Categories of Analogy for Bio-inspired Design

When looking to nature for inspiration, there are a variety of analogies that can be derived from the physical and behavioral aspects of the biological system. Often a single biological system can lead to multiple analogies that result in different engineering solutions. The following categories of analogies in Table 1 aim to guide the designer in understanding the inspiring biological system from a variety of viewpoints. Analogies related to physical characteristics are in orange, and those related to non-physical characteristics are in blue.

Function analogies relate what the system is designed to do or does as a result of its design. Structure analogies are those that describe the internal aspects of a system, which support the form. Form analogies relate to structure and capture the external geometry and aesthetics of a system. Surface analogies focus on the textures or topologies of an object or component's surface. Material analogies capture the aspects of the biological materials. Process analogies entail a series of actions or steps being carried out such as fabrication, navigation, or communication. System analogies capture the essence of the biological system and how it interacts with its surroundings, and could encompass many other categories.

Table 1: Analogy Category Definitions and Examples

Category	Definition	Examples
Form	Visual features including shape, geometry, and aesthetic features; external morphology	Mercedes-Benz bionic car inspired by fish body shape, High speed train inspired by kingfisher beak
Material	Attributes or substances that relate to material properties	PureBond Adhesive
Surface	Attributes that relate to topological properties; surface morphology	Sharklet Technologies Anti-bacterial surfaces, Gecko inspired dry adhesive
Architecture	Internal features including, geometry that support the form; internal morphology; Interconnections among sub-systems	Woodpecker inspired shock absorption, Pigment free color
Function	The actions of the system or what the biological system does; physiology	Termite mound inspired self heating and cooling buildings, IR detection inspired by fire beetles
Process	Series of steps that are carried out; behavior	Photosynthesis based solar cells, Locomotion for robotics
System	High level principle, strategy, or pattern; When multiple sub-categories are present	Wind Farm design inspired by schooling fish

References:

Nagel, J.K.S., Schmidt, L., Born, W. (2018) "Establishing Analogy Categories for Bio-Inspired Design," Designs, Vol. 2(4), pp.47-64. doi:10.3390/designs2040047

Nagel, J.K.S., Schmidt, L., Born, W. (2015) "Fostering Diverse Analogical Transfer in Bio-inspired Design," Proceedings of ASME IDETC/CIE 2015, DEC-47922, Boston, MA.