PHYTOREMEDIATION AND GENETICALLY ALTERED PLANTS

Denise Valentin

BSC2010 Intro to Biology I, Dr. Katherine Peach, Broward College

WHAT IS PHYTOREMEDIATION?

Phytoremediation is the use of plants and associated microbes to provide the following processes in cleaning up organic and non-organic (man-made) toxic compounds:

- Phytoextraction uses plants to store high concentrations of inorganic pollutants such as metals
- Phytodegradation uses both plants and soil microorganisms to degrade organic contaminants
- Phytovolatilization releases toxins from the plant into the air
- Phytostabilization uses plants to immobilize contaminants

Fig. 1 below shows where the types of phytoremediation in a plant occur and the functions they perform.

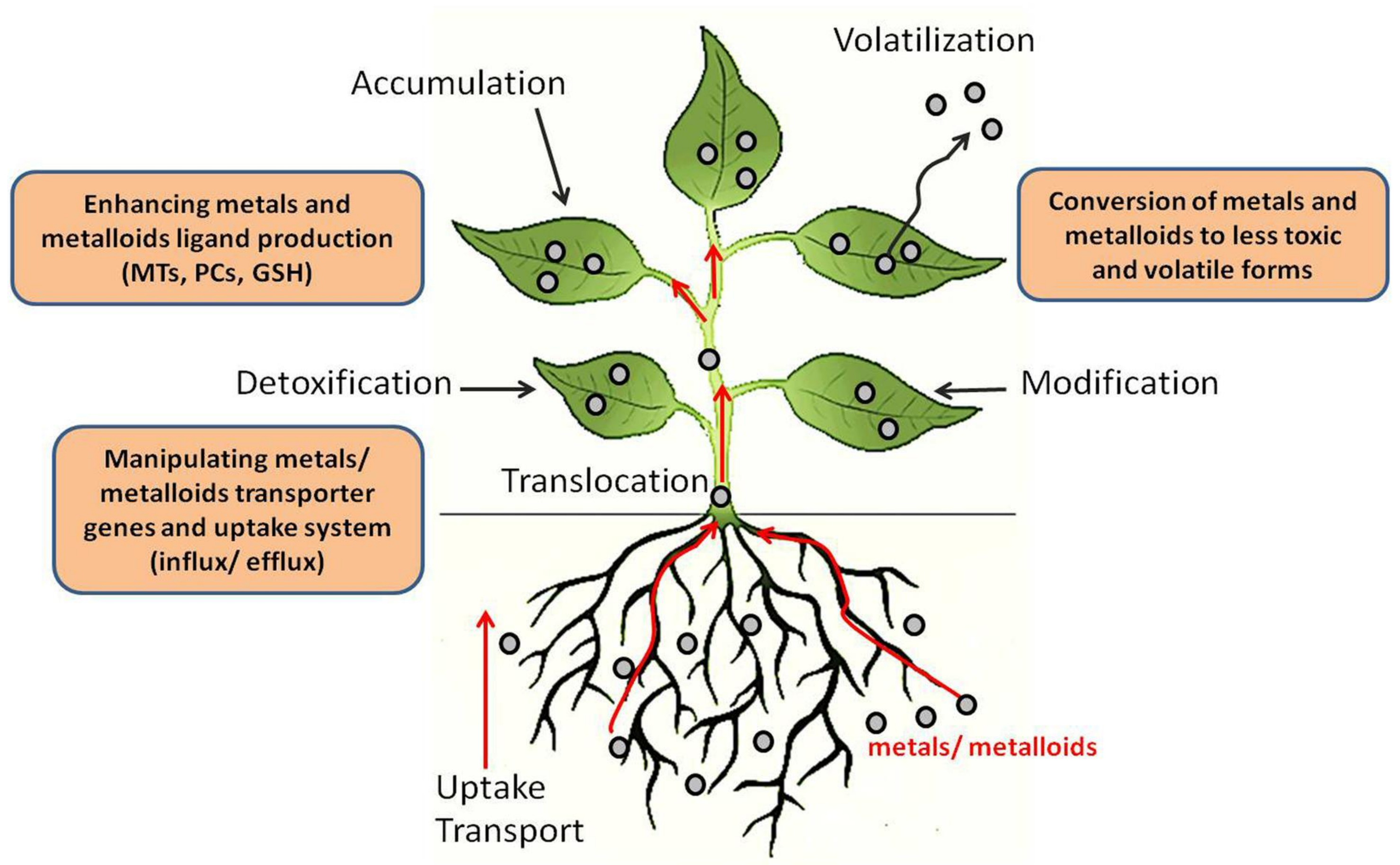

Fig. 1 Potential biotechnological strategies for phytoremediation

HISTORY OF PHYTOREMEDIATION

- Metal and hazardous organic pollutants have increased in the environment due to industry, agriculture and mining
- The old ways of remediation (stabilization, soil excavation and landfilling, soil washing, and/or cleanup using chemicals) are not only very expensive but are also ineffective, causing major destruction to natural habitats and their inhabitants
- Phytoremediation started in the 1980's, after observations in an area of heavy mining that showed certain plant species demonstrated high storage capabilities of toxic metals in their tissues
- Scientists then found that genetic manipulation of hyper-accumulators (plants with high ability to detoxify soil and water) improved the storing and degrading of toxins, thereby increasing their efficiency for phytoremediation
- The first patent application for phytoremediation was filed on November 22, 1985 in Japan

GENETIC APPLICATIONS

Hyperaccumulators are plants that provide a 50-500 times higher potential for detoxification and storage of toxins than regular plants. Research is underway to make these hyperaccumulators even more functional for use in phytoremediation. Hyperaccumulators undergo genetic engineering to transfer genes or traits to increase plant biomass and bioconcentration (ratio between useable part of plant and the concentration of pollutants in the soil) in order to increase plant performance.

The following are some of the different genetic applications being done with plants and trees:

- Plants enzymes are genetically increased to help with metal tolerance and accumulation while increasing antioxidants in the plant
- Plants are genetically altered with synthesized peptides (chains of amino acid) to increase tolerance to metals, especially lead (Pb) and cadmium (Cd) from an increase in root length and greener leaf color
- Plants are genetically altered with genes taken from bacteria, yeast or animals to increase detoxification processes
- Plants are genetically modified with mercury-detoxifying bacteria genes to (1) increase the plants mercury resistance, (2) increase its ability to volatilize (release mercury from the plant), and (3) increase mercury storage in above-ground tissues

Fig. 2 below shows the steps in genetically engineering plants for phytoremediation.

