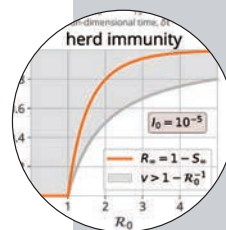


Contents

2 Fifty Ways to Beat a Virus (Part 1)

In 2020, the world for the first time in a century confronted a global pandemic that would claim millions of lives. While students were sent home and campuses closed, many mathematicians found an opportunity to join the fight against COVID-19. Even simple differential equation models can teach us important lessons about the exponential growth of a new epidemic and the importance of threshold behavior. Using more elaborate (and realistic) models, two mathematical modeling groups, in Texas and Illinois, had a profound and positive effect on the management of the epidemic by local and state authorities during the first waves.



18 Fifty Ways to Beat a Virus (Part 2)

Continuing the previous chapter, Part 2 discusses the problems confronted by mathematicians and epidemiologists in the later part of 2020 and in early 2021. How could universities re-open safely? How does the uncontrolled spread of an epidemic in prisons affect the surrounding community, and what can be done about it? And the biggest question: could vaccination bring the epidemic under control? Even though the coronavirus kept throwing surprises at us, mathematicians did a surprisingly good job of developing strategies, giving realistic answers and highlighting the main reasons for uncertainty.



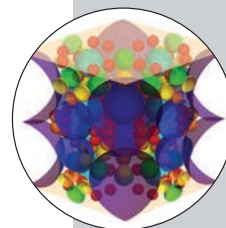
30 Fifty Ways to Beat a Virus (Part 3)

Another important front in the battle against COVID-19 was to understand how the infection progresses within the human body. Why do some people have life-threatening symptoms, while others have none at all? An online group called the "Immune Gals" highlighted the delayed release of interferon as a characteristic marker of severe cases. Another mathematician used the tools of graph theory to identify parts of the viral RNA that are especially vulnerable to attack by drugs or gene therapy. And a third group adapted a machine-learning language model to detect escape variants of coronavirus. In effect, they taught the computer to "speak virus."



46 Descartes' Homework

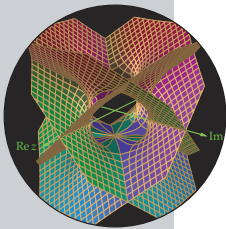
A homework problem assigned in 1643 by René Descartes to his star pupil, Princess Elizabeth of Bohemia, backfired when Descartes himself couldn't solve it. But he redeemed himself by solving a special case that still fascinates geometers and number theorists. Descartes' theorem and its generalizations have revealed startling symmetries in infinite foams (called Apollonian packings) that are created by squeezing circles as tightly as possible into the spaces created by other circles. New Apollonian and Apollonian-like patterns continue to be discovered in the plane, in 3-space, and in higher dimensions all the way up to dimension 20.





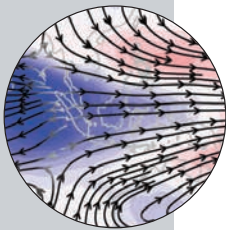
64 **Square Pegs and Squiggly Holes**

A century-old “folklore problem” in topology asks whether any continuous loop in the plane that does not cross itself must contain four points that form a perfect square. This is known as the Square Peg Conjecture. Recently, a team of two geometers proved something even better: if the curve is smooth (i.e., it has no corners or cusps) then it contains rectangles of all conceivable shapes, and also quadrilaterals of any shape that will fit snugly in a circle. Their proof ingeniously weaves together 2000-year-old theorems of Euclidean geometry with less than 20-year-old theorems of symplectic geometry.



78 **Dancing on the Edge of the Impossible**

The ultimate dream of many number theorists would be an algorithm that inputs a polynomial equation and outputs all the rational solutions to that equation. For equations with integer coefficients in one variable, it’s easy. For equations with nine or more variables, it’s impossible. But equations in two variables are right on the edge. Faltings’ theorem, proved in 1983, guarantees (for most such equations) that there are only finitely many solutions... but it doesn’t say whether there are four or four million. Number theorists are now inching closer to an “effective” Faltings theorem that would tell them when they can stop looking for more solutions.



94 **A Climate for Math**

Unprecedented heat waves. Orange skies. Ten-thousand-year floods. When the weather gets weirder than ever before, whom are you going to call? A climatologist, sure. But you might want to talk with a mathematician, too. This chapter explains how mathematical techniques like extreme value analysis, differential equations, changepoint analysis, and machine learning can give us some idea of what has happened already and what will happen next in climate change.



112 **Much Ado About Zero**

What is the friendliest research community in mathematics? You could make a good case for zero-forcing. This mash-up of linear algebra and graph theory has been in existence for less than 20 years, but has attracted a large following, with a sizeable proportion of young mathematicians and people from diverse academic and social backgrounds. Zero-forcing is a way to turn hard problems about eigenvalues of matrices into easy games played on graphs (i.e., dot-and-line networks). Or vice versa, it’s a way to turn simple graph games into challenging math problems. Applications to quantum control and electrical and civil engineering are the icing on the cake.