

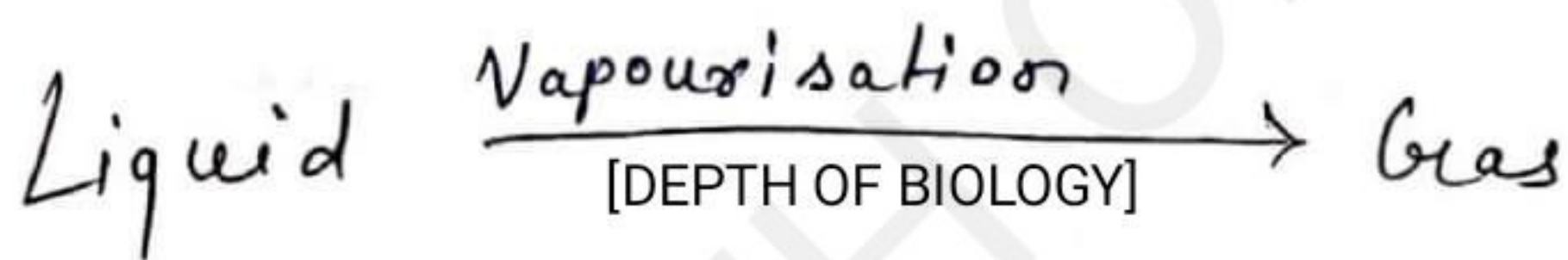
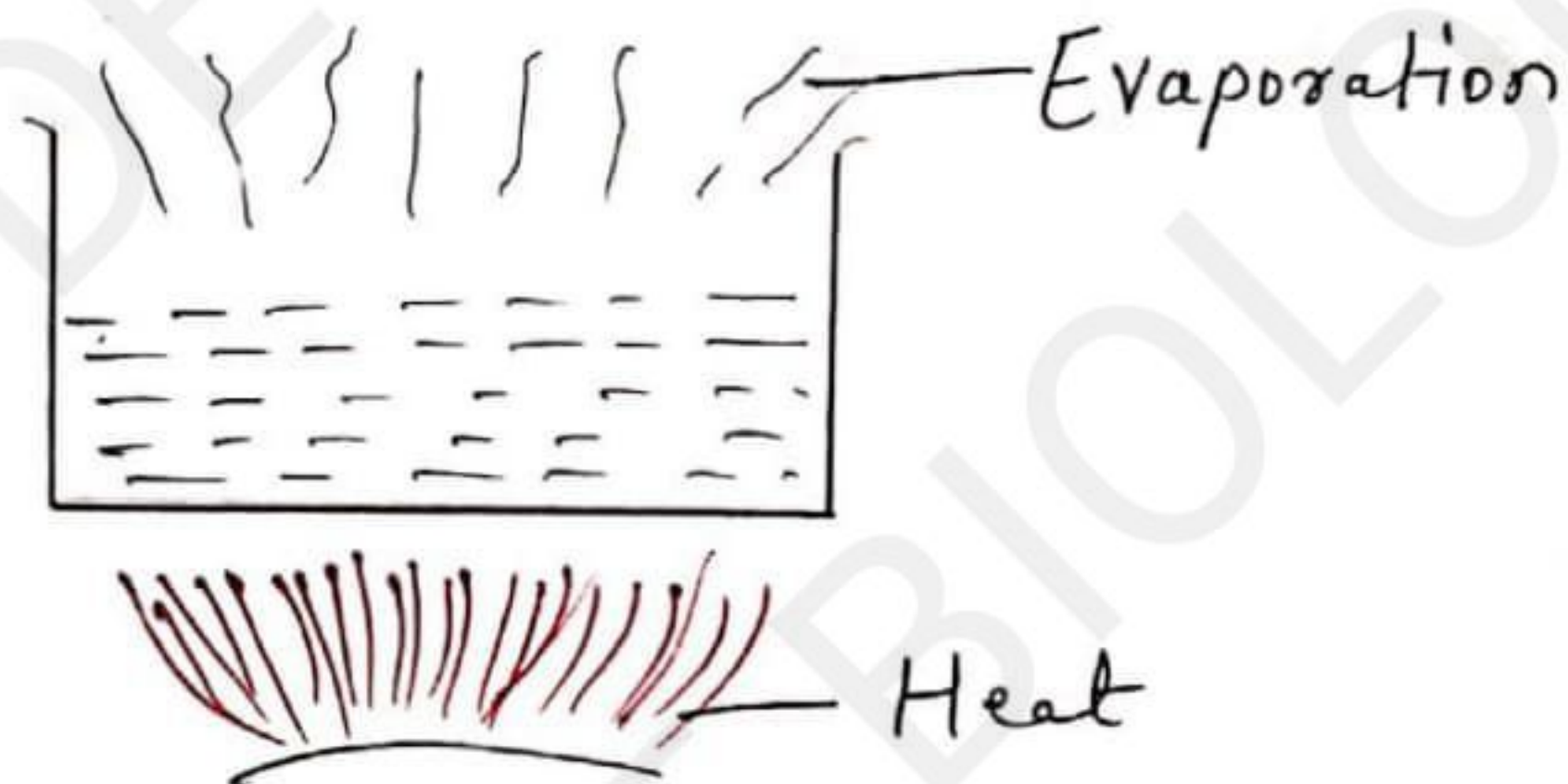
Unit - 2