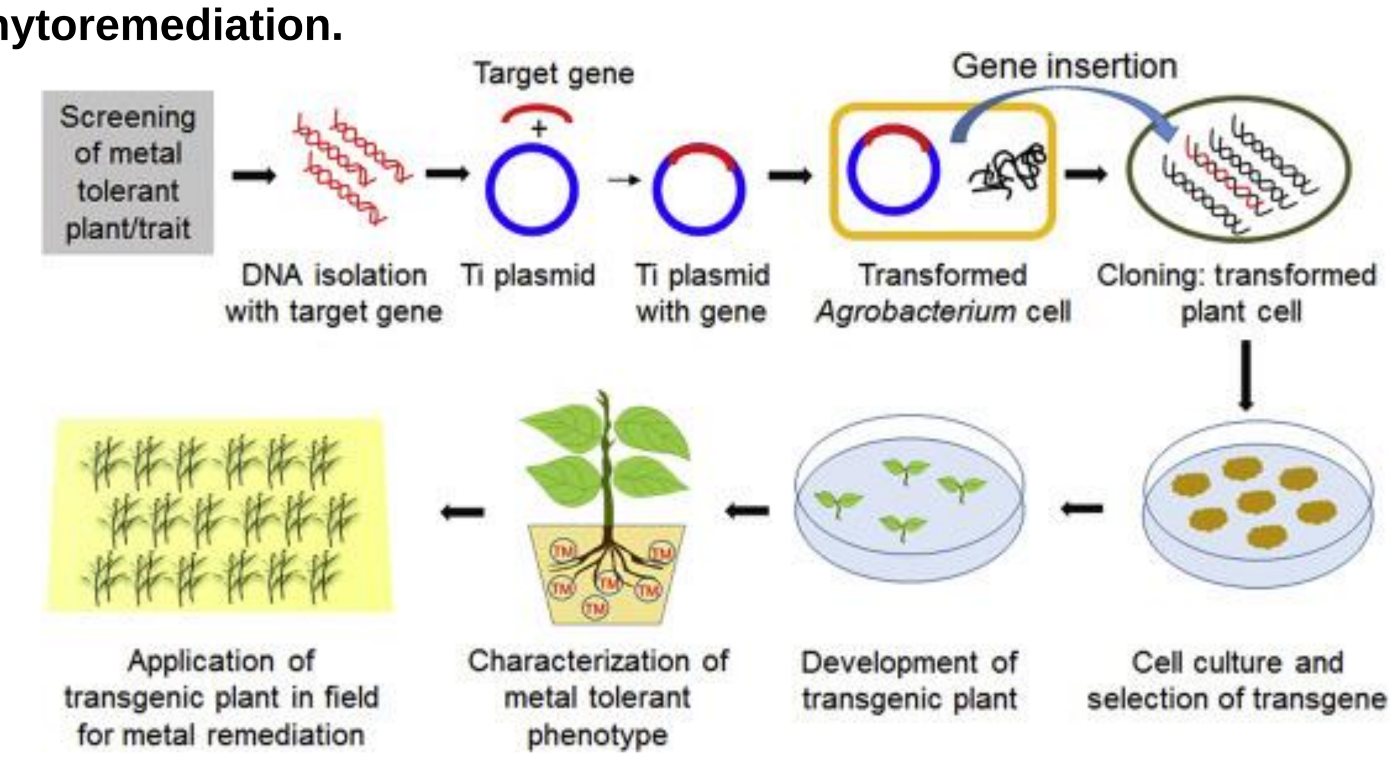

Fig. 2 Gene Expression and Genetic Engineering

POTENTIAL BENEFITS

- Environmentally friendly use of genetically enhanced plants will lower costs significantly compared to the large-scale decontamination projects
- The lower cost of using genetically enhanced plants will allow for more projects to remove toxic chemicals from surface water, ground water, soils, and allow for damaged ecosystems to restore themselves
- Since genetically modified plants are more effective in removing toxins in the environment, this will help keep those toxins from moving up the food chain and inevitably entering human bodies
- The altering of genes in plants keep the plants safe against the toxins by (1) increasing their tolerance to metals, (2) allowing them to store more pollutants in the leaves and stems, and (3) transport toxic molecules across membranes easier

POTENTIAL RISKS

- There can be a possible spread of altered genes to other plants in the same or different plant species if correct methods are not used to inactivate unwanted traits
- Genetically-altered plants may become an invasive species (non-native plant that could cause harm to an ecosystem)
- Genetically altered plants may alter soil fertility
- Storage of contaminants in the genetically altered plant may harm other cellular functions of those plants
- Herbivores (plant eating animals) may not feed from the genetically altered plants

RESEARCH LIMITATIONS

- Hard to predict long-term environmental effects when using non-native genetically engineered plants
- Hard to assess all environmental risks as it may take time for them to show up in ecosystems
- Scientists do not fully understand plant and microbe relationships, metal accumulation in the environment and ion homeostasis (equilibrium)

CONCLUSIONS

