From bioinspired to bioinformed: benefits of greater engagement from biologists

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Supplementary methods:

We conducted our systematic assessment of the bioinspiration/biomimetic literature following recommendations from PRISMA 2020 guidelines (Page et al., 2021). The primary purpose of our assessment was to determine (i) the growth of research interest in bioinspiration/biomimetics; (ii) the proportion of biologists engaged in such research, and (iii) the distribution of taxa within this research. All articles screened were extracted from the Web of Science (WoS; Clarivate 2021) database and processed according to the search objective. Further, all search processes were conducted by a single author (LN).

i. Growth of research interest in bioinspiration/biomimetics

We used the topic search term (bioinspir* OR biomim*) to extract bioinspiration/biomimetic related articles. We used the ‘NOT’ operator to exclude articles related to biocompatibility, biomaterials, and bioidentical materials (biocompatib* OR biomateria* OR bioidenti*). This was because such terms largely relate to materials that do not elicit a host immune response in medical applications. Therefore, such research focuses on the direct usage of biological materials to interface with the human body, rather than the process of creatively drawing on knowledge from biology necessary to the bioinspiration/biomimetics design process. We added the ‘Years Published’ search field to restrict our search to articles published from 1990 to 2020. We used the filter functions to refine our search to the ‘Articles’ and ‘Reviews’ document type categories, arriving at a total of 35265 articles (23rd June 2021). The ‘Analyze Results’ function was used to calculate the number of publications per year.

To establish a comparative baseline for research growth, we used the ‘Year Published’ search field to view all articles published between 1990 to 2020. We used the filter functions to refine our search to
articles under the ‘Materials Science Multidisciplinary’ WoS category, and to the ‘Articles’ and ‘Reviews’ document types. We arrived at a total of 2411337 articles (23rd June 2021) and the ‘Analyze Results’ function was used to calculate the number of publications per year.

![Graph showing the growth of bioinspiration/biomimetic and materials science publications over the years.](image)

**Figure S1.** The growth of bioinspiration/biomimetic publications in the past 30 years (blue). The materials science discipline (including bioinspiration/biomimetics) has also experienced considerable growth throughout the years (grey).

ii. **Proportion of biologists engaged in bioinspiration/biomimetics research**

We used the number of articles with authors affiliated with a bio-related department/organisation as a liberal indication of research engagement from biologists. We exported the author addresses from the WoS article records of the 35265 bioinspiration/biomimetic research articles. The ‘Grep’ function from the base package of R studio (RStudio Team 2016) was used to search the author records for character strings including ‘Bio, bio, Eco, eco, Environ, environ, Evo, evo’. We found that 14332 articles (40.6%) contained at least one of these character strings.
iii. **Taxonomic distribution within bioinspiration/biomimetics research**

