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Classification of animal biomimetic characteristics for tribological applications

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KEYWORDS

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Green tribology
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ABSTRACT

The rapid rate of technological growth makes the demands for the application of tribology that are environmentally friendly and can be renewed increasing. Therefore, it is necessary to do research on tribology that is environmentally friendly and can be renewed. Green tribology is one solution that can be used. The biomimetic approach is one of the principles of green tribology that can be used to challenge the need for effective and efficient technology applications. Biomimetics is materials, mechanisms, and systems created by humans by imitating designs and systems found in nature. Biomimetics can imitate living things such as animals and plants. So far, researchers have only focused on biomimetics that mimics animals. The purpose of this study was to find out which animal species have been imitated the most by researchers to make biomimetic materials related to tribology. The research method used is a comparison of the biomimetic characteristics of several types of animals that are closely related to tribology. The results of this study are biomimetic materials produced by imitating the types of reptiles and insects to date are still the most dominant used in finding solutions related to tribology.

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1.0 INTRODUCTION

Along with the rapid rate of technological growth, there is a higher level of need for the application of tribology that is environmentally friendly and can be renewed. Therefore, it is necessary to do research on tribology that is environmentally friendly and can be renewed. Practicing sustainable and environmentally friendly techniques have become a major concern in various research fields in the twenty-first century due to the environment's declining health since the industrial revolution (Ahmad et al., 2020). Green tribology is one solution that can be used.

There are twelve principles formulated in green tribology, namely (Nosonovsky & Bhushan, 2012): 1) minimizing friction. Friction is mechanisms that remove material from solid surfaces via contact and sliding (Norani et al., 2021), 2) minimizing wear, 3) reduction or total elimination of lubrication, including self-lubrication, 4) natural lubrication, 5) biodegradable lubrication, 6) using sustainable chemical and engineering principles, 7) biomimetic approaches, 8) surface texture, 9) environmental implications of coatings, 10) real-time monitoring, 11) design for degradation, 12) sustainable energy applications.

There are three fields in green tribology, namely biomimetics for tribological applications, environmentally friendly lubrication, and tribology for renewable energy applications

During 3.8 billion years of biological evolution, many functional principles have been developed in all areas of life that allow the healing of various types of damage. Inspired by this, it makes the field of biomimetics even more interesting to study to make materials that can renew themselves (Speck & Speck, 2019). The biomimetic approach is one of the principles of green tribology that can be used to answer the challenges of the need for effective and efficient technology applications. The term biomimetics implies an understanding of biological structures and processes and their comparable technological applications, methods, or procedures. Biomimetics is not just imitating nature, both in material and functional as well as in creative terms, but also understanding the principles of nature to assist in understanding analog, technological questions, which can then be solved by the application of optimized technology. The science of biomimetics is about discovering the wealth of natural experiences that will be utilized for man-made products.

Biomimetics is materials, mechanisms, and systems created by humans by imitating designs and systems found in nature. Designs and systems that exist in nature can include living and non-living things. Biomimetics can imitate living things such as animals and plants. So far, researchers have only focused on biomimetics that mimics animals.

The formulation of the problem in this study is as follows: What types of animals are most often imitated by biomimetic materials? The aim of this research is to determine the type of animal that is most often imitated by biomimetic materials. The limitation of the problem in this study is that it is only limited to biomimetics that mimics the characteristics of animals that are related to tribology.

2.0 EXPERIMENTAL PROCEDURE

A literature search for this study was conducted from existing online databases such as Springer, Elsevier, etc. The keywords used in the literature search for this research were bio-tribology, tribology, biomimetics, biomimicry.

