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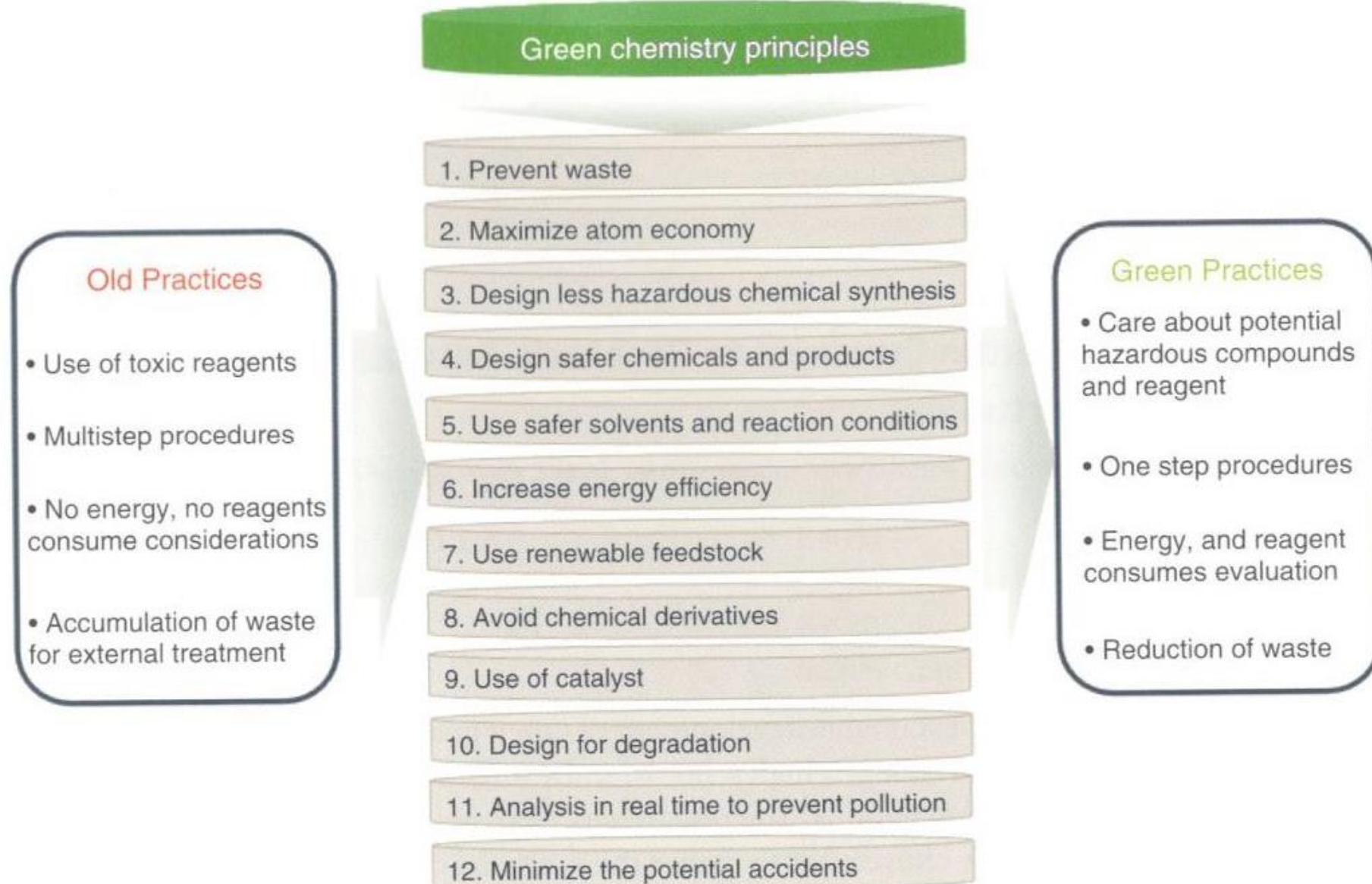
Green Chemistry



