* Biodegradation → controlled by nature, happen everywhere → living organisms used to degrade chemical compounds or use it as nutrients in some cases (natural process)
  ↓
  slow process

* Bioremediation → cleaning environment from toxic substances
  - produced by human activities

  ↓
  engineered process & it's faster & with human intervention, happen at contaminated sites, Require experts, always beneficial

* Biodegradation sometimes it's beneficial but sometimes it cause harmful

* some chemicals will produce vapors which contain air, some chemicals will find their way to the surface soil, to the sediment, surface water, also in some cases they might their way to the Ground water

* principles of cleaning up using bioremediation

- Bioremediation require use of organisms & mainly microbes

↓

convert these chemicals into harmless substances by their metabolic reactions & some microbes will use these chemicals as a source of food, energy & atoms

& In order to do that microbes use aerobic & anaerobic metabolism & they rely on a type of chemical reaction called oxidation & reduction reaction

* Aerobic bacteria → clean the enviroment where there is oxygen at surface

* Anaerobic → clean in the deap like in soil

* Microbes are everywhere → so we have what we call Indigenous microbes

↳ Microbes that are found everywhere around us & they are found at the site of contamination we are trying to clean by bioremediation

- Some Indigenous microbes when they are living in the soil & the soil become contaminated they can start cleaning the enviroment without our help

↳ Many of the bacterial species that are used to treat the enviroment they were found in the contaminated enviroments

- If a soil is contaminated with a chemical, the most likely place to find bacteria that will degrade this chemical in the site of contamination itself

Because → If there is any bacteria still living in the soil that is contaminated with the chemical, this mean this bacteria can resist this chemical & utilize this chemical

* Their are many Bioremediation Genomics programs trying to identify new organisms by studying their genomes & look for new genes that could remove chemicals from enviroment

* The native bacteria could help with the bioremediation process

Forex → If some soil that contain rock, become contaminated with oil, the bacteria living on the rock some of them they will start growing & use the oil as a source of energy.

but sometimes we need to help this bacteria by adding Fertilizers

Nitrogen, hydrogen carbon, phosphorus essiential atoms that will help to grow & increase the number of bacteria & then they can quickly clean the soil from contaminates

& this is called Biostimulation

providing bacteria with enough oxygen, air, fertilizers, to help the native bacteria to clean the envi. at a faster rate

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* & sometimes we need to add some bacteria or microbes

↳ wt / engineered

to help native bacteria to completly clean the enviroment

Because sometimes native bacteria convert oil to substance A & A is a toxic , so

Oil → A $\xrightarrow[\text{or microbe}]{\text{bacteria}}$ B (harmless)

↓

can't convert oil to A just A → B

→ & sometimes we need to add fertilizers to these bacteria / microbes.

This is called Bioaugmentation

(it might involve biostimulation or might not

* Plants could be also used to clean up chemicals in soil, water, air.

→ There are many types of plants that have been successfuly used for this purpose

— So plants could be planted in area's where their is chemical pollutants, & it could be absorb by the root of the plant

& → in this case plants will have enzymes that could degrade, these chemical pollutants, or some plants absorb these chemicals but can't degrade them & eventually it could kill the plants & these plants must be removed

* 2 Major strategy to clean the soil

1 → Ex situ → contaminated area that will be removed (at treatment plant)
(cleaning happen in an other site)

2 → In situ → contaminated area that we clean it when it's in original location (most common use)
(area contaminated large)

* In situ bioremediation →

- Organisms might require the Indigenous micro-organism specially carry aerobic degradation might require oxygen & this could be done by

↳ pumping air into the soil or H_2O_2

this process called bioventing

Also: Fertilizers might be used to stimulate growth & increase the number of Indigenous

- This approach doesn't always work

*Ex situ →

- Faster & more effective

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↓

1. slurry phase

→ Take soil, mix with water & fertilizers & put it in bioreactors

→ smaller amount

2. solid phase

* 2 Major types of water that require continuos bioremediation

1. Wastwater → produced by human activities

→ will be collected by pipes & eventually it will be transfered into waste water treatment