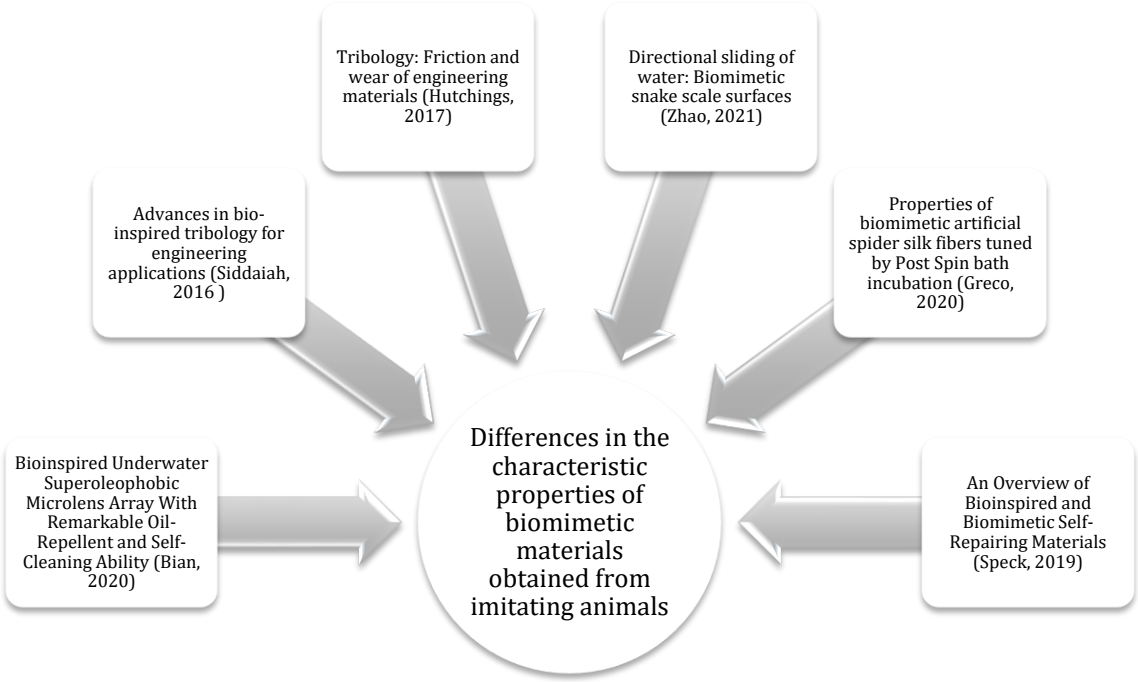

Figure 1: State of the art.

The state of the art of this research can be seen in Figure 1. This study is a comparison between the different characteristics of the biomimetic material obtained from imitating animals. Some references in this research are: bioinspired underwater superoleophobic microlens array with remarkable oil-repellent and self-cleaning ability, advances in bio-inspired tribology for engineering applications, tribology: friction and wear of engineering materials, directional sliding of water: biomimetic snake scale surfaces, properties of biomimetic artificial spider silk fibers tuned, an overview of bioinspired and biomimetic self-repairing materials, and so on.

The flow chart of this research method can be seen in Figure 2. The research starts from data collection, then data processing, then data comparison, after that it is continued with data grouping. The research data obtained were then analyzed to obtain a conclusion. The initial stages of this research activity are preliminary studies and literature studies related to biomimetics. After that, it is continued with the identification of existing problems based on data and facts. After that, data were collected on biomimetic characteristics that mimic animal traits. Then the data is processed which is then compared to the differences in characteristics and after that, the biomimetic data is grouped that imitates animal characteristics. Then after that an evaluation of the data that has been compared and has been grouped is carried out. After that, a comparative analysis of the data was carried out for each of the grouped data. After that, the overall conclusion is drawn.

