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Mathematics, Governor of the Universe: its Beauty and Utility

Mathematics is often glorified as the best tool ever concocted, the purest study, or even governor of the universe itself. It has guided countless great minds to scientific breakthroughs, whether they were deliberately studying it or not. From ancient Egyptians mastering fractions and Chinese calculating π, to Mandel discovering heredity from counting peas (Watson pars. 12, 17), even to Newton single-handedly inventing calculus (Cohen par. 1). While mathematics' criticality to science is undeniable, what makes it so uniquely intertwined with nature itself that it appears everywhere one may look?

As much credit as we might like to give ourselves, mathematics was not invented, but instead discovered. It is the language of the universe, which every object speaks to communicate and interact. It logically follows that everything in the universe obeys the same set of rules, which is evidently a vital idea in science. For example, Aristotle-likes believed that the universe was majorly separated into terrestrial and celestial regions, where distinctly different physical rules applied (Lindberg Ch. 3 par. 32), proposing baseless and sometimes contradictory theories to explain various phenomena (Lindberg Ch. 3 par. 41). They lacked scientific breakthroughs in this regard until Newton's proposal of universal gravitation revolutionised science (Cohen par. 2). However, focus not on Newton's work itself, but rather on how he concretely put mathematics into physics, defining quantities and measures of physical properties (Newton 63-64) and mathematical formulations (Newton 67-69). Ideas were no longer vague as in Aristotle-like philosophy-based discussions (freefalling objects fall faster and faster), but instead quantised (velocity is proportional to time[1]). Mathematics now provides the tools to calculate and prove by quantising phenomena and applying equations to them, even if the variables are indirect, obscured, or obfuscated. It extended the scientific method commendably and encouraged many

[1] As in the first quation of motion, with initial velocity as zero: $v = u + at$

to tackle complex subjects by streamlining the process of understanding them, eliminating much aimless wander.

Definitions were a cornerstone: everything being clear and precise allows everyone to be on the same page, unlike the subjective vocabulary seen in Chinese science where no consensus on what the five elements, production, and conquest meant existed (Needham par. 14). Moreover, mathematics is inherently binary, being only correct or incorrect, without an in-between “maybe”. This grants falsifiability[2] to theories built upon it, which is the most critical thing mathematics offers, as it hosts the grounds for scientific discussions to transpire, making the success of modern science.

Of course, theories also cannot be contradictory. Mathematics, being based entirely upon deductive reasoning, also prides itself in its solidity of logic. False conclusions cannot arise should all premises be true, and no steps taken be unsound. Complex theories can develop from trivial postulates, as demonstrated in Euclid’s work of geometry (Euclid 273-288). It is thus immune to controversies, an uncommon trait to possess. For example, Darwinism was not well-received in its debut because it conflicted with religious beliefs, despite being the now-verified model for evolution; but Euclid’s work gained widespread acceptance easily. Furthermore, it empowers us to confidently theorise about far-fetched things and propose conjectures by observing mathematical properties of various phenomena. Einstein proposed that gravity is merely an illusion created by distorted spacetime in his *Relativity* long before being strongly supported by the undiscovery of “graviton” within the elementary particles, again highlighting mathematics’ ability to guide theories.

Besides guiding discoveries, mathematics also facilitates knowledge propagation as it is indiscriminate and transferable. There are often parallels across aspects of science. For instance, exponential equations in studying radioactive decays and linear attenuation[3]; inverse-square law in forces and light intensity[4]; harmonic means in electrical resistances and focal lengths[5]; chaos

[2] An important concept in logic where falsifiable statements can be definitively proven or disproven.
[3] Both follow the format of $x = Ax_0e^{-kt}$.
[4] Both are proportional to the reciprocal of the square of the distance.

theory manifests like bifurcation in population evolutions (Fussman et al.) and cardiac arrhythmias (Karagueuzian et al.); the Fibonacci sequence appearing unfathomably everywhere. As exemplified, mathematics is not limited to any field of study; it from one can be generalised and applied onto something else with similar properties, thus increasing the value of any single theorem (Poincaré Ch. 1 par. 6). Mathematics is therefore also scalable, whether atomic or astronomical.

However, observing mathematics' usefulness is only trivial. Where it truly shines is its ability to operate outside physical constraints. Unrelated phenomena like friction or resistance can be ignored to facilitate studying pure interactions without distractions. The concept of infinity was even said to have helped Newton draft his physics unrestrictedly (Cohen par. 22). Mathematics can thus calculate and predict the future precisely, as exhibited in the prediction of Halley's comet's return (Cohen para. 62). In addition to predicting actual events, mathematics can also discover outlandish theories we were not even investigating. Equations can have more than one solution[6], implying that the most apparent physical solution is often not the only possibility, thus kindling theories from dark matter to quantum mechanics. The boundaries of mathematical models often coincide with the universe's, which undoubtedly broadened our insights into what nature itself allows beyond our usual reaches.

Being a versatile and essential tool, mathematics is the closest we can get to peeking behind the curtains. And if even nature is so obsessed with it, why should we not admire its beauty alongside countless great minds?

(798 words)

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[5] All follow the format of $a^{-1} = b^{-1} + c^{-1} + \cdots$.
[6] Most commonly seen in equations involving square roots or polynomials.

Works Cited

Cohen, I. Bernard. *The Birth of a New Physics: Revised and Updated*. W. W. Norton & Company, Inc., 1960. Rpt. in *In Dialogue with Nature: Textbook for General Education Foundation Programme*. 2nd ed. Hong Kong: Office of University General Education, 2012. 49-62.

Euclid. *Elements*. Tr. Thomas L. Heath. Perseus Digital Library Project, 1956. Rpt. in *In Dialogue with Nature: Textbook for General Education Foundation Programme*. 2nd ed. Hong Kong: Office of University General Education, 2012. 273-288.

Fussmann, Gregor F. et al. "Crossing the Hopf Bifurcation in a Live Predator-Prey System." Science 290.5495 (2000): 1358-60.

Karagueuzian, Hrayr S et al. "Bifurcation theory and cardiac arrhythmias." American journal of cardiovascular disease vol. 3,1 (2013): 1-16.

Lindberg, David C. *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, Prehistory to A.D. 1450* (Second Edition). Chicago: The University of Chicago Press, 2007. Rpt. in *In Dialogue with Nature: Textbook for General Education Foundation Programme*. 2nd ed. Hong Kong: Office of University General Education, 2012. 11-48.

Needham, Joseph, et al. *The Shorter Science and Civilisation in China: An Abridgement of Joseph Needham's Original Text,* Vol. 1 (1978). Cambridge: Cambridge University Press. Rpt. in *In Dialogue with Nature: Textbook for General Education Foundation Programme*. 2nd ed. Hong Kong: Office of University General Education, 2012. 193-216.

Newton, Isaac. *The Principia: Mathematical Principles of Natural Philosophy*. California: University of California Press, 1999. Rpt. in *In Dialogue with Nature: Textbook for General Education Foundation Programme*. 2nd ed. Hong Kong: Office of University General Education, 2012. 63-70.

Poincaré, Henri. *Science and Method* (1914). Tr. Francis Maitland. Rpt. in *In Dialogue with Nature: Textbook for General Education Foundation Programme*. 2nd ed. Hong Kong: Office of University General Education, 2012. 159-176.

Watson, James D. et al. *DNA: The Secret of Life*. DNA Sow LLC, 2003. Rpt. in *In Dialogue with Nature: Textbook for General Education Foundation Programme*. 2nd ed. Hong Kong: Office of University General Education, 2012. 97-140.