→ Greywater domestic water from household without fecal contamination

* wastwater treatment

1. physical - primary -
2. Biological
3. chemical

→ first step is ferliration or screening, next is Grit chamber, then the water will contain suspended substances that will be collected in a large tank (primary sedimentation tank)

we collect the water from the top & now it's called primary effluent

will contain:
soluble organic mater that could be utilize by micro-organisms (aerobic micro-organism) as a source of energy & food & this happen in Aerating tank & activated sludge system

& → the water that is produced then is considered secondary effluent (no toxin, still have bacteria & it could be kill by a chemical treatment which is chlorinator & then pass it to uv light to make sure that it's microbes free)

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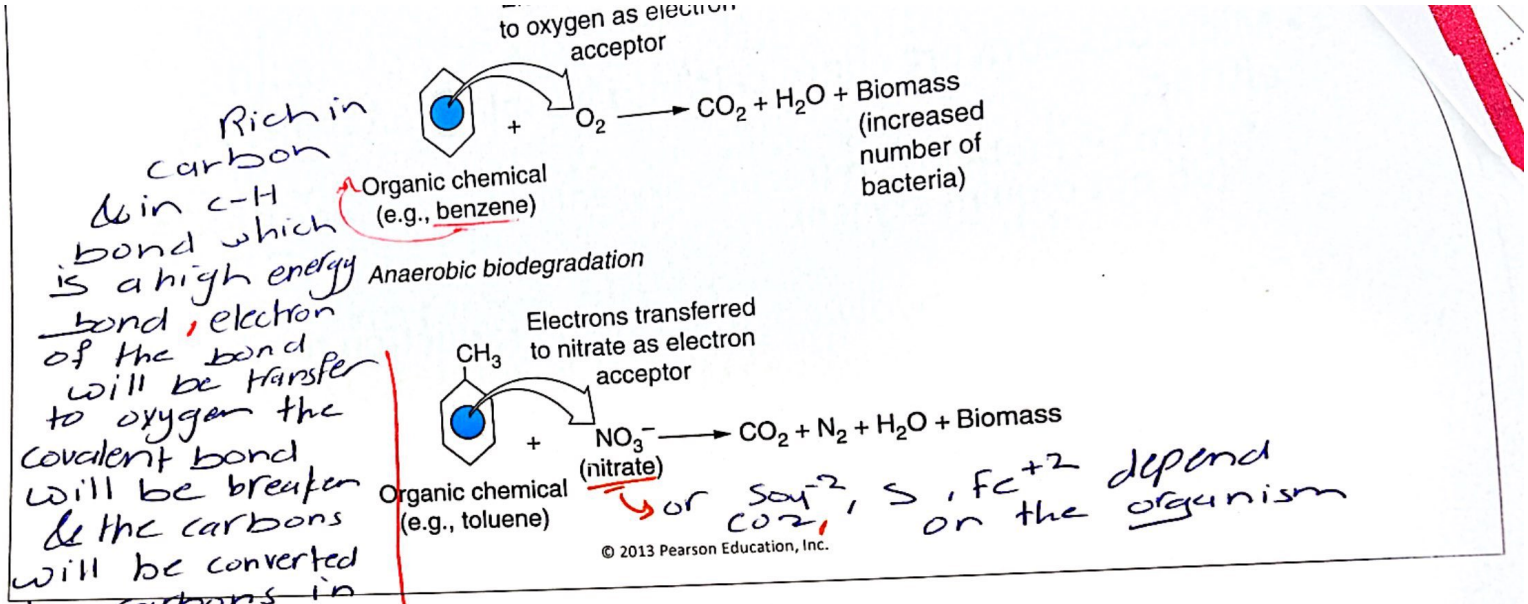
* Also their will be some sedimentation collected from aerating tank & activated sludge system & this is called secondary sludge.

these sedimentation still reach in organic mater that could be degraded by Anerobic bacteria (sludge digestion) & some of these bacteria/microbes will produce methane gas, & this gas could be burned to produce electricity

* cleaning the Groundwater →

• If the Groundwater is contaminated it could be pump out & this water could be mixed with Fertilizers & O2 inside bioreactor in this case we have Ex situ bioreme. (we could add bacteria/microbes to inhance the cleaning) & then the water will be pump back to it's original site & this is an example of In situ biore. (here both Ex situ & In situ plays in the same time)



