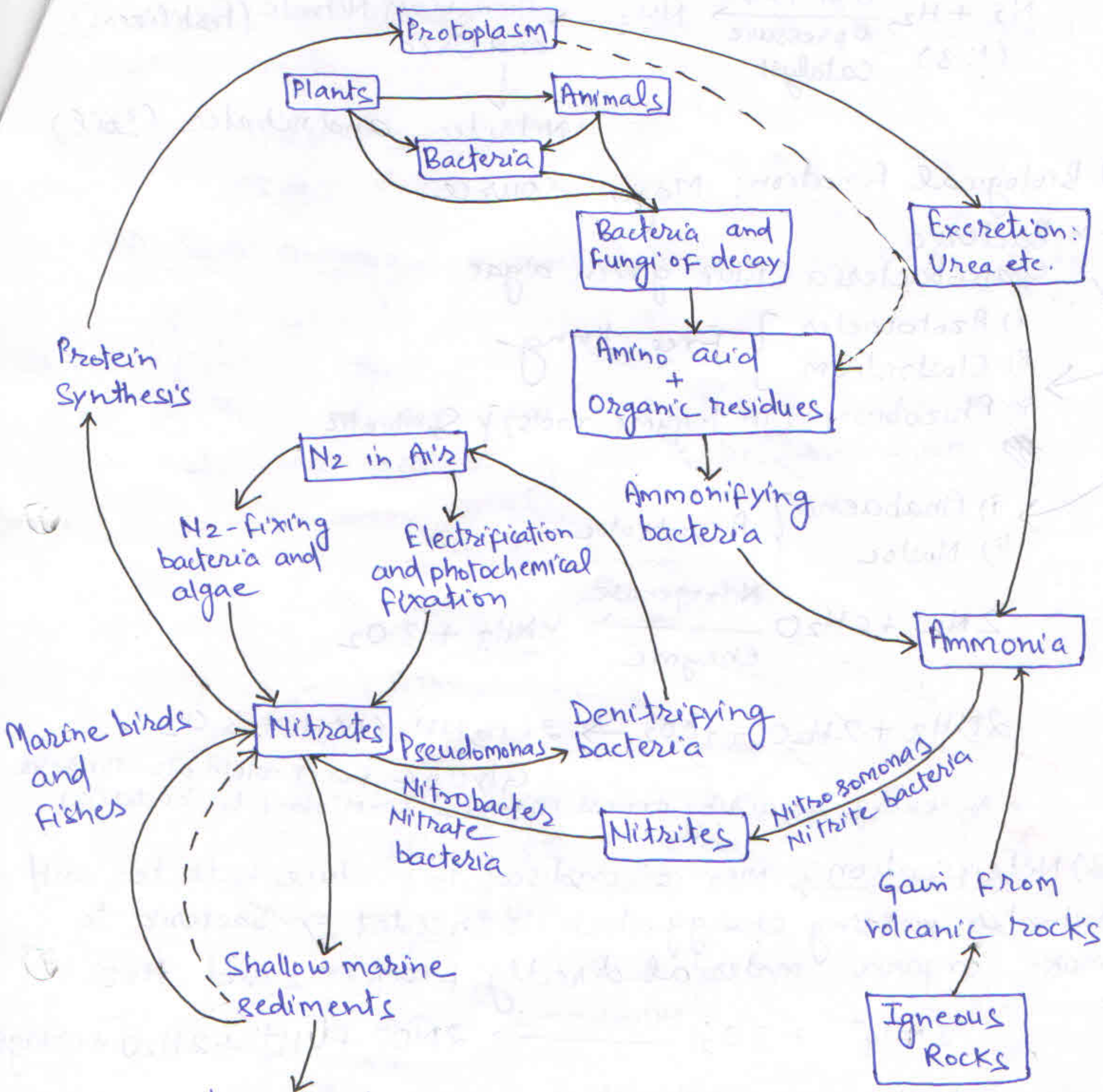
(i) Gaseous: Here the reservoir is in the atmosphere or hydrosphere e.g. C, O_2, N_2, H_2O.

(ii) Sedimentary: Here the reservoir is in the earth's crust or lithosphere. Elements are non-gaseous e.g. P, K, Ca, Mg, Cu, B, Zn etc.



Cycling of Minerals in the Ecosystem

NITROGEN CYCLE



* N_2 is most abundant element of atmosphere (78.084 %)
* Essential constituent of: Amino acids, proteins, nucleic acids etc.
* Plants take it from surroundings as Nitrate and Ammonia.

