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EDITORIAL

Mathematical Biology, an interdisciplinary future

Mathematical Biology is a scientific field devoted to the study of biological processes using mathematical techniques. It is an area where the interests of biologists and mathematicians mainly converge, and to a lesser extent those of researchers from other branches of knowledge.

It is without doubt an attractive field that is now on the rise. It has progressed rapidly during the last two decades and has modified the controversial, historical relation between experimental science, Biology, and Mathematics, the latter being characterized by its degree of abstraction. Traditionally, biologists have not disguised their mistrust in the contributions made by mathematicians, on the grounds that the level of complexity of living beings could not be translated into terms provided by a handful of equations. At present, the close interaction between professionals belonging to both fields has made these equations into a mathematical synthesis capable of encapsulating the essential aspects of a biological reality while leaving other superficial considerations aside. While the resulting mathematical model seeks to be useful, it does not claim to be infallible; on the contrary, advances in science are normally based on the study and improvement of previously developed models.

The origins of this scientific discipline date back to the 18th century with the theoretical models proposed by the mathematicians Daniel Bernouilli and Leonhard Euler for the spread of epidemics and for fluid mechanics, respectively. In the first half of the 19th century, Thomas Robert Malthus and Pierre François Verhulst presented the Malthusian and logistic equations as mathematical models for the evolution of populations. Their equations, together with the differential equations proposed independently by Alfred J. Lotka in 1925 and Vito Volterra in 1926, provide the foundations for the basic mathematical models in Mathematical Biology and its applications, and are still being studied today. Modern Mathematical Biology first emerged with Nicolas Rashevsky, who in 1938 published the first scientific article on this discipline, and who in 1939 created the Bulletin of Mathematical Biophysics (currently the Bulletin of Mathematical Biology), the first specialized journal devoted to the field. In 1952, in a work on reaction-diffusion equations in Morphogenesis, Alan Turing attempted to describe the biological processes governing the growth of an organism, which among other applications enabled to determine whether a tumor was benign or malign. Turing's work was the precursor of the three components which have proven to be fundamental in contemporary Mathematical Biology: the modeling process, the use of differential equations, and the use of computers as an essential tool in the learning process.

Today, the branches of study continue to grow; in Biology, every problem addressed is singular, and as a result the mathematical tools employed are very varied. Specifically, the use of complex networks in epidemiology requires ideas belonging to graph theory; combinatorial algebra is applied to systems control in ecology; the topological branch of knot theory describes the way in which a DNA molecule is configured; research into molecular genetics requires certain stochastic processes (Markov chains and processes, branching processes, Brownian motion, diffusion processes); Monte Carlo Markov chains and numerical methods based on the theory of large deviations are found in the simulation of rare events in biological models; linear and nonlinear models in neurobiology employ deterministic and stochastic partial differential equations; in addition, measured or sampled data lead to goodness of fit and estimation procedures in statistics.

Computational advances in recent decades and the development of new numerical methods have enabled the diverse challenges faced

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by biomathematicians to be tackled in areas such as cell biology, neurobiology, genetics, population biology and genetics, ecology, epidemiology, immunology, molecular biology, protein structure and DNA, biological fluids, the biology of behavior, evolution and so on. The most promising of these challenges consists in understanding the dynamics of cancer from the perspectives of morphology, genomics, proteomics and mathematics, and translating the models and the data into clinical practice. The currently most popular application in epidemiology concerns social networks (Facebook), which require the use of powerful computational tools with a large quantity of individual components that interact mutually. Complex networks are the main subject of study in biological processes, ranging from molecules to ecosystems.

Mathematical Biology and, in particular, epidemiology and population dynamics, are fields that arouse much interest in Spanish and European universities and research centers. With the purpose of reflecting this intense activity, and in collaboration with the Stochastic Modelling Group (SMG), the Institute of Mathematical Sciences (ICMAT) hosted a "Two-day Meeting on Mathematical Biology" at the end of October. Over the course of these two days, a select group of invited speakers and participants came together to showcase the recent advances made in this discipline. This issue of the ICMAT Newsletter, devoted largely to Mathematical Biology, pursues the same aim.