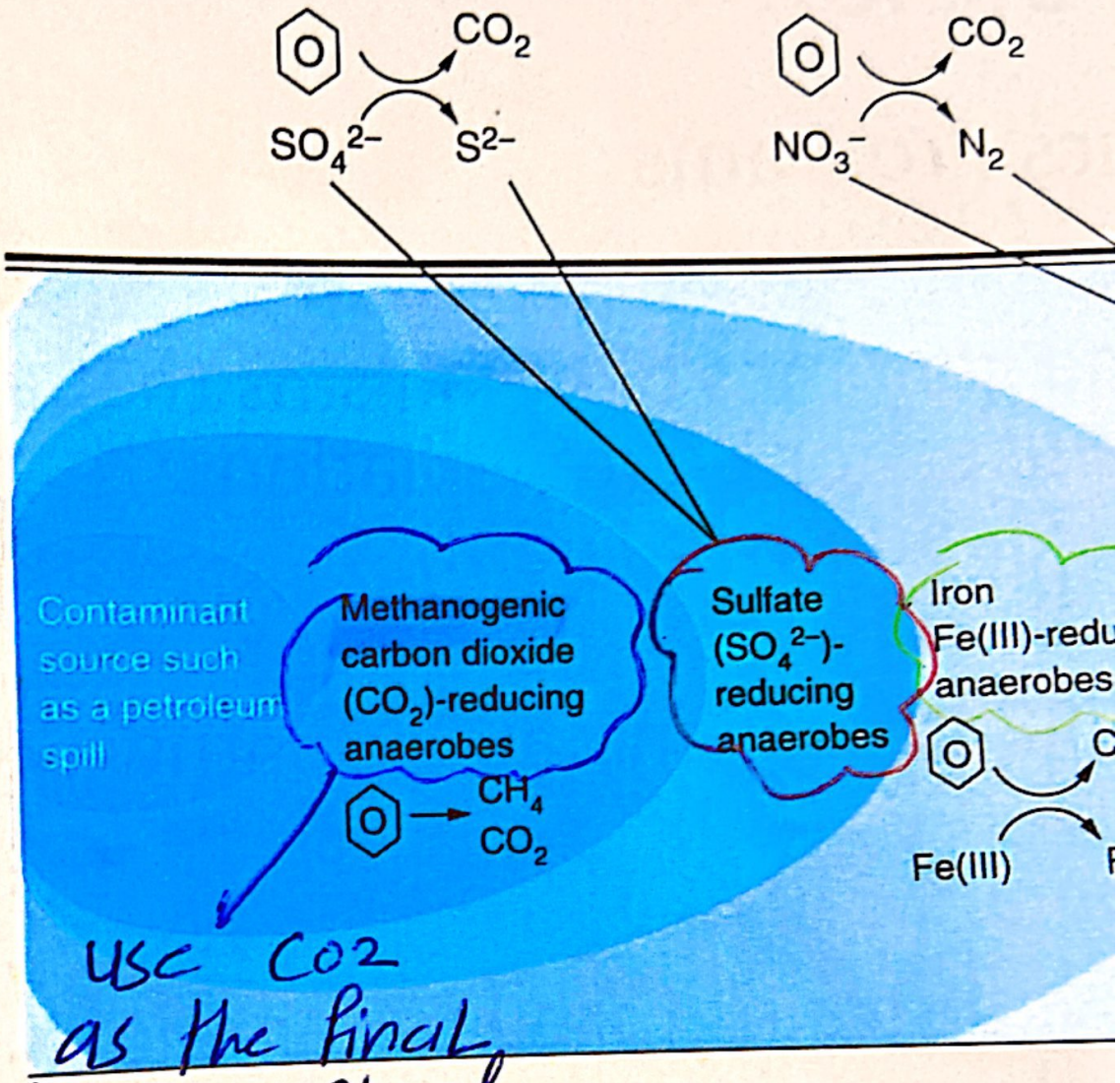
Rich in carbon & in C-H bond which is a high energy bond, electron of the bond will be transfer to oxygen the covalent bond will be breaker & the carbons will be converted to carbons in CO_2 while C are moving to oxygen energy will be released but will be utilize by microbes to increase their number to start growing, carrying out DNA replication, transcription, translation build their membrane. their cell wall, so biomass will increase