(A) Nitrogen Fixation: →

(1) Atmospheric fixation: Conversion of N_2 into nitrogen oxides and ammonia by lightening or cosmic radiations. Washed down by rainfall and converted into nitrites and nitrates in soil.

② Industrial Fixation: Haber's process.

$N_2 + H_2 \xrightarrow[\text{\& pressure}]{\text{High Temp.}} NH_3 \rightarrow$ Ammonium Nitrate and Urea (Fertilizers)
(1:3) Catalyst

↓

Nitrites and nitrates (Soil)

③ Biological Fixation: Major source

* Bacteria
* Cyanobacteria (Blue green algae)

i) Azotobacter
ii) Clostridium } Free living

iii) Rhizobium (in legume roots) } Symbiotic.

i) Anabaena
ii) Nostoc } Asymbiotic

$2N_2 + 6H_2O \xrightarrow[\text{enzyme}]{\text{Nitrogenase}} 4NH_3 + 3O_2$

$2NH_3 + 2H_2O + 4CO_2 \rightarrow 2CH_3NH_2COOH + 3O_2$

Glycine for protein etc. synthesis.

* An energy requiring process. (Extracted from plant by bacteria).

(B) Nitrification: NH_3 is oxidised to produce nitrites and nitrates yielding energy which is needed by bacteria to make organic material directly from CO_2 and H_2O.

$2NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 4H^+ + 2H_2O + \text{energy}$

$2NO_2^- + O_2 \xrightarrow[\text{Oxidation.}]{\text{Nitrobacter \& Nitrocystis}} 2NO_3^- + \text{energy}$

* NH_3 and NO_3^- obtained by N_2 fixation are directly consumed by plants to synthesize proteins of protoplasm. and other molecules.
* N_2 compounds then enter body of animals which feed on plants. When plants and animals die they are decomposed by micro-organisms. A part is converted into inorganic nutrients which are recycled through living organisms. Remaining N_2 compounds enter sediments by sedimentation

By volcanic eruption they are ejected back to atmosphere.

(C) Denitrification:→ Degradation of nitrate is called denitrification.

$$4NO_3^- + 2H_2O \xrightarrow[\text{Pseudomonas denitrificans}]{} 2N_2 + 5O_2 + 4OH^-$$

(Soil) → (Atmosphere)

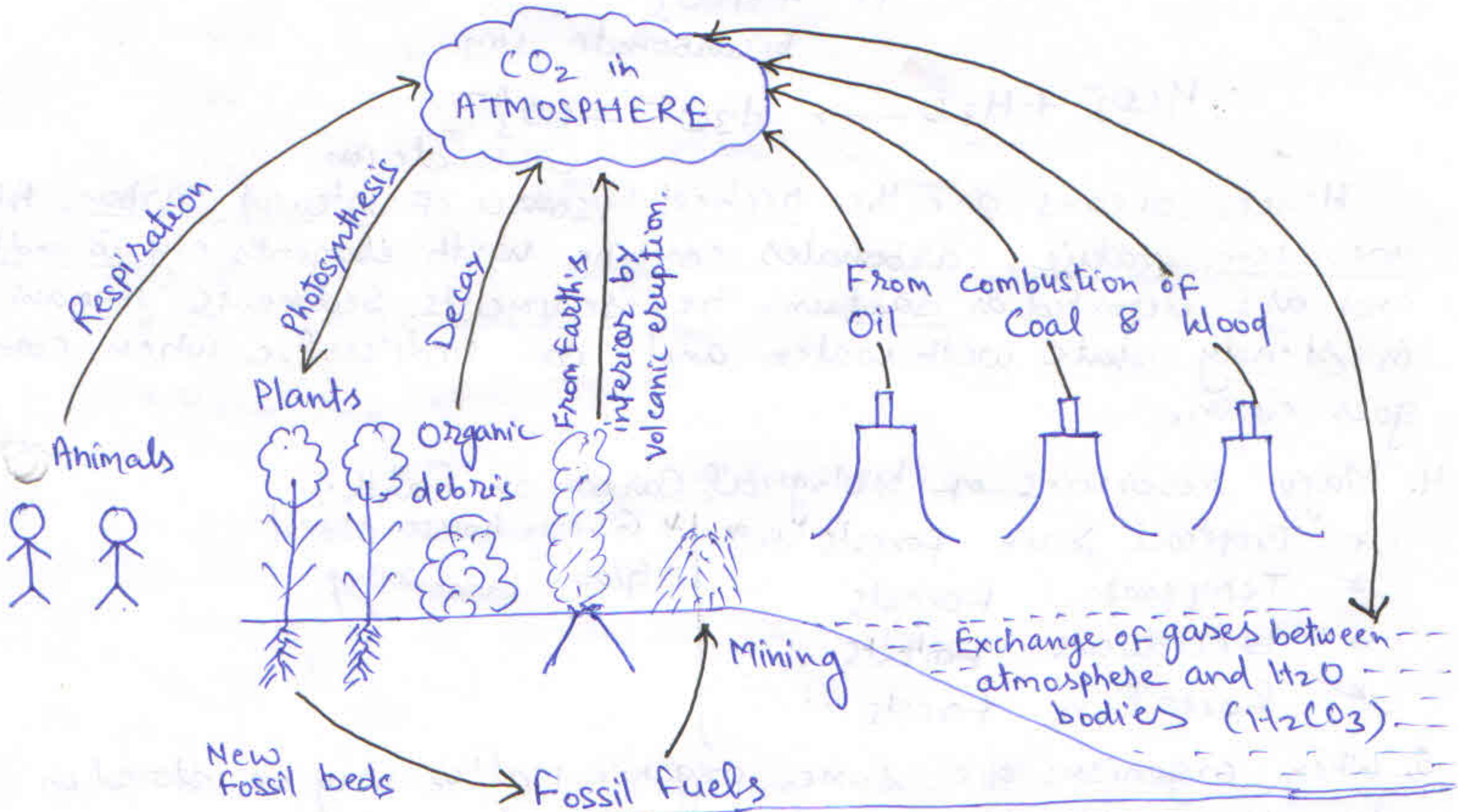
(D) Sedimentation:→ Soil nitrates lost by processes