Green Chemistry

- = sustainable chemistry
- design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances and waste
- environment friendly
- cost-effective
- renewable plant resources
- alternative solvents
- reduction of energy consumption

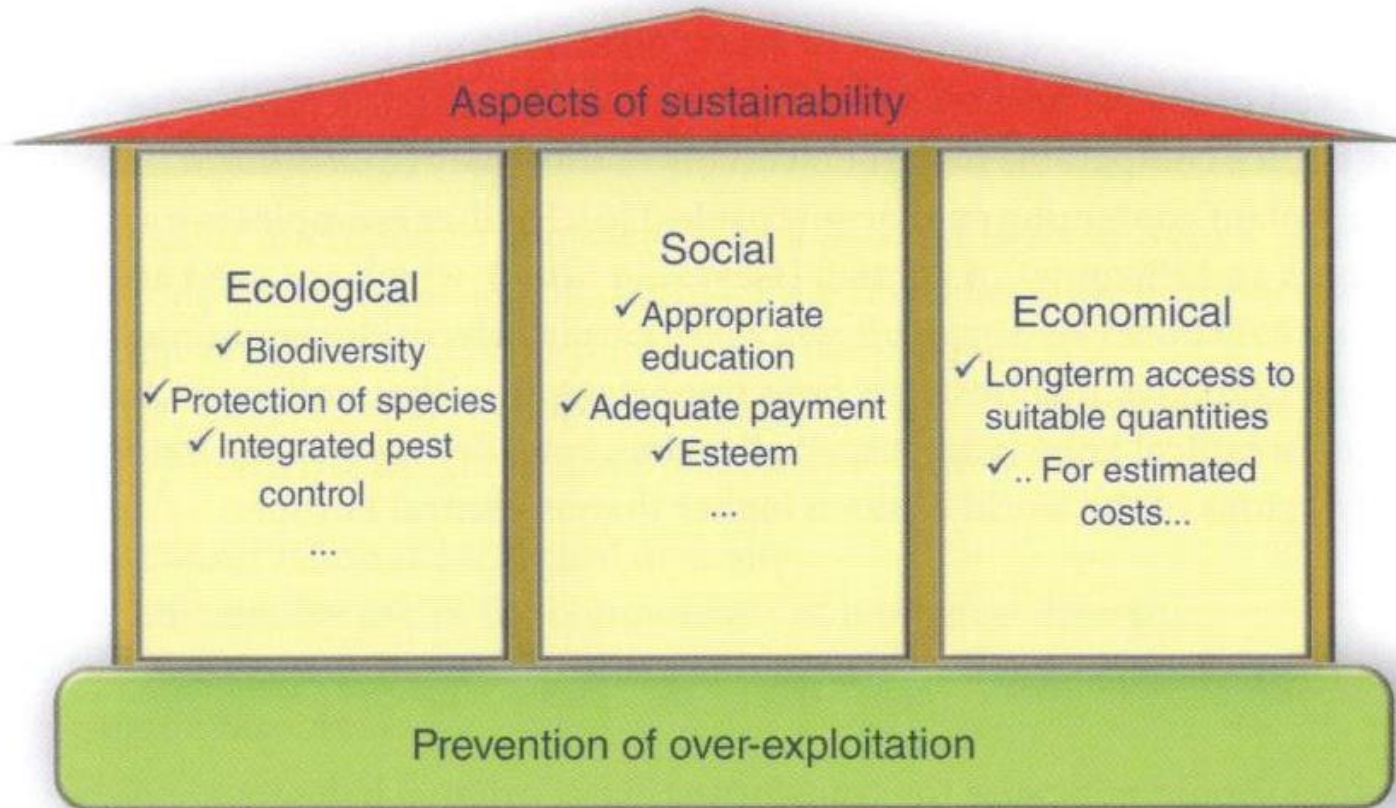
Green Chemistry Principles



Sustainable Processes

- **Social sustainability** = the ability of a social system to function with a level of well-being
- **Environmental sustainability** = the ability of the environment to provide a level of environmental quality and to assure that no species becomes endangered or even extinct
- **Economic sustainability** = the ability of an economy to assure a defined level of economic production