Evaporation

Objective, applications & factors influencing evaporation :-

[DEPTH OF BIOLOGY]

- A process of converting liquid into gas by absorption of heat.



- Boiling point :-

↳ The temperature at which a liquid starts boiling and gets converted into vapours. [DEPTH OF BIOLOGY]

↳ It is different for different liquids.

Vapour pressure :-

→ Tendancy of a material to change into a gaseous state.

→ That's too different for different liquids.

[DEPTH OF BIOLOGY]

eg:- Boiling point of -

Water = 100°C

Alcohol = 78.37°C

► Evaporation is a surface phenomenon in which first of all liquid on surface evaporate.

Objective and Applications :-

→ For getting concentrated product.

→ Removal of water from aqueous solⁿ.

→ Removal of water from solid particles for getting dry products.

→ For reduction of weight.

→ Drying of clothes.

→ Drying of drugs for further use in manufacture of medicines.

[DEPTH OF BIOLOGY]

[DEPTH OF BIOLOGY]

Factor influencing Evaporation :-

- ① Temperature
- ② Surface Area
- ③ Vapour pressure
- ④ Humidity [DEPTH OF BIOLOGY]
- ⑤ Wind speed

Rate of evaporation :- The rate at which evaporation increase or decrease.

① Temperature :-

Temp. $\propto$ Rate of evaporation

i.e. Rate of evaporation increase or decrease with respect to temperature.

② Surface area :-

Surface area $\propto$ Rate of evaporation

i.e. Rate of evaporation increase with respect to surface area. [DEPTH OF BIOLOGY]

③ Vapour pressure :-

$$\text{V.P.} \propto \text{Rate of evaporation}$$

On increasing the vapour pressure of liquid rate of evaporation also increases. [DEPTH OF BIOLOGY]

④ Humidity :-

$$\text{Humidity} \propto \frac{1}{\text{Rate of evaporation}}$$

The rate of evaporation decreases as the humidity in atmosphere increases.

⑤ Wind Speed :-

$$\text{Wind Speed} \propto \text{Rate of evaporation}$$

Rate of evaporation increase with increase in wind speed. [DEPTH OF BIOLOGY]

Difference betⁿ evaporation and other heat process :-

Evaporation

↳ The part left over is concentrated liquid. [DEPTH OF BIOLOGY]

↳ Transformation of liquid into a gas.
(No need of separation)

↳ Motive is to get concentrated liquid.
[DEPTH OF BIOLOGY]

↳ Liquid into gas.

↳ It happened too in room temperature.
[DEPTH OF BIOLOGY]

Other heat process

Drying → The part left over is solid.

Distillation → A process of separation.
(Separation is compulsory)

Crystallisation → Motive of concentrating solution to get crystals.

Sublimation → Transition of solid into gas.

Boiling → Process of evaporation of a liquid at the boiling point of the liquid.

