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Biosensing of Heavy Metals

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Abstract Naturally occurring, regulated resistance mechanisms of bacteria against various heavy metals and metalloids have been used to construct whole-cell living biosensors or bioreporters. Molecular fusions of regulatory circuits with reporter genes encoding easily detectable reporter proteins enable bioreporters to sense metal targets, typically at concentrations in the nanomolar to micromolar range, although more sensitive sensors also exist. The biological components of extant bioreporter constructs and the target ranges and sensitivities of bioreporter constructs are presented. An outlook on developments using novel molecular interactions as triggers of the biological responses and strategies for the improvement of bioreporters is given. Application examples are presented that illustrate the capability of bioreporters to measure bioavailable fractions of the target species rather than total loads.

1 Introduction

The binding of a chemical to a biological receptor can be regarded as the consequence of the successful recognition of these two partners. As such it is potentially useful for the analysis of the chemical, provided that there is a possibility to observe the binding in a way that has advantages over the chemical analysis of the chemical. From a practical point of view, the usefulness of receptor–ligand interactions for analytical purposes depends primarily on the kind and extent of a conformational change resulting in the receptor,

and on the biological role that the receptor molecule plays. Those receptor molecules that are involved in cellular signalling chains or circuits are particularly promising targets for the development of biological sensor systems. This is for two reasons: Firstly, ligand-binding to such receptors typically has a natural function in connection with the biological effect of the ligand, be it the induction of a catabolic pathway by a substrate or the up-regulation of a defence reaction by a toxicant. Secondly, the binding typically activates a functional detection chain that provides a good basis for extension by an observable reporter principle.

2 The Principle of Bioreporter Organisms

So-called whole-cell living biosensors or bioreporter organisms rely on biological recognition and, unlike many enzyme-based biosensors, make use of an extant detection chain. This has the advantage that the technical periphery for signal transduction and interpretation can be simplified and reduced or even omitted, for instance in the case of bioreporter reactions that can be interpreted with the naked eye. The fact that living organisms are used for chemical analysis has advantages such as the ease and low price of bioreporter

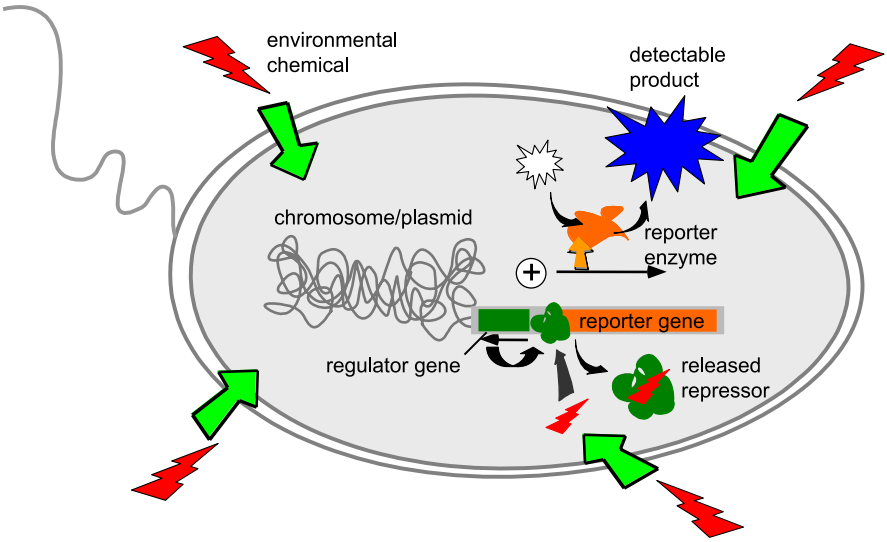

Fig. 1 Schematic representation of a class I bioreporter bacterium for an environmental chemical (drawn as a *flash*). Upon entering the cell the chemical induces the transcription of a reporter gene, in the case depicted here by causing a repressor protein to leave the promoter/operator region. The accumulation of a visible reporter enzyme product results in signal amplification. Reproduced from (Harms et al. 2006)