Antonio Gómez Corral, member of thr Institute of Mathematical Sciences (ICMAT) and associate professor at the Complutense University of Madrid (UCM).

Report: Mathematics as a vital key for understanding how the brain works

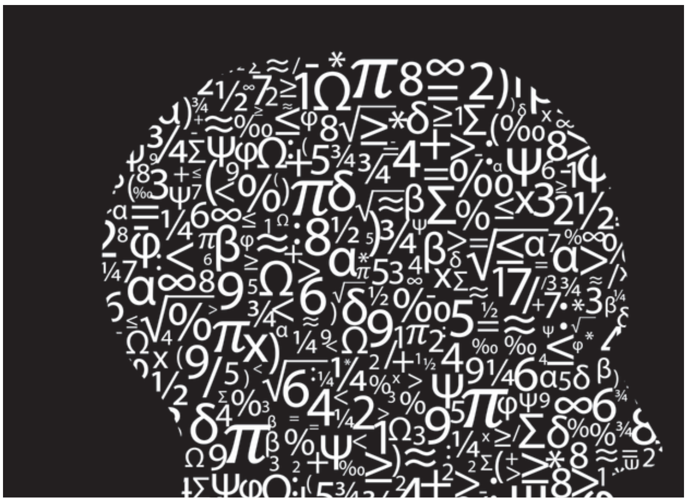
The strange relation between numbers and neurons

Advances in mathematics enable models to be created for describing mental processes concerning bipolar disorder and memory. Various experts in this promising interdisciplinary area that combines mathematics and neuroscience came together in the special sessions of the 10th American Institute of Mathematical Sciences (AIMS) Conference on Dynamical Systems, Differential Equations and Applications, which was held between July 7th and July 10th of 2014 at the Autonomous University of Madrid Cantoblanco campus.

Blanca Mª Fiz del Cerro. Bipolar disorder has for a long time been regarded as a curse disguised as madness or depression that was better left hidden, and it was not until the 19th century that it began to be understood as an illness. Also known as manic depression, it affects more than 30 thousand people in Spain alone, according to estimates by the World Health Organization (WHO). A new mathematical model seeks to explain what happens during outbreaks of this illness.

The cycles of manic depression are described by patterns of oscillations, and we are just beginning to understand how these mood swings occur thanks to geometrical theories of perturbation. Mathematicians are still unable to guarantee that their proposals will prove to be of clinical use, but as Ekaterina V. Kutafina points out, "what is certain is that this model explains the mechanisms that are behind the development of the illness." She is a researcher at the AGH University of Science and Technology in Krakow (Poland) and was a speaker at one of the sessions of the 10th American Institute of Mathematical Sciences (AIMS) Conference on Dynamical Systems, Differential Equations and Applications, held at the Autonomous University of Madrid Cantoblanco campus between July 7th and July 10th. These special sessions consisted of 13 talks scheduled to take place during the conference and were devoted to the applications of mathematics to neuroscience.

"Neuroscience is one of the most active scientific fields and requires the participation of experts from other disciplines. Its computer science aspects play a highly important role in modeling and experimentation, as well as in explaining the neurophysiological mechanisms and cognitive processes," said Roberto Barrio, professor and researcher at the University of Zaragoza (Spain), and Antoni Guillamon, researcher at the Technical University of Catalonia (Spain), in their introduction to the special session they organized together, which was devoted to nonlinear dynamics in neuroscience. "Differential equations are essential for the modeling of these phenomena, and as



Depositphotos

a consequence the techniques of dynamical systems and nonlinear dynamics have become resources for studying neurological models." In order to predict neuronal biological processes, it is very useful to describe the properties of neurons mathematically, and this is done by means of models. One of the most commonly used models is that by Hodgkin and Huxley, which explains the electrical behavior of nerve cells through the generation and propagation of electrical impulses. Simplifications such as those by FitzHugh-Nagumo and Hindmarsh-Rose have been proposed to make the most manageable model with computers. These simplifications have the peculiarity of only describing the dynamic as the transition between periods of rest and "explosions" of electrical impulses and their rhythms. Thanks to their great computational efficiency, they enable a large number of interconnected nerve cells to be simulated, thereby forming a neuronal network and the changes in the structure of these cells.