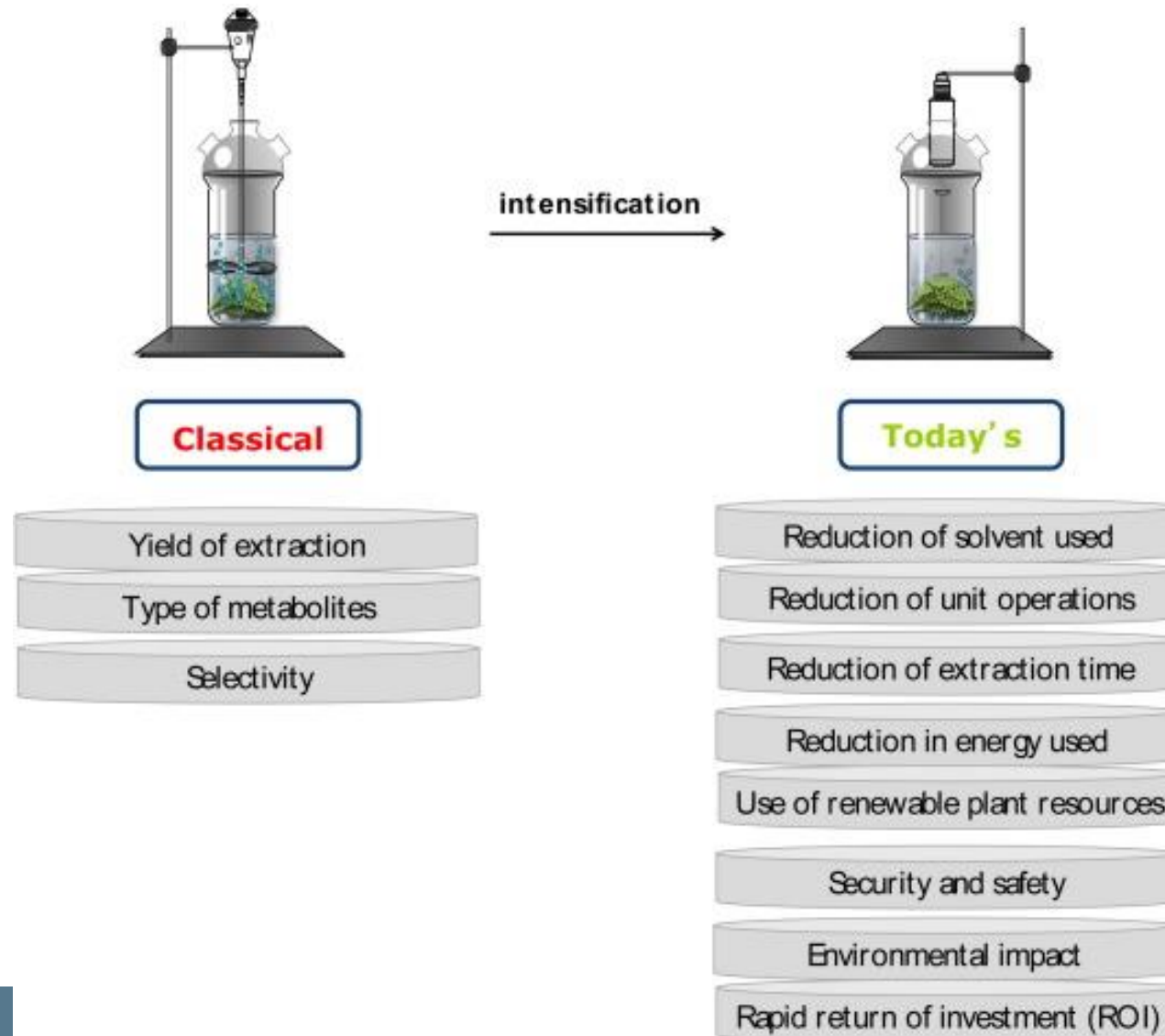
Pillars of sustainability



Green Extraction Principles

- Innovation by selection and use of varieties of renewable plant resources
- Use of alternative solvents, principally water or bio-based solvents
- Reduction in energy consumption by energy recovery, using innovative technologies
- Manufacture of coproducts instead of waste to include the bio- and agro-refining industries
- Reduction in unit operations, favoring safe, robust, and controlled processes
- Aiming for a non-demand and biodegradable extract without contaminants