Steam Jacketed Kettle

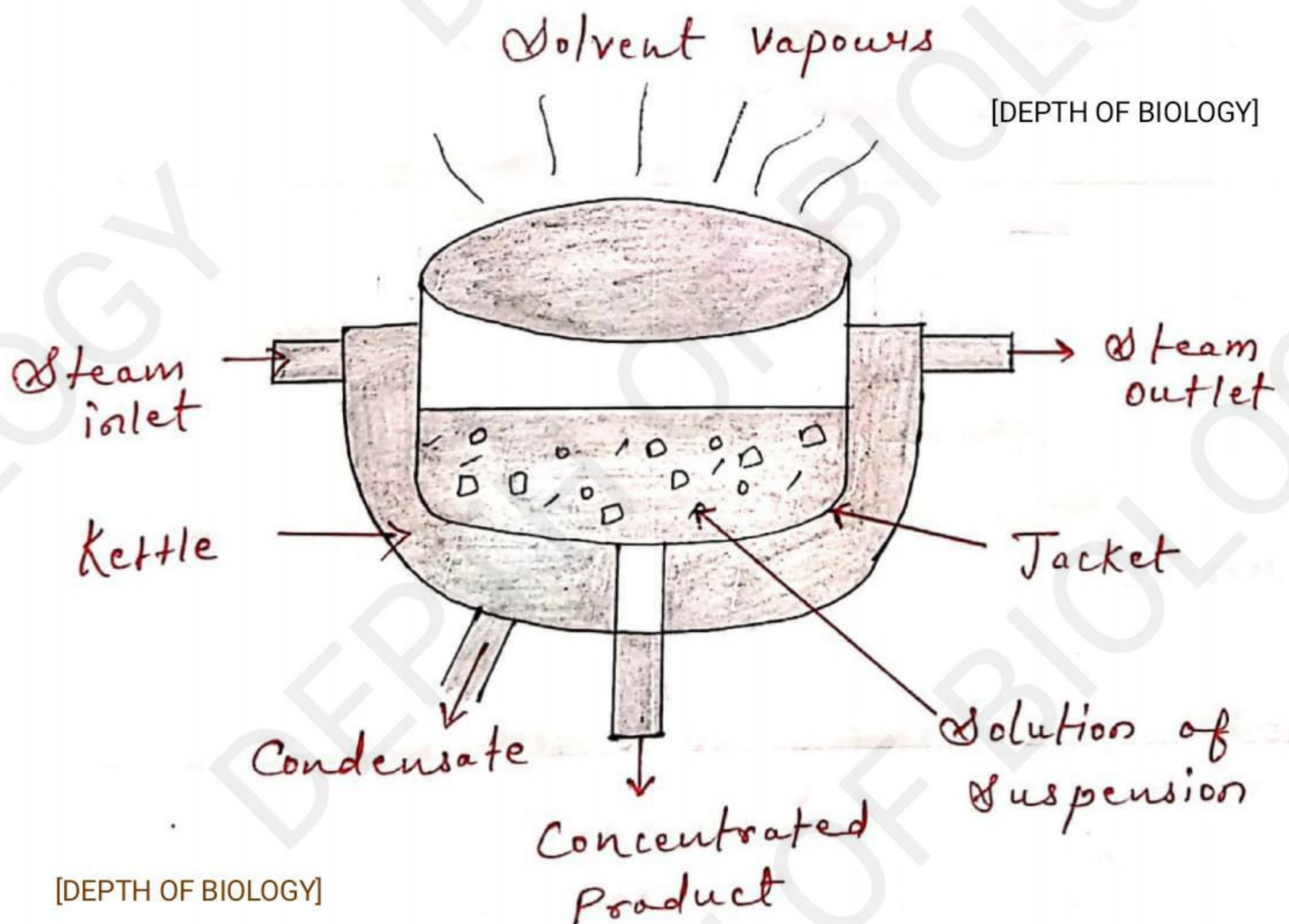
[DEPTH OF BIOLOGY]

↳ Also called evaporating pan.

Principle :- Based on the principle of evaporation.

In this steam gets passed and by absorbing heat liquid get evaporate.

Construction :-



↳ Consists of a hemisphere pan which is made up of a copper or a stainless steel.

[DEPTH OF BIOLOGY]

↳ The pan is covered at downside by a tube made up of copper and is called Jacket.

↳ Steam is passed from a Jacket. Jacket contains one inlet for steam & attached with condensate outlet and vent for non-condensed gases.

↳ One outlet at downside in Kettle for discharge of products.

Working :-

[DEPTH OF BIOLOGY]

↳ First of all solution is placed in Kettle.

↳ Now hot steam is supplied in jacket.

↳ If it is done in small scale then it is to be stirred manually and if in large scale then machines are used for stirring.

↳ Solution absorb heat from jacket and start converting into vapours.

[DEPTH OF BIOLOGY]

↳ That steam which condensed it out from condensate outlet and remaining steam is out in the form of vent.

↳ After evaporation in Kettle final product is collected from the product outlet.

Use:- Used for concentrating aqueous extract and thermostable liquors.

Advantages:-

↳ Used for both small and large scale.

↳ Simple construction. [DEPTH OF BIOLOGY]

↳ Easy in use, cleaning and maintenance.

Disadvantage:-

↳ Unsuitable for heat sensitive material.

↳ Heat economy is less.

