Translating from nature to technology: Framework to compare innovation pathways in biomimicry

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Biomimicry is a growing area of research that seeks to abstract functions and architectures observed in nature to solve problems in science and engineering. Previous studies have documented biomimicry efforts in individual subfields, and discussed the philosophical foundations of biomimicry as a sustainability-oriented innovation strategy. Less work has been done, however, on describing the individual steps of abstraction taken in the course of biomimicry innovation efforts. Studying this question can add to an understanding of how the process of replicating or mimicking nature works in practice, and whether successful outcomes result from similar inputs.
Here we begin to address this gap by compiling a database of the most widely discussed biomimicry applications. We use this database to develop a conceptual framework to describe the process through which biological phenomena have been translated into technologies (Fig. 1). We use the term 'translate' to indicate that there are different ways to start from an observation of nature and end with a technology, just like there are multiple ways to translate words from one language to another.
We find that a variety of biomimicry pathways have led to inventions and commercial products, ranging from those where the biological phenomenon is partially or fully explained and mechanisms or entire architectures can be replicated through engineering design (mechanistic pathway), to those where the biological phenomenon is observed and mimicked, but may not be fully understood (phenomenological pathway). We also classify biomimicry applications along other dimensions, including whether the translation process encompasses changes in the spatial scales or the media in which mechanisms operate. The goal of this work is to take stock of past biomimicry efforts in a way that identifies common and differentiating characteristics of biomimicry efforts.

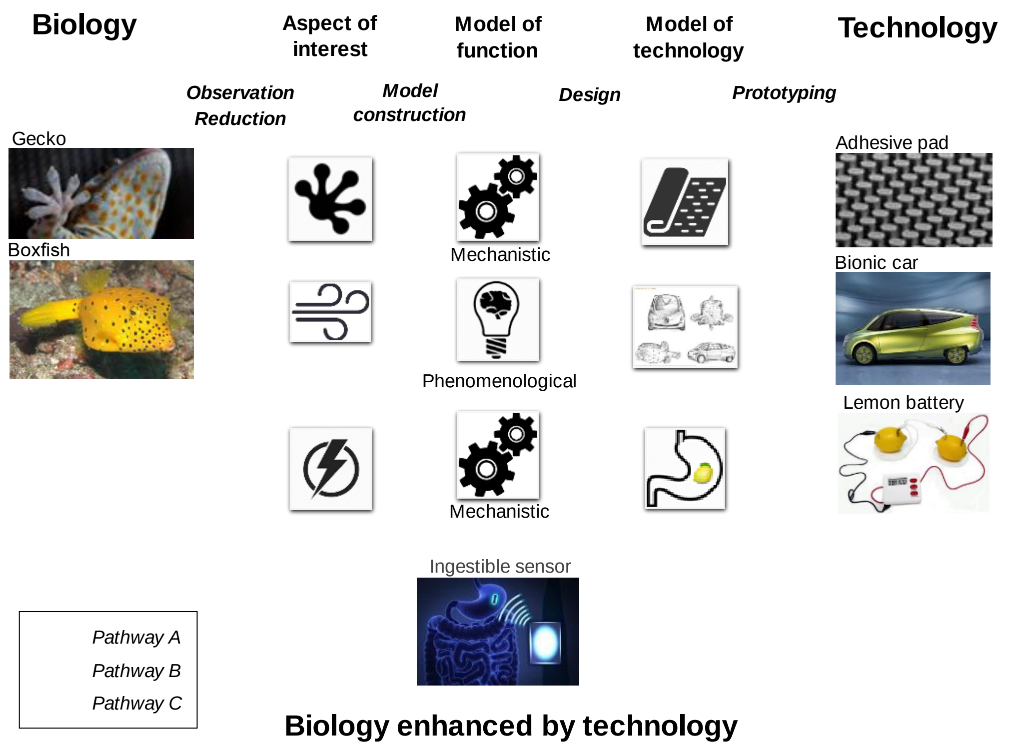

Figure 1: Pathways to translate functions observed in nature (left) into technological applications (right), or vice versa. Observation and reduction, model construction, design, and prototyping are common to all three pathways. Design may involve changing the context of a biological function (spatial and temporal scale, media such as water, air) to match the engineering problem at hand. Pathway A (blue) involves an understanding of the mechanisms governing a biological function (mechanistic model), while pathway B (red) draws on interpretations of why functions occur to inspire designs (phenomenological model). Pathway C (grey) involves the use of technologies in interaction with biology, for instance in medicine, and therefore starts off in the opposite direction of A and B. Our examples draw on innovations in materials science (pathway A: adhesive materials replicating van der Waals forces governing Gecko foot hair), automotive design (pathway B: Bionic car modeled after boxfish), and biomedicine (pathway C: long-lived, low-