1. **Research species**

We explored the taxonomic distribution of bioinspired/biomimetic research centred on butterflies and spiders. For butterflies we used the topic search term ‘(bioinspir* OR biomim*) AND butterfl*’, and for spiders we used the topic search term ‘(bioinspir* OR biomim*) AND spide*’. As we were exclusively interested in peer-reviewed research articles, we used the ‘NOT’ operator to exclude the search term ‘review’. We then used the filter function to refine our search to the ‘Articles’ document type category. Our search retrieved 201 research articles for butterflies (20th May 2021) and 365 articles for spiders (7th June 2021). We screened these articles for eligibility by reading the abstract; articles would be accepted if they were relevant to bioinspiration/biomimetics but were rejected if they were not relevant to such research, if they were not peer-reviewed research articles (i.e. not book chapters or conference proceedings), if they were repeated articles, or if they were not directly relevant to the animal (e.g., butterfly valve related research was removed as there was no direct relation to the species). 137 articles were found to be eligible for full-text assessment for butterflies, and 232 for spiders. Full-text assessment was conducted by searching for and recording species and genus name from each article to establish the focal species and genus involved in the research, as well as studies in which multiple species or genera were involved in the research. We focussed particularly on the genus level as many articles report the genus but omit species name (e.g. Morpho), therefore we opted to include articles where the specific species was unclear, but the genus was clearly reported. We further excluded articles during this full-text assessment if the article did not report any specific species or if the involvement of the species was highly superficial. We define superficial bioinspiration/biomimetics as studies that mention species or common name but do not further discuss the biological mechanisms in subsequent methods. Following this assessment, we arrived at 116 articles for butterflies and 124 articles for spiders which report the focal or model species involved. To include relevant studies that were not yet captured by our search, we screened the reference lists of our remaining articles. This was because some articles use specific terms in the title or abstract which do not contain our broad search term of ‘butterfl*’ (e.g. Morpho) or ‘spide*’ (e.g. Orb-weaver). We searched for titles within reference lists that were relevant to bioinspiration and either butterflies or spiders, then viewed the abstracts of relevant articles to screen for eligibility. We then recorded the species names from the full-text of eligible articles, adding 57 articles for butterflies and 94 articles for spiders. Therefore, our final total articles were 173 for butterflies and 218 for spiders (Figure S2). We presented our results with a focus on the distribution of genera (Table S1, Table S2).
2. Design challenges

We explored the taxonomic distribution of bioinspired/biomimetic research centred on drag reduction and surface adhesion. For drag reduction we used the search term ‘(bioinspir* OR biomim*) AND drag AND reduc*’, and for surface adhesion we used the search term ‘(bioinspir* OR biomim*) AND adhesiv* AND surfac* AND (adhere OR attac*)’. Again, we used the ‘NOT’
operator to exclude the search term ‘review’. Our search retrieved 212 research articles for drag reduction (27th May 2021) and 337 articles for surface adhesion (13th June 2021). We followed the same screening and assessment processes reported for our ‘Research species’ search to select articles for full-text assessment. Due to the broad taxonomic range of species in research involving design challenges, we extracted the taxonomic class rather than species or genus involved. 162 articles were found to be eligible for drag reduction, and 174 for surface adhesion. We arrived at 125 articles for drag reduction, and 142 articles for surface adhesion after full-text assessment. We then retrieved an additional 31 articles for drag reduction and 130 articles for surface adhesion from the references of eligible articles. Therefore, our final total articles were 156 for drag reduction and 272 for surface adhesion (Figure S2, Table S3, Table S4).

Figure S2. Flow diagram of assessment process.
Table S3. Distribution of taxonomic classes in drag reduction research

| Class         | Count |
|---------------|-------|
| Chondrichthyes| 49    |
| Actinopterygii| 22    |
| Insecta       | 18    |
| Multiple      | 15    |
| Magnoliopsida | 12    |
| Aves          | 10    |
| Polypodiopsida| 10    |
| Mammalia      | 7     |
| Bivalvia      | 4     |
| Entognatha    | 3     |
| Malacostraca  | 2     |
| Reptilia      | 1     |
| Opisthophora  | 1     |
| Arachnida     | 1     |
| Phaeophyceae  | 1     |

Table S4. Distribution of taxonomic classes in surface adhesion research

| Class         | Count |
|---------------|-------|
| Reptilia      | 119   |
| Bivalvia      | 52    |
| Insecta       | 30    |
| Cephalopoda   | 13    |
| Amphibia      | 13    |
| Arachnida     | 10    |
| Actinopterygii| 9     |
| Multiple      | 9     |
| Magnoliopsida | 7     |
| Gastropoda    | 2     |
| Maxillopoda   | 2     |
| Aves          | 1     |
| Bacillariophyceae| 1   |
| Rhabditophora | 1     |
| Phaeophyceae  | 1     |
| Polychaeta    | 1     |
| Holothuroidea | 1     |

References

Page, M.J., Moher, D., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., et al. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 372, n160. doi: 10.1136/bmj.n160.

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