Green Extraction



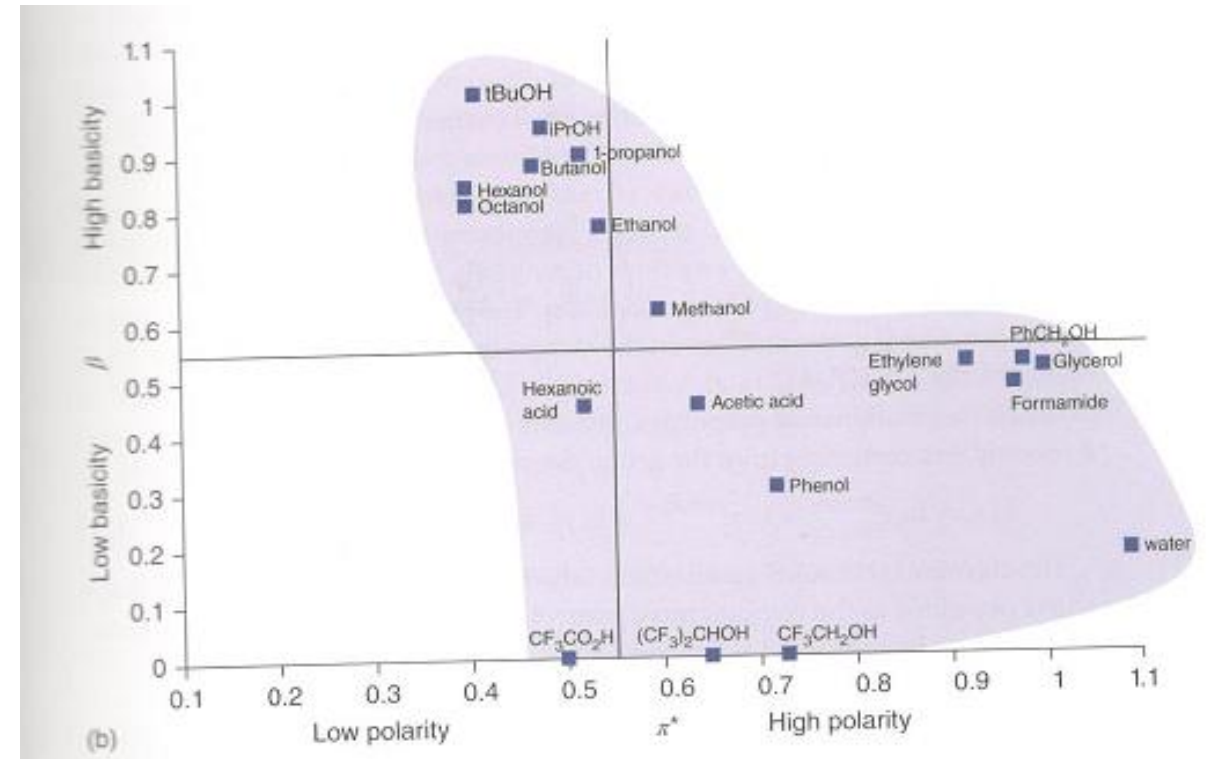
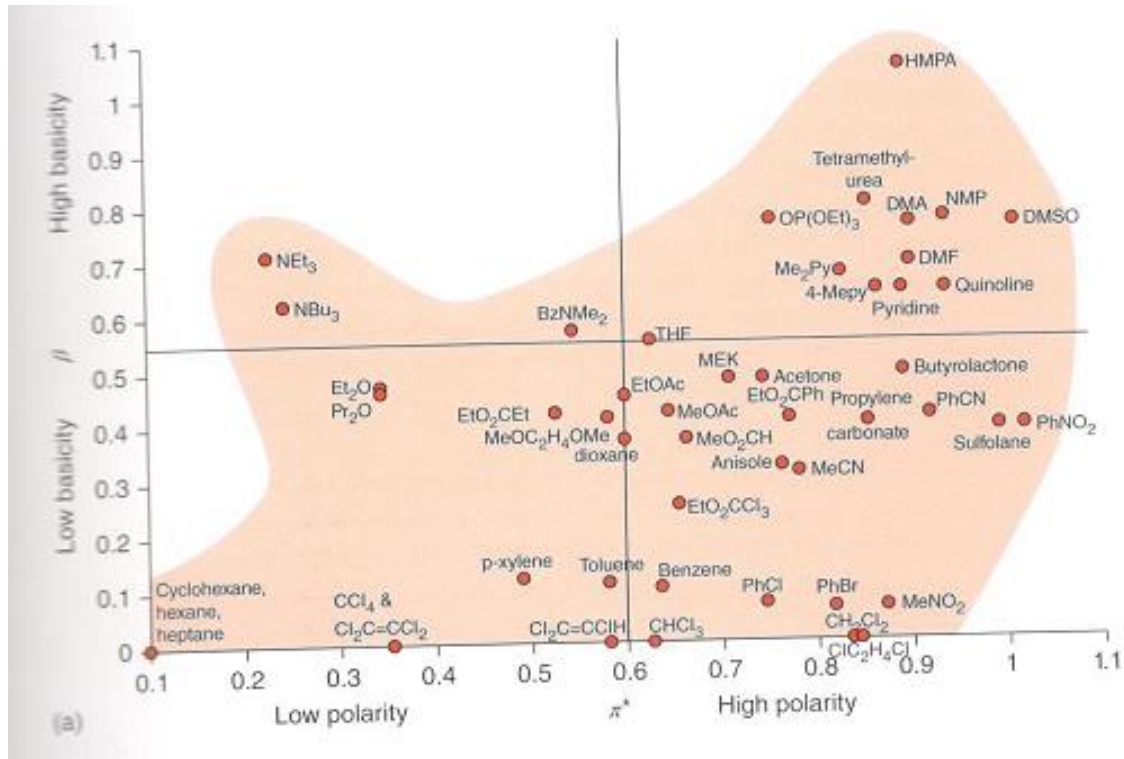
Innovation by Selection of Varieties and Use of Renewable Plant Resources