Research continues using the manipulation of genes to increase the phytoremediation capabilities of plants and trees. However, more genetic engineering and testing of those plants is needed. The good news is that measures have been found to (1) prevent the spread of the mutated plants and (2) to prevent horizontal gene transfer to other plants. Plants are a positive way to clean up the environment as they require little maintenance, reduce movement of contaminants and supply nutrients for necessary microbes needed to break down toxins. Most importantly, plants remove CO_2 and give off oxygen, a necessity for all living things on this planet. They are the green way to clean up our polluted lands and waters.

References

Cherian, S., & Oliveira, M. M. (2005). Transgenic Plants in Phytoremediation: Recent Advances and New Possibilities. *Environmental Science & Technology*, *39*(24), pp. 9377–9390. Retrieved from https://doi.org/10.1021/es051134l

Davison J. (2005). Risk Mitigation of Genetically Modified Bacteria and Plants Designed for Bioremediation. *Journal of Industrial Microbiology & Biotechnology,* Vol. 32 (11/12), pp. 639-650. Retrieved from Ebscohost.com DOI:10.1007/s10295-005-0242-1.

Maestri E, & Marmiroli N. (2011, January) *International Journal of Phytoremediation*. Vol. 13, pp. 264-279. Retrieved from Ebscohost.com DOI:10.1080/15226514.2011.568549.

Mosa, K., Saadoun, I., Kumar, K., Helmy, M., & Dhankher, O. (2016, February 25). Potential Biotechnological Strategies for the Cleanup of Heavy Metals and Metalloids. Retrieved from https://www.frontiersin.org/articles/ 10.3389/fpls.2016.00303/full

Kumar, A., & Prasad, M. (2019, January 11). Plant Genetic Engineering Approach for the Pb and Zn Remediation: Defense Reactions and Detoxification Mechanisms. Retrieved from https://www.sciencedirect.com/ science/article/ pii/B9780128143896000171