i) Erosion to sea

ii) Leaching by rain waters

iii) Thus become part of rocks. Volcanic eruption and rock weathering again releases them.

CARBON CYCLE



* Carbon is present in atmosphere mainly as CO_2 (0.032%).
* It is the basic constituent of all organic compounds e.g. carbohydrates synthesized by photosynthesis.
* Active pools: Atmosphere and sea surface.
  Storage pools: Carbonate sediments and fossil fuels.

1. C - from atmospheric pool moves to green plants (producers) then to animals (consumers) and finally to micro-organisms (decomposers) that return it back to atmosphere by decomposition of dead organic matter. ($CO_2 \xrightarrow{\text{Photosynthesis}}$ Organic compounds)
   ↓
   Phytoplanktons (Photosynthesis)
2. Sources of Atmospheric CO_2:
   - ✓ * Cellular respiration. (Plants & animals)
   - ✓ * Decay of organic matter
   - ✓ * Fossil fuel burning
   - ✓ * Weathering of C - containing sediments.
3. A part of C - cycle is inorganic i.e. it does not involve biological activities. CO_2 is soluble in water and is exchanged b/w atmosphere and ocean/fresh water lakes by simple diffusion. It forms carbonates and bicarbonates ~~from~~ ~~to~~ in water.

$$H_2O + CO_2 \longrightarrow H_2CO_3$$
Carbonic acid

$$H_2CO_3 \longrightarrow H^+ + HCO_3^-$$
bicarbonate ion

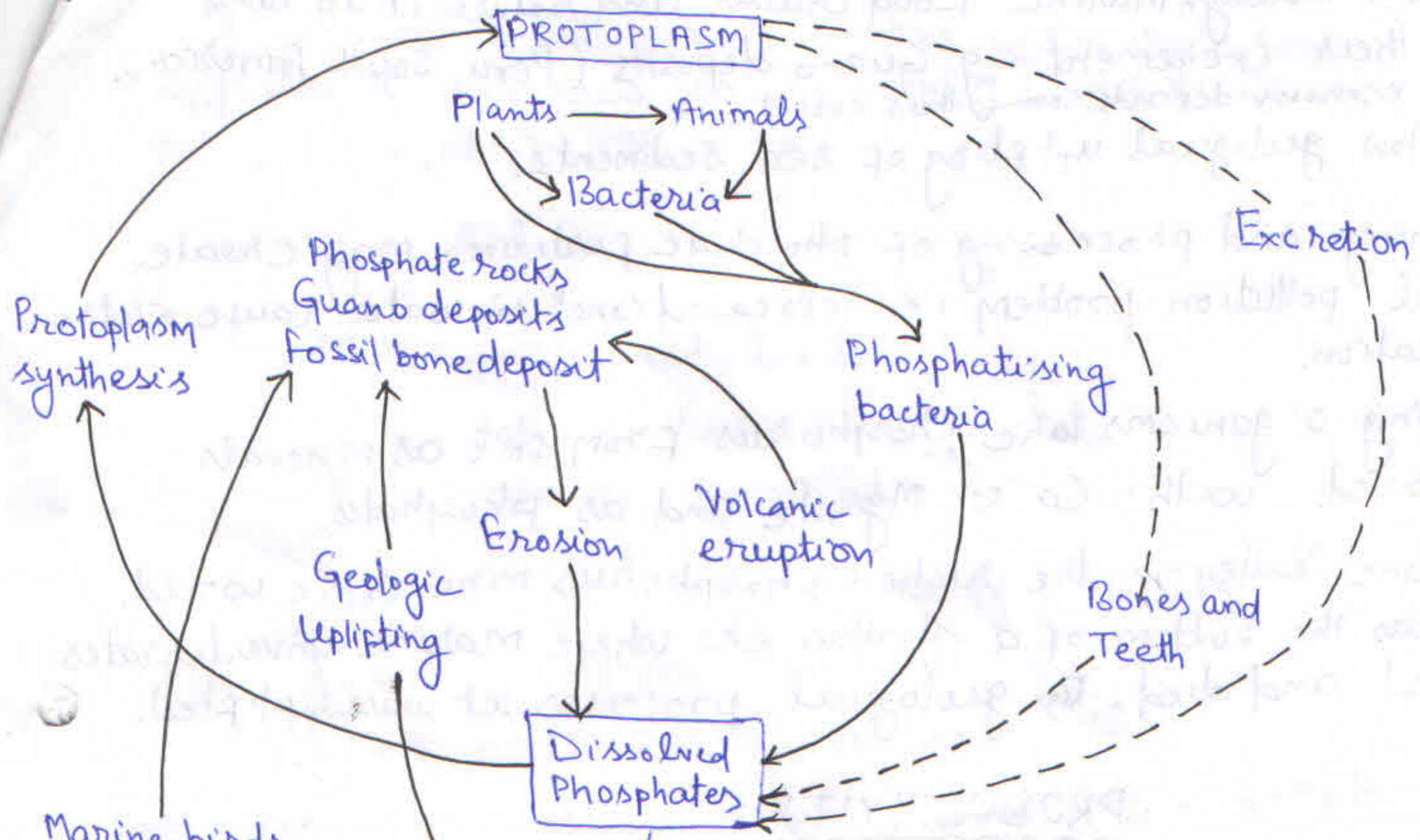
$$HCO_3^- + H_2O \longrightarrow H_3O^+ + CO_3^{2-}$$
Carbonate ion.

Hence, oceans are the richest source of stored carbon. At saturation value, carbonates combine with elements e.g. Ca and Mg and are deposited as salt in the sediments. Sediments remain in steady state with waters and can redissolve when conch. goes down.