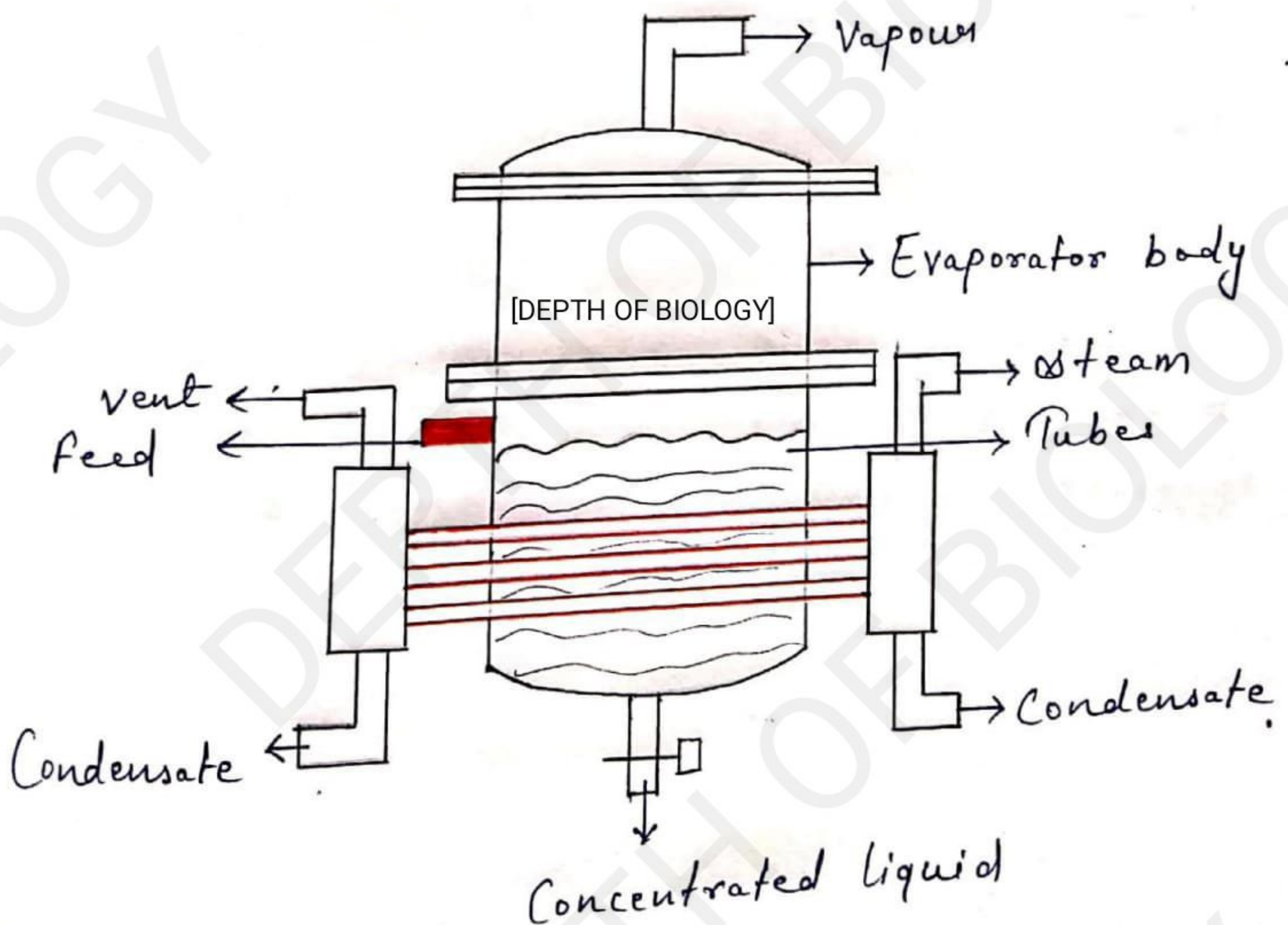
Horizontal Tube Evaporator

Principle :- Evaporation takes place through a horizontally fitted tube.

[DEPTH OF BIOLOGY]

↳ Steam passed through tubes and liquid outside the tube get heated by absorbing heat and convert into vapours and pass out from top.

Construction :-



↳ Consists of a large cylinder body, some tubes are fit in between, cylinder horizontally.

↳ Made up of cast iron or plated steel. [DEPTH OF BIOLOGY]

↳ It is about 1.8 to 2.4 m wide and 2.4 to 3.6 m long.

↳ One inlet for feed and outlet at downside for concentrate products.

↳ Steam inlet from where steam enters condensate for steam and outlet for steam.

↳ There is one outlet at top for discharge vapours.

[DEPTH OF BIOLOGY]

↳ Also there are steam compartment in which 6-8 horizontally placed tubes and steam passed through it.

Working:—

- ↳ First of all feed enter through inlet and steam enter from steam inlet.
- ↳ Through tubes steam is released and liquid absorb heat & because of this heat started to convert into vapours. [DEPTH OF BIOLOGY]
- ↳ Vapours escape from outlet at top.
- ↳ Process continues untill we get the concentrated product that we need.
- ↳ Atlast product is collected through outlet at bottom.

Uses:— For non-viscous solutions.

Advantages:—

- ↳ Cheap
- ↳ Suitable for non-viscous liquids.
- ↳ Easy to install and operate.

Disadvantages:— [DEPTH OF BIOLOGY]

- ↳ Unsuitable for viscous liquid.
- ↳ Heat sensitive material.

Climbing Filter Evaporator

↳ Also called Rising Film Evaporator.

Principle :— [DEPTH OF BIOLOGY]

↳ Evaporation takes place through a tube that are fitted vertically in cylinder.

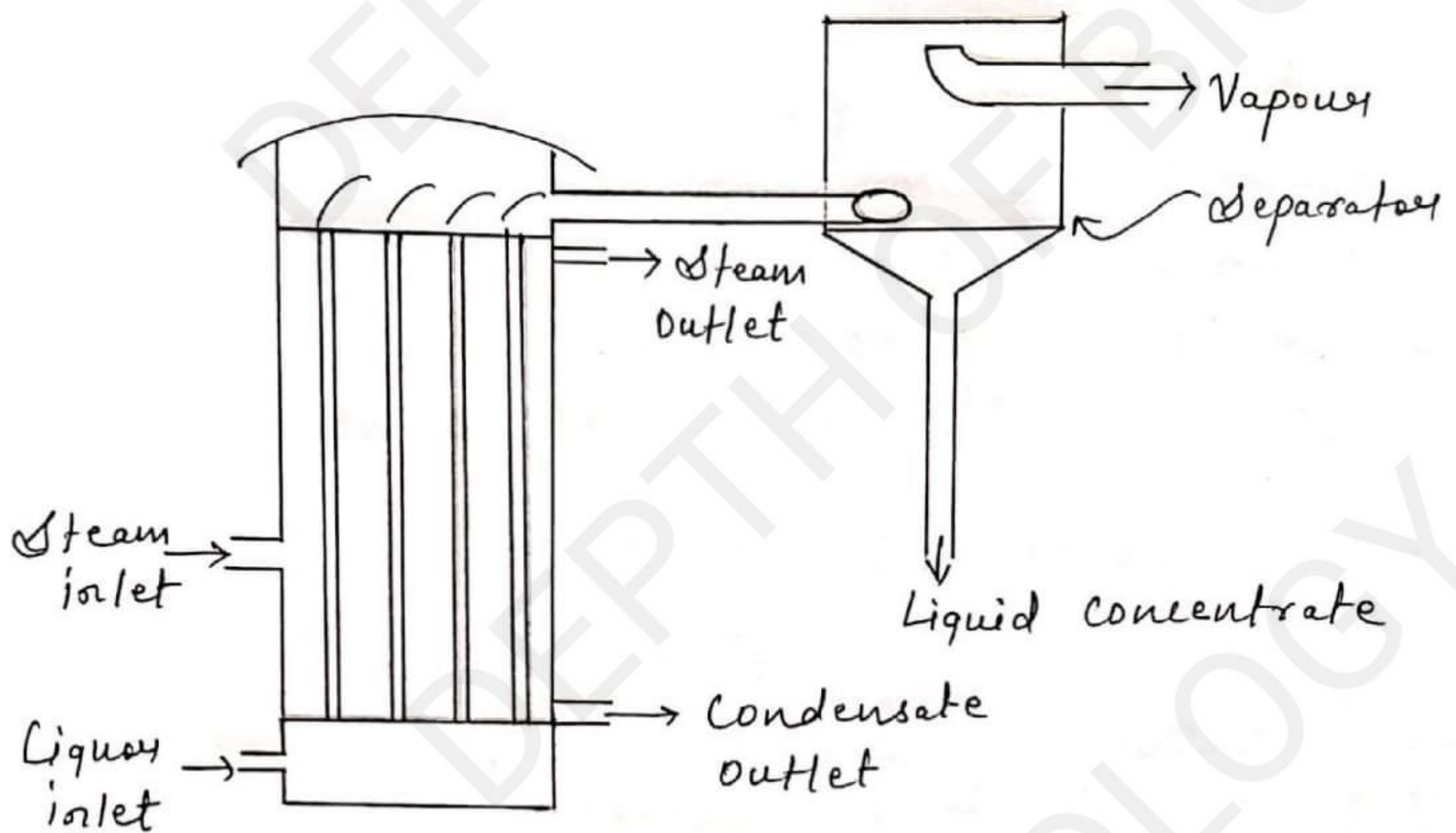
↳ Heat passed through steam in tubes & liquid outside the tubes absorb heat and gets heated, convert into small bubbles which climbs upward.

