With the development of civilization and climate change, an increasing portion of generated energy is used to ensure thermal comfort through heating and cooling buildings, depending on the season and local climate. To reduce energy consumption for these purposes, solutions are being developed that provide passive heating and cooling, enabling either the absorption or reflection of sunlight. This project will investigate coatings that mimic structures found in very black butterflies and spiders, as well as very white insects, which contribute to high absorption or reflection of sunlight, respectively.

The work will be carried out by a consortium consisting of specialists in the development of nanomaterials and thermoelectric materials from the Łukasiewicz Research Network - Institute of Microelectronics and Photonics, specialists in the characterization of nanostructures from the Faculty of Physics at the Warsaw University of Technology, and specialists in insect zoology from the Nature Education Center at the Jagiellonian University, in collaboration with specialists in modeling the optical properties of structures found in insects from the University of Chicago and the Karlsruhe Institute of Technology. This collaboration will generate new knowledge important not only for the design and production of materials and nanostructures for effective temperature regulation but also for zoology. We aim not only to be inspired by nature in creating new materials and technologies but also to enhance the understanding of natural processes of evolutionary development of species traits related to temperature management.

The main goal of the project is to find correlations between the structure and thermal properties of bio-inspired inorganic very black and very white thin-film structures in relation to structures found in insects. The project will involve collecting specimens of butterflies characterized by very black and very white colors, as well as describing their behaviors and habitats, particularly in the context of how these animals manage their body temperature. The structures responsible for their coloration will be identified using electron microscopy and mathematically described through modeling. New materials will be produced by magnetron sputtering to obtain structures analogous to those found in insects. Measurements of light reflection will be conducted for both laboratory-produced and natural structures. Experimental and theoretical data will allow the determination of the properties of structures responsible for high light absorption for heating or high light reflection for cooling. Evolutionarily significant effects will be identified and compared between different species. Ultimately, thermoelectric modules will be prepared, coated with the developed layers, and exposed to standardized solar radiation to measure the efficiency of the developed coatings in cooling and heating.

The project will result in the creation of new knowledge in the field of the physics of thin-film structure growth and their optical properties in terms of light reflection, the development of technologies for producing coatings with high solar light absorption and high solar light reflection, and will contribute to the understanding of the evolution of temperature management structures in selected insect species.