- Proper selection of feedstock biomass
- Breeding
- Seed production/Vegetative propagation
- Crop rotation
- Choice of cultivation location
- Fertilization
- Organic farming
- Diseases and pests

Use of Alternative Solvents and Agro Solvents

- Chemically inert, nonflammable, temperature stable, and of low or negligible corrosiveness
- HSE (health, safety, environment)
- Bio-sourced/bio-based solvents are not necessarily „green“

Physical properties of solvents



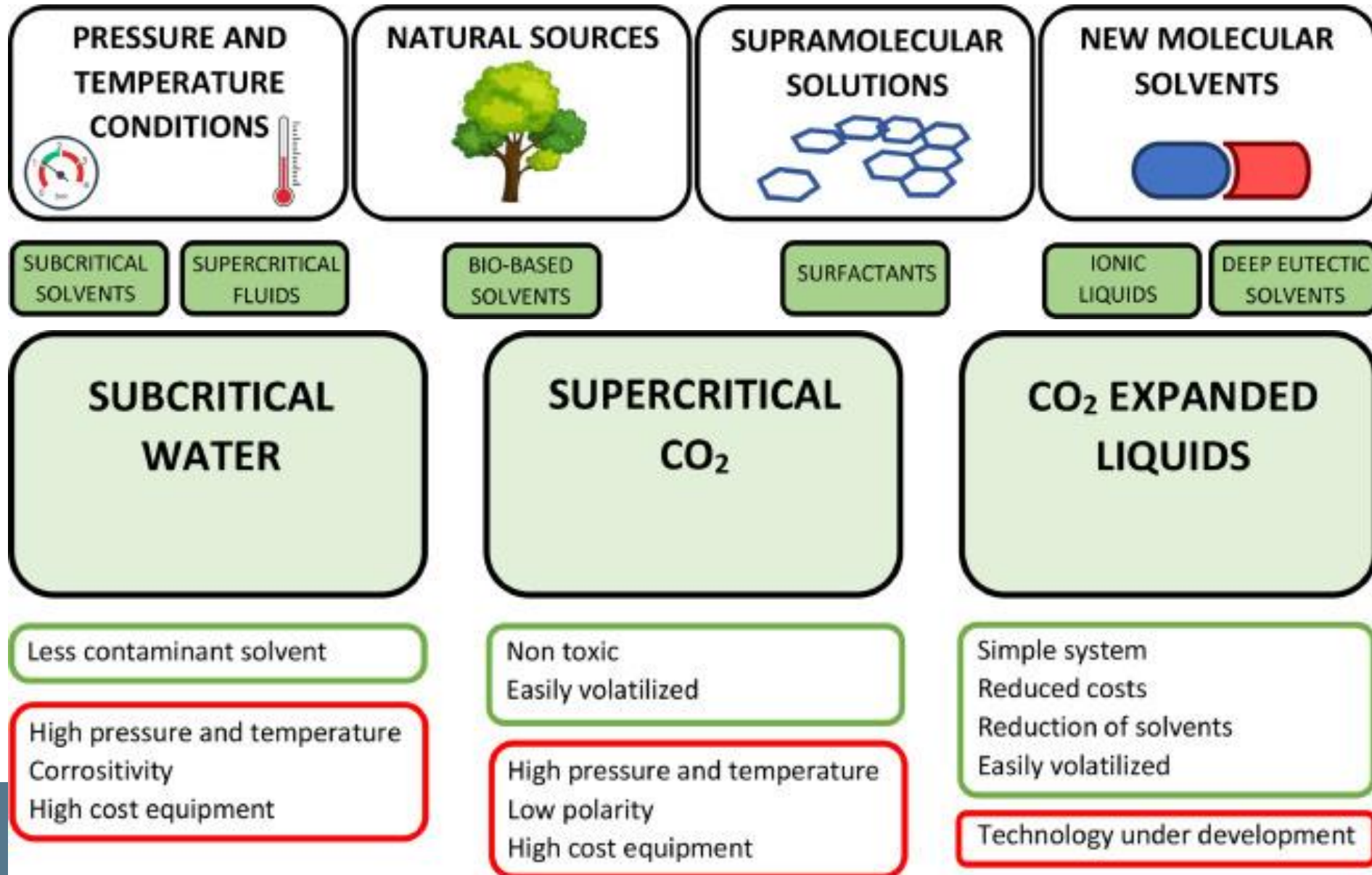
Alternative green solvents - criteria



Alternative green solvents

- Subcritical water
- Supercritical fluids
- Bio-based solvents
- Surfactant-based solvents
- Deep eutectic solvents
- Ionic liquids