4. Major reservoirs of biological Carbon on Earth.
   - ✓ * Tropical rain forests
   - ✓ * Temperate forests
   - ✓ * Deciduous forests
   - ✓ * Boreal forests

   | * Green house effect
   | * Global warming
5. When organisms die, some organic matter may be stored in deep sea sediments which becomes part of geological/rock cycle.
6. ✓ * Phytomass increase
   ✓ * Forests and plantations
   ✓ * Accumulation of humus and litter
   } C - Accumulation in Ecosystem
   ✓ * Industrial Emission
   * Forest burning
   * Organic matter loss in forests
   * Jhum cultivation
   * Fire and litter destruction
   } Loss of C

PHOSPHORUS CYCLE



① Phosphorous cycle is a sedimentary cycle. It is an important constituent of:
- * Nucleic acids i.e DNA
- * Cell membranes
- * Bones and teeth (Calcium phosphates)
- * AMP, ADP, ATP (Energy currency of cell).

② Active pool: decaying organic matter
Storage pool: sediments.
From sediments it can become available to living organisms by:
(i) Slow uplifting and weathering of rocks.
(ii) Mining.

③ Phosphorus released from sediments enters the soil as phosphate ions which are taken up by living organisms. When organisms die, the micro-organisms transfer, phosphorus from body of dead animals to soil. It may be recycled to the living organisms. A part of it goes to ocean through rivers to be consumed by marine life.

④ Two processes transfer phosphorus from ocean to terrestrial environment: