Weird Science, Odd Elasticity, and Why Science Needs Philosophy

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(Padavic-Callaghan, 2023)

1. Introduction

Analytic philosophy of science, as practiced in the so-called "Anglosphere"—English-speaking countries including the United States and Australia—is methodologically conservative, holding that the role of philosophy of science is to act as an underlaborer to the sciences, and not engage in any sort of critical evaluation of supposed knowledge claims, let alone attempt to refute various claims (Hanna, 2021). This position contrasts with an alternative "life-shaping philosophy," such that philosophy is not isolated from the sciences as a distinct discipline, but whereby the philosopher is trained in disciplines other than traditional Analytic philosophy, and works with scientists and thinkers from various fields to address issues needing specialist knowledge (Hanna, 2022).

Contrary to Analytic philosophy of science, in this paper we will critically examine an extraordinary claim that has been made in a reputable scientific journal, and offer a refutation of the claim, namely that human sperm can violate Newton's

Third Law of Motion. We believe that this is the appropriate forum for a fair hearing of our position, and from here we can invite the criticized scientists to show why exactly our refutation fails. As their claim is quite extraordinary our argument should be something of philosophical and scientific interest, no matter who is ultimately "right."

2. The Claim: Human Sperm Violate Newton's Third Law of Motion!

When reading about this in the popular scientific press, we thought that this must be the work of an internet troll. But, it was not April 1, and the same type of headline was found in multiple sources, leading us to the actual scientific paper where the claim was to be supposedly justified. Thus: *New Scientist* 20 October, 2023: "Sperm Caught Breaking Newton's Third law of Motion" (Padavic-Callaghan, 2023); WIONEWS: "Human Sperm is Breaking One of Newton's Laws of Motion and the Finding May be Revolutionary (Mandloi, 2023); if/science.com: "Sperm Caught Breaking the Law – Newton's Third Law of Motion, That Is" (Chapman, 2023); and Phys.org: "Odd Elasticity Helps Sperm Skirt Newton's Third Law of Motion" (Yirka, 2023). According to Yirka,

> In the real world, Newton's third law of motion is often skirted by creatures that have evolved in ways that allow them to conserve energy, which in turn means they do not need as much food to survive. (Yirka, 2023)

The principal scientific paper is by Ishimoto et al.: "Odd Elastohydrodynamics: Non-Reciprocal Living Material in a Viscous Fluid" (Ishimoto et al., 2023). This research team undertook mathematical modelling of human sperm cells, and *Chlamydomonas* algae moving through their respective viscous fluid mediums. Both use wave-like movements but, according to the summary by Yirka,

> such movements, the researchers note, should result in reactions from the fluid due to Newton's third law that would greatly slow progress. But that was not the case. (Yirka, 2023)

This seemingly miraculous event was brought about by means of "odd elasticity," by

> bending in tiny ways in response to recourse from the liquid, the flagella were able to avert an equal and opposite reaction, thereby conserving the energy of their owner. (Yirka, 2023)

The classical idea of classical elasticity says that energy conservation arises by the assumption of the existence of an elastic potential, but according to the non-classical idea of odd elasticity it is held that

> the elastic stresses must be due to gradients of displacement, which [are] sufficient to ensure linear momentum conservation, but not angular momentum conservation. (Scheiber, et al., 2020: pp. 476-477)

Before examining the paper by Ishimoto et al., we'll first rehearse Newton's Third Law of Motion. "Whenever an object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first" (Giancoli, 2016: p. 81). Thus, if one pushes one's hand against the desk, the desk pushes back against one's hand, with the same magnitude of force as the hand exerted on the desk. And in walking forward, "when one foot pushes backwards against the ground, the ground pushes forward on that foot" (Giancoli, 2016: p. 82). There are various microphysical cases in which Newton's Third Law is broken (Cornille, 1999; Ivlev, 2015), but until now, it has been believed the law held at least for macroscopic objects such as sperm. Hence, we should carefully and critically examine the supposed demonstration that objects like sperm can violate the Third Law.