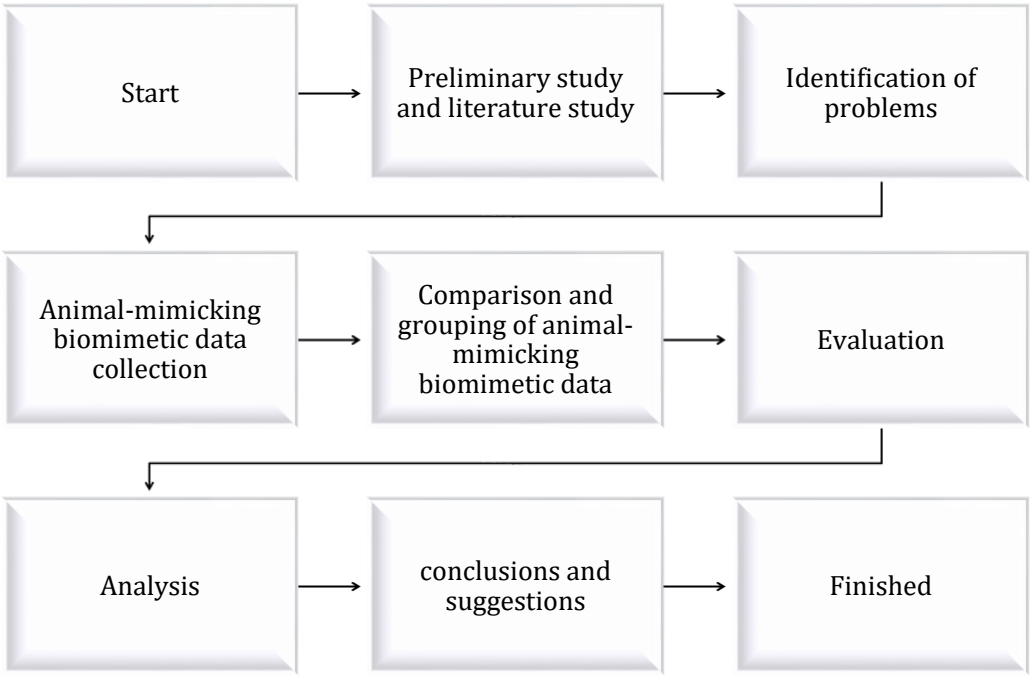

Figure 2: Research flow chart.

3.0 RESULTS AND DISCUSSION

Based on the results of the literature study, it was found that researchers carried out a lot of biomimetic research that imitated the types of properties of animal groups. Figure 3 shows that about 53% of vertebrates and 47% of invertebrates have been studied by researchers for the benefit of biomimetics. In Table 1, it can be seen the grouping of animal species imitated for material purposes and biomimetic design related to the application of tribology.

The animals mentioned in Table 1 have unique characteristics that can inspire the manufacture of artificial products for tribological purposes. Synovial fluid in mammals really keeps joints from wearing out easily. Until now, researchers have not found and will continue to try to imitate a fluid formula that is similar to synovial characteristics in order to meet the lubrication needs. The gecko's feet, which have extraordinary adhesion, can be imitated by making synthetic keratin and choosing materials that are superhydrophobic. The dust repelling properties can be imitated from the lubricating wax produced by cockroaches. Imitation of the texture of the lizard's outer skin can reduce friction and wear. The structure of the best needle design for the world of health can imitate that of mosquitoes and the surface structure of crickets. To make a strong material can imitate the structure of spider silk fibers. The movement of ships in the sea can be even faster if they imitate the shape of the structure of the skin of a shark.

The results of the study show that so far, researchers have used more biomimetic properties than imitating the characteristics of reptiles and insects. The result of this research is that the material produced by mimicking the biomimetic properties of reptiles and insects is still the dominant one used in finding solutions related to tribology.