↳ Vapours discharged from top and concentrated liquid goes to bottom by product outlet.

[DEPTH OF BIOLOGY]

Construction :-

[DEPTH OF BIOLOGY]



↳ Consist of steam jacketed tube.

↳ At the top to the vapour head an entrainment separator is placed. Also condensate outlet for steam and vent outlet. [DEPTH OF BIOLOGY]

↳ Feed inlet from bottom.

↳ One pipe for recirculation that circulate feed again. [DEPTH OF BIOLOGY]

↳ At bottom one product outlet from which product is obtained.

Working:-

↳ From bottom preheated liquid feed is introduced. & Steam introduce into tubes. [DEPTH OF BIOLOGY]

↳ Heat absorbed by liquid and started to make small bubble which started to climb upward.

↳ Bubbles got separated through deflector which is present on vapour head.

↳ Liquid part is passed in pipe for recirculation and vapour goes into separator.

↳ From top vapour discharge and liquid recirculate.

↳ When liquid is concentrated, product obtained from product outlet.

Uses:- [DEPTH OF BIOLOGY]

↳ Used for clear, foaming liquids and corrosive solution.

↳ for insulin, vitamins etc.

Advantages:- [DEPTH OF BIOLOGY]

↳ Supply large area of heat transfer.

↳ Acceptable for heat sensitive material.

↳ Acceptable foam-forming liquids.

Disadvantages:-

↳ Expensive

↳ complicated construction

↳ Not easy to clean

↳ Unsuitable for very viscous liquid

[DEPTH OF BIOLOGY]

Forced Circulation Evaporator

[DEPTH OF BIOLOGY]