Alternative green solvents

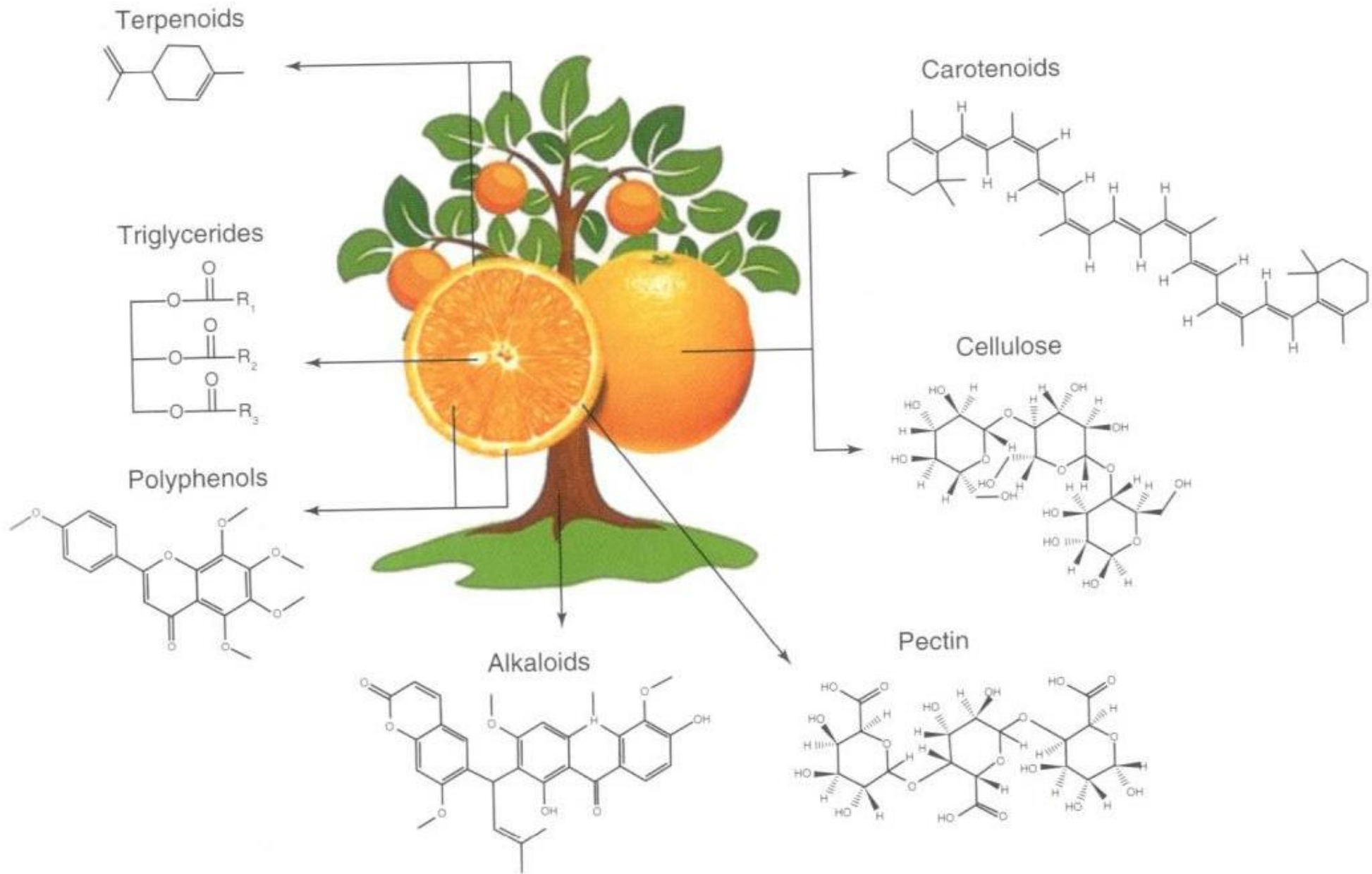


Production of Coproducts Instead of Waste

- An effort to use as much as possible
- **Coproduct** = product manufactured along with a different product, in a process in which both are required in the production of another product
- **By-product** = output other than the principal product(s) of an industrial process; usually an undesirable product of low value
- (see *Citrus* example)

Prioritizing a Non-denatured and Biodegradable Extract without Contaminants

- Resulting safe extract
- Without residual solvents
- Without contaminants from raw material
- Without denatured compounds due to drastic extraction conditions (= artifacts of separation procedure)



Study literature

- *Green extraction of natural products : theory and practice*. Edited by Farid Chemat - Jochen Strube. Weinheim: Wiley-VCH, 2015. xviii, 363. ISBN 9783527336531.
- KUSUMA, Heri Septya; ALTWAY, Ali; MAHFUD, Mahfud. Solvent-free microwave extraction of essential oil from dried patchouli (*Pogostemon cablin* Benth) leaves. *Journal of Industrial and Engineering Chemistry*, 2018, 58: 343-348.
- ARMENTA, Sergio, et al. Alternative green solvents in sample preparation. *Green Analytical Chemistry*, 2022, 1: 100007.