or SO_4^{-2}, S, Fe^{+2} depend on the organism

9.2 Bioremediation Basics

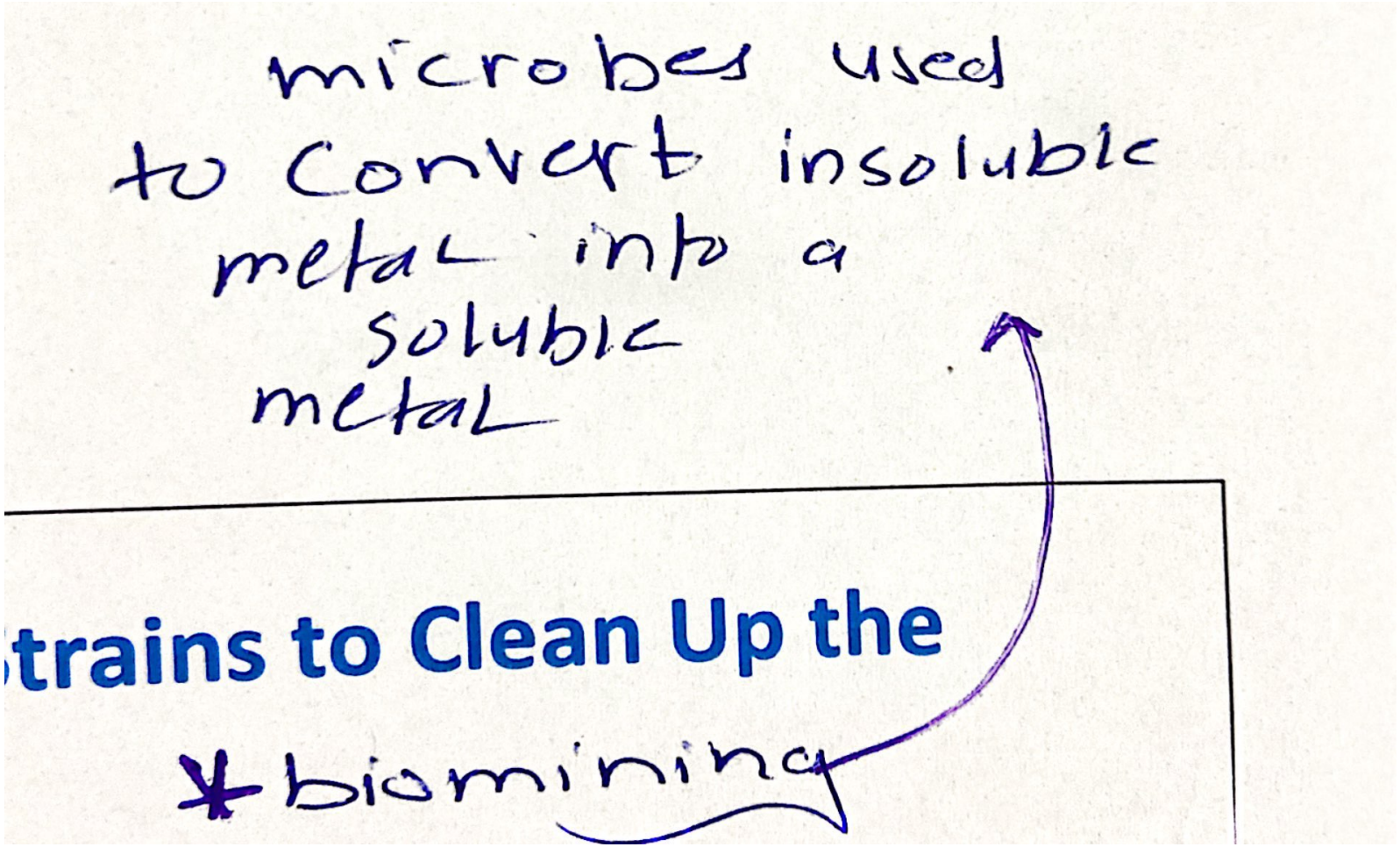
Many rely on

- **The Players: Metabolizing Microbes** From the metabolic reaction in microbes or enzyme that catalyze these reaction
  - Scientists use microbes, especially bacteria, as tools to clean up the environment



use CO_2 as the final electron acceptor & they can degrade organic compound into CH_4 & CO_2

microbes used to convert insoluble metal into a soluble metal



trains to Clean Up the

* biomining