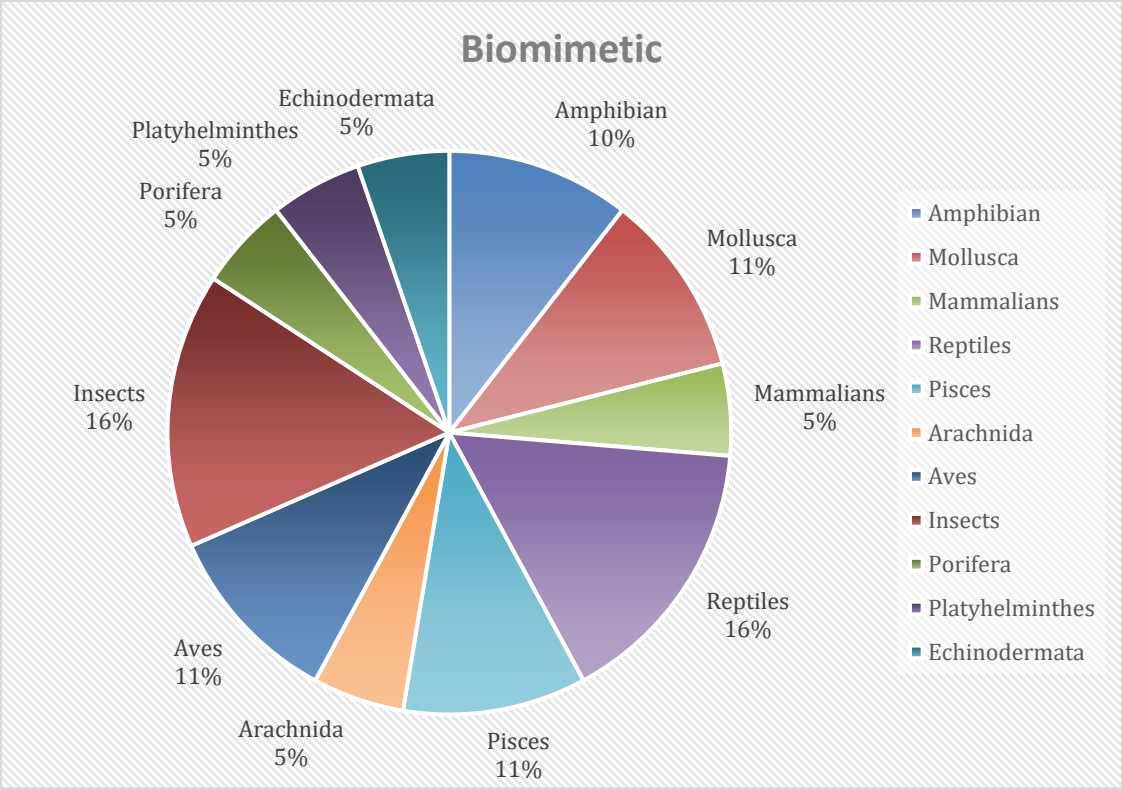

Figure 3: Percentage of biomimetic mapping by animal species.

Table 1: Comparison of biomimetics between animals.

Animal type	**Class**	**Biomimetic type**
All vertebrate mammals	Mammals	Synovial fluid (Hutchings & Shipway, 2017). The interaction of sliding materials with the synovial fluid is responsible for the lubrication mechanisms that are expected to minimize friction and wear (Kamis et al., 2020).
Gecko	Reptile	The gecko's feet show extraordinary adhesion properties due to the five hundred thousand hairs or keratin setae on one gecko's foot which can produce high adhesion (Lehn & Benyus, 2012). The skin of the gecko exhibits superhydrophobic and anti-wet properties and the ability to self-clean through the rolling of nanometer-sized water droplets at low speeds (Wang & Chung, 2013). Geckos can stick to rough, wet, and dirty surfaces, but most synthetic imitations cannot maintain their function in similar situations because the gecko naturally has a cushioning adhesive system on the gecko's toes, as well as an anti-adhesive system resulting from chemicals and structures, toe pads (superhydrophobicity) and the role of surface lipids in gecko adhesion and anti-adhesive (Stark et al., 2016).

Cockroaches	Insects	The wax produced by cockroaches has lubricating properties that form a thin layer and can repel dust or self-cleaning (Özgen, 2018).
Snail	Mollusca	The wet surface of the snail shell is hard to be contaminated because the superoleophobic property underwater makes the snail shell clean (Bian et al., 2020).
Lizard	Reptile	The outer skin of lizards has shown various functions, especially tribological functions such as friction reduction and wear protection (Kalauni et al., 2014).
Snake	Reptile	The specific ventral surface ornament of the California King Snake reduces wear by having a specific ventral surface ornament that reduces the coefficient of friction (Zhao et al., 2021).
Albatrosses	Aves	Albatrosses that fly very far have dark upper wings. The temperature difference between the light and dark upper wings increases the temperature in the dark upper wings. This reduces the drag force of the skin over the wing (Pfeifhofer & Tributsch, 2014).
Mosquitoes	Insects	The non-smooth surface structure of mosquitoes having the effect of reducing drag is adopted in the needle design. Insect-inspired drones, namely micro air vehicles, are capable of automatic flight, usually operating at low speeds in the Reynolds number regime of 10^4-10^5 or lower (Liu et al., 2016).
Crickets	Insects	The non-smooth surface structure of crickets having the effect of reducing drag is adopted in the needle design. Crickets have clavate hairs to sense the acceleration of gravity to get information about their orientation. A clavate hair-inspired one-axis biomimetic accelerometer has been developed and fabricated using SU-8 surface micromachining and lithography (Droogendijk et al., 2014).
Spider	Arachnida	Spider silk fibers can absorb almost three times more energy than Kevlar before breaking (Greco et al., 2020).
Shark	Pisces	Sharkskin can reduce drag (Wen et al., 2014).
Catfish	Pisces	Catfish secrete mucus from their skin which allows them to swim through the water easily by acting as a lubricant (Triantafyllou et al., 2016).
Penguins	Aves	The phenomenon of air lubrication helps emperor penguins reach high speeds (Siddaiah & Menezes, 2016).

CONCLUSION

Based on the results of the study, it was found that there were differences in the characteristics of the biomimetic properties that were imitated from animals. The types of animals that are most often imitated by biomimetic materials are reptiles and insects.

Researchers over the last decades have only focused on a few types of macro-organism animals that were investigated to be imitated in making biomimetic materials for tribology purposes and still few have explored the types of small animal microorganisms. For future research, researchers

should prioritize biomimetic research rather than imitating the characteristics of microorganisms.

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