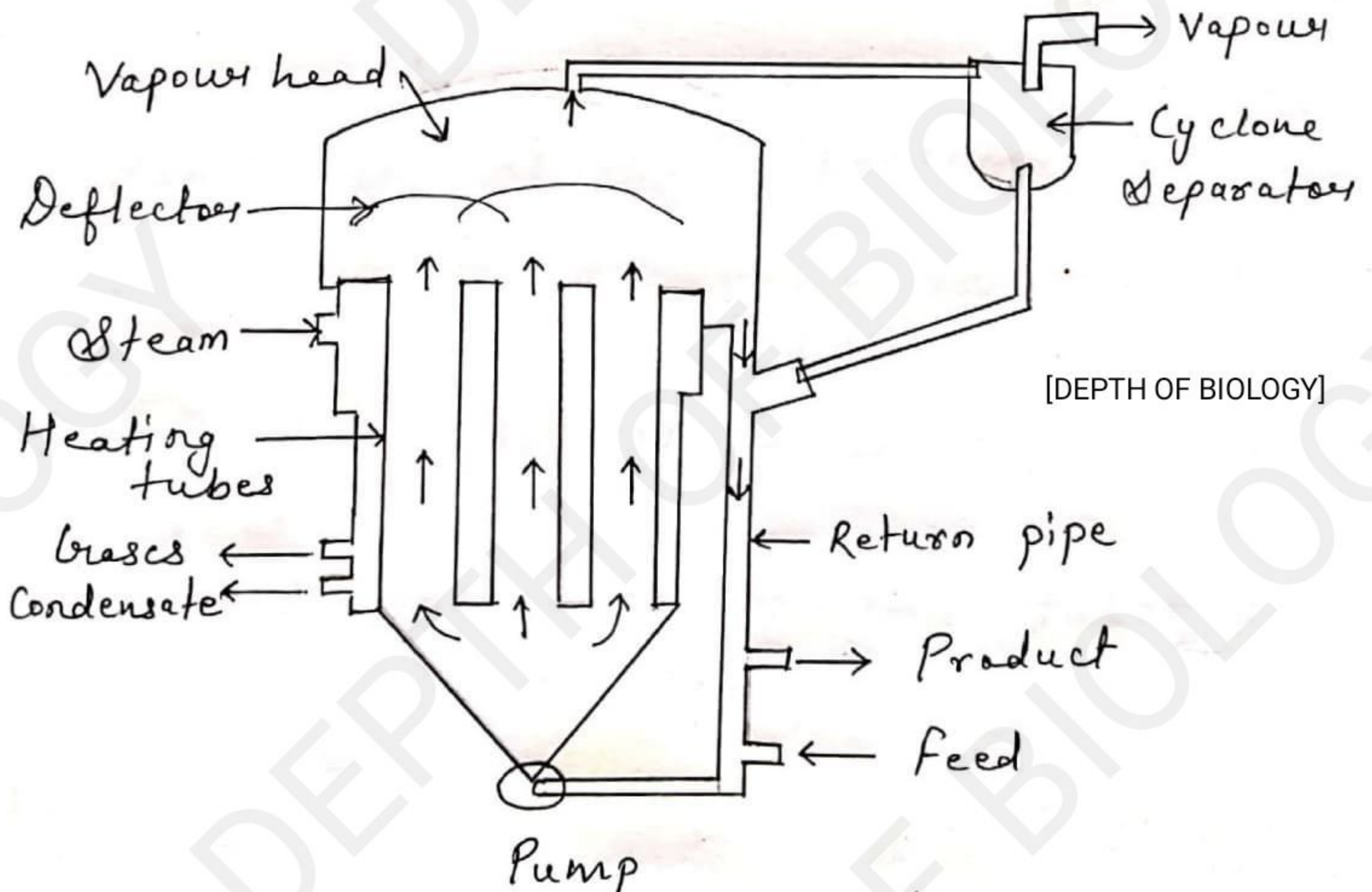
Principle:-

- Liquid is circulated through tubes at high pressure by using pumps.

- Boiling does not take place due to high pressure because boiling point is elevated.

- Liquid creates some form of agitation. Pressure falls suddenly when the liquid leaves the tubes and enters the vapour head. [DEPTH OF BIOLOGY]
- This leads to the flashing of superheated liquor, thus the evaporation occurs.

Construction :-



↳ One centrifugal pump.

↳ Between two tube sheets steam jacketed tubes are held.

↳ Tube measure = 0.1 m diameter
2.5 m long

[DEPTH OF BIOLOGY]

↳ A vapour head with deflector & one cyclone separator which separate vapour & discharge from top from liquid.

↳ There is an outlet for product discharge at the bottom.

Working :-

↳ First of all steam is supplied in tubes.

↳ Liquid introduce to the tubes with high pressure by pump.

↳ After that liquid get heated and move upward.

[DEPTH OF BIOLOGY]

↳ It strikes the deflector and by deflector liquid & vapour separated.

↳ Moreover, Vapour enter in cyclone Separator in which vapour discharge from top and concentrated liquid fallen down. [DEPTH OF BIOLOGY]

↳ If we want more concentrated product it recirculate again.

↳ Atlast concentrated product from outlet is collected.

Uses :-

↳ Suitable for thermolabile substance if used under reduced pressure.

↳ For concentration of insulin and liver extracts.

Advantages :- [DEPTH OF BIOLOGY]

↳ Due to high heat transfer coefficient there are rapid liquid movement.

↳ Suitable for the viscous preparation because pumping mechanism is used.

Disadvantages :-

- Expensive [DEPTH OF BIOLOGY]
- Power is required for circulating the liquids.

Multiple Effect Evaporator

Principle :-

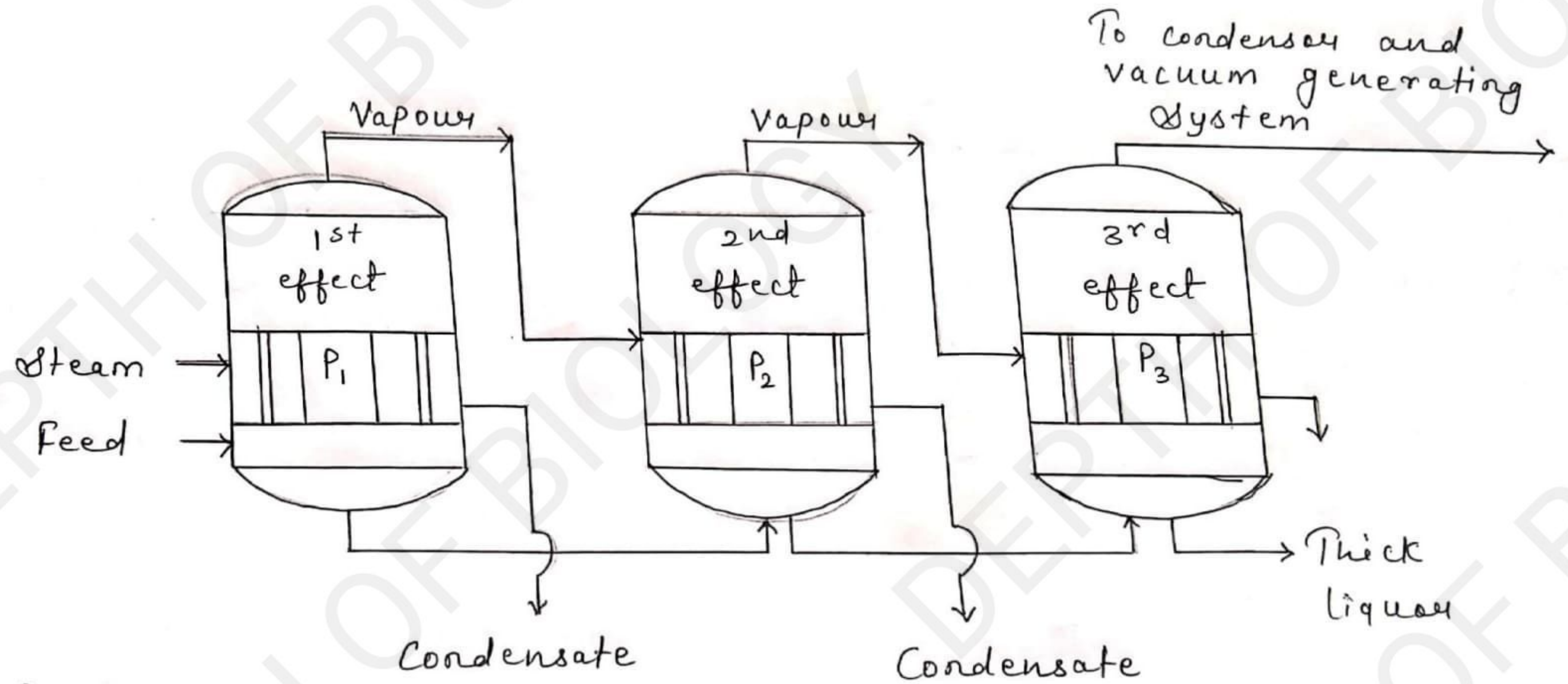
- Vertical tube evaporators are connected in series.
- Used for large scale evaporation and also for higher concentrated product.