Ishimoto, et al.'s abstract begins by stating that living systems, such as single cells undertaking motility "are characterized by nonconservativity of energy and a large diversity of spatiotemporal patterns" (Ishimoto et al., 2023). This might mean that living systems somehow violate the law of conservation of mechanical energy (Giancoli, 2016: p. 151); or perhaps they violate the first law of thermodynamics (Giancoli, 2016: p. 423); but we are not told that, and the paper does not address those issues. We are told in the abstract that "fundamental physical principles to formulate their behavior are not yet fully understood" (Ishimoto, et al., 2023). Then they say that their present study

> explores a violation of Newton's third law in motile active agents, by considering non-reciprocal mechanical interactions known as odd elasticity. (Ishimoto, et al., 2023)

In Ishimoto et al.'s model, they develop the notion of odd elasticity in a non-linear context, with reference to the motility dynamics and wave patterns of *Chlamydomonas* flagella and human sperm tail motion, a theory they call *elastohydrodynamics*. Their key innovation, they say, is the introduction of the new concept of an *odd-elastic modulus*, involving spatial Fourier transforms, a complex function with real and imaginary parts in an extended space. Using this, they set up a mathematical model for the odd elastohydrodynamics of microswimmers in a fluid and the odd-elastohydrodynamics equations of such three-dimensional objects in a viscous fluid, using a version of the Stokes equation. There then follows the definition of an elasticity matrix and balance equations for the forces and torque. The microswimmer is thus represented by a first order differential equation dz/dt, where z is an element of the complex numbers, a normal form of the Hopf bifurcation (Guckenheimer & Holmes, 2013). The dynamics of the shape space are then written in matrix form, and integrating the system over the cycle of shape deformation to arrive

at the swimming formula. Using Lagrangian coordinates and Fourier transforms of the nonlocal elastic modulus they finally end up with two integral equations (20) and (21), where the former is a real function, and the later purely imaginary, encoding the odd elasticity. The question must be asked as to why human sperm tail motility requires such advanced mathematical modelling using complex functions, rather than simpler real-valued first order differential equations? Whatever happened to the ideal of parsimony?

Other models are explored in section IV and Appendix A and B of the paper. But what is clear to us, having gone through this labyrinth of mathematical formulas, is that after the abstract, there is nothing at all said about violations of Newton's Third Law of Motion! The issue does not arise, and nor can we see how it is some sort of obvious implication of the modelling. Saying that a fundamental law of classical mechanics is violated by macroscopic objects is an extraordinary claim, which requires proof. And this is simply not given: no argument at all is presented.

What would happen if, to take one example, human sperm's wave-like tail motion *did* violate Newton's Third Law of Motion? Our hypothesis is that the tail in moving would not be subjected to an equal and opposite reaction from the viscous medium in which the sperm is swimming. Hence, for a given tail movement, the first swish would encounter no reaction force, and in accordance with Newton's First Law of Motion, the tail would therefore move in a straight-line until acted upon by an external force (Giancoli, 2016: p. 77). This would mean that the tail would keep moving dragging the sperm out of the viscous medium, until it hits something to which the Third Law does apply, such as, supposedly the vaginal wall. There the sperm will die. So, if the claim that sperm motility violates Newton's Third Law of Motion were true, sperm would be unlikely to survive to implant the female egg, and the human species would have died out. Since this has not yet occurred, by *reductio ad absurdum*, we can conclude that Ishimoto et al., are wrong about their violation claim.

3. Conclusion

In this essay, we've refuted the claim that human sperm motility, by means of odd elasticity, violates Newton's Third law of Motion. The first part of our argument said that when we consider the principal scientific paper making the claim (Ishimoto et al., 2023), we do not find any actual demonstration of that claim. And the second part said that even if this claim were true, then it would lead to sperm dying by motion that would remove them from their viscous medium, thereby leading to the dying-out of the human species, which obviously has not (yet) occurred. Making a more general philosophical point, it has also been shown that scientific claims, however abstract, can still be subject to cogent philosophical critique, which contradicts the methodological conservatism of Analytic philosophy of science.

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