LETTER

Mathematical illiteracy impedes progress in biology

Fawcett and Higginson (1) have shown that citation rates of biology papers with equations in the main text are lower than those of papers without equations. They claim that this implies "heavy use of equations impedes communication among biologists" and recommend that equations be moved to appendixes to improve citation rates. We suggest that a better interpretation of their results would be "mathematical illiteracy impedes progress in biology."

The authors base their conclusion on the assumption that a simple count of citations is a useful measure of communication and value of scientific work. However, not all citations demonstrate understanding. A citation of a paper embedded in a long list of citations to show awareness of the field is far less valuable than a citation of a paper that forms the foundation of new work. The primary goal of a scientific paper should not be to maximize its citation index but to improve readers' understanding of physical and biological phenomena.

If ideas are expressed vaguely, it is often impossible to build on them, and mathematics (as represented by "equations" in the authors' work) is often essential for expressing ideas precisely. An example from our own work is a model of malaria immunity that we expressed entirely in analogies (2). We have not been able to translate this into a formal description, making it essentially useless as a source of further scientific development. Complicated expressions do need explanatory text to ease understanding, but hiding them in appendixes only serves to obscure the readers' understanding of the subject matter. Moving equations to an appendix means the authors are less likely to put in the required effort to explain the meaning of the equations, the reviewers less likely to check them, and the readers less likely to put in the required effort to understand the meaning. None of these consequences benefit scientific communication.

As biology focuses increasingly on complex systems and automated data gathering, mathematical and statistical literacy are more important than ever. Authors of theoretical papers in biology should include the mathematics and make the effort to explain it in an easily understandable manner. The readers should make a corresponding effort to understand that theory.

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2. Smith T, Felger I, Tanner M, Beck HP (1999) Premunition in *Plasmodium falciparum* infection: insights from the epidemiology of multiple infections. *Trans R Soc Trop Med Hyg* 93(suppl 1):59–64.

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