The three steps included are :-

- (1) Pre-heating of solution.
- (2) Withdrawal of water as vapour by steam heating. [DEPTH OF BIOLOGY]
- (3) Condensing the vapour removed.

Construction :-

- Consists of three evaporators in series.
- Each evaporator consists of large cylindrical body made up of cast iron. [DEPTH OF BIOLOGY]
- First evaporator has one steam inlet and one for feed.
- First evaporator's vapour outlet is attached with second evaporator's steam inlet and second is attached with third.
- There is one outlet in third evaporator through which we get highly concentrated product.
- In this approx. 100 tubes are fitted.
- For steam each evaporator has condensate. [DEPTH OF BIOLOGY]
- Vapour is discharged in atmosphere through separator in last evaporator.



$P = \text{Pressure}$

$$P_1 > P_2 > P_3$$

[DEPTH OF BIOLOGY]

Working:-

↳ First of all pre-heated solution is introduced in each evaporator up to the level of upper tube sheets.

↳ The steam is introduced in first evaporator and it supply continuously untill desired pressure is created in steam space of first evaporator.

↳ Transfer of heat from steam to liquid. [DEPTH OF BIOLOGY]

↳ During this also some steam is convert into condensate that is removed from condensate outlet.

↳ Liquid temperature increases by absorbing heat and it started to convert into vapours.

↳ The formed vapour move to steam space of second evaporator and work as a steam. [DEPTH OF BIOLOGY]

↳ The vapour of 1st evaporator transmit its heat to the liquid of second evaporator and

through condensate outlet condensate removed. [DEPTH OF BIOLOGY]

↳ In third evaporator same process is applied.

↳ Steam continuous to supply until heat is same in all three evaporators.

↳ Evaporator's product outlet is also connected in next evaporator feed inlet. So feed is same in all evaporators. [DEPTH OF BIOLOGY]

↳ Untill liquid in evaporators reaches the desired viscosity the process is continued.

[DEPTH OF BIOLOGY]

↳ Atlast concentrated product collected from third evaporator outlet.

[DEPTH OF BIOLOGY]

↳ The vapour remained is discharged or separated through

Separator that is connected with third evaporator. [DEPTH OF BIOLOGY]

Uses :-

- Used for large scale and continuous operation.
- When compared with single effect it is highly economical.

Economy of multiple effect evaporator :-

$$\text{Economy} = \frac{\text{Quantity of vapour produced}}{\text{Steam admitted}}$$

↳ It does not require any extra heat for boiling as pre-heated liquid is used. [DEPTH OF BIOLOGY]

↳ There is no loss of heat as there is complete transformation into liquid.

∴ Economy of an multiple-effect evaporator is N times the economy of the single-effect evaporator.

[$N = \text{no. of evaporator used in multiple effect evaporator}$]

[DEPTH OF BIOLOGY]

↳ This is due to one steam inlet and get vapours in one evaporators in single effect.

↳ By applying steam in only one evaporator we get vapour more and more in many evaporator in multiple effect.

[DEPTH OF BIOLOGY]