"In order to predict neuronal biological processes, it is very useful to describe the properties of neurons mathematically, and this is done by means of models"

Understanding the capacity of neuroplasticity for repairing brain damage

In contradiction to the popular Spanish saying, knowledge does indeed occupy space. When something new is perceived, neurons develop filaments known as axons and dendrites that form connections with other neurons to create what is known as a neuronal network. This mesh of nexuses is where memory is housed, so the more stimuli and experiences a person perceives, the more connections he or she develops. These connections occupy space and cause the brain to increase in volume, but with age the process of neuronal atrophy begins and with it a reduction in the neuroplasticity of the brain. This capacity of the nervous system to respond to new information may hold the key to the development of more effective ways of treating brain damage caused by traumatic lesions, cerebrovascular accidents, deterioration due to age or to degenerative diseases. Many biochemical and physiological components lie behind this process, which requires different reactions both inside and outside the neurons that generate this response.

Neuro-DYVERSE (which stands for DYnamically-driven VERification of Systems with Energy considerations) is a new application aimed at understanding of how human memory functions by means of new perspectives in modeling, analysis and control of systems such as neuroplasticity. It arose in response to the lack of knowledge about the functioning of neuronal networks and their relation with memory and the learning process. According to Eva Navarro-López from the Faculty of Computer Science at the University of Manchester (United Kingdom), "Existing models are very limited. This project is a step towards a better understanding of the adaptive dynamical processes involved in the formation and consolidation memory in the human brain."

In order for the brain to be able to produce memories, it must be capable of strengthening the most frequently used connections, which is what is known as long-term potentiation. Channels that are activated by nuerotransmitters form part of this process. When this molecule enters the synaptic cleft of the neuron it creates an electrical impulse. This "positive" connection triggers a series of biochemical processes that turn the neuron into a "favorite" channel for future connections, thereby making it stronger. The process increases the number of channels as well as changing the shape of some spines found in the dendrites and improves the connection. As Navarro López explains, "We still don't know anything about these neuronal interactions. Neurons are important, but what happens when they act as a whole?"

This is where Neuro-DYVERSE comes in; it combines theories from different disciplines such as hybrid systems, engineering, dynamical systems and network science. On the one hand, hybrid systems provide the models that represent the dynamical or variable behavior of the system. Since we are dealing with neurons, it is related with fuzzy logic theories and neuronal networks.

However, Neuro-DYVERSE is just one of the applications with the DYVERSE research network, the aim of which is to understand the complex behavior of hybrid systems (the dynamic of which is both discrete and continuous). To that end, DYVERSE consists of a three-step system. It first extracts information from the dynamical system under study. It then proceeds to a formal verification that checks to see whether the system if behaving correctly, and finally it supervises the process by control engineering. Once this process has been carried out, the theoretical data is validated experimentally by means of a prototype.

This is the result of a long research process combining engineering, computer science and the theory of dynamical systems. Eva Navarro-López says that "the tools involved in hybrid systems may be able to provide answers from a different point of view." Despite recent progress, challenges still remain to be tackled, such as the appropriate gathering of data in complex systems and simulations in real time.

"Neuro-DYVERSE is a new application aimed at understanding of how human memory functions by means of new perspectives in modeling"

Navarro-López ended her intervention with a quote from "Degeneration and Regeneration of the Nervous System" by Spanish Nobel laureate Ramón y Cajal: "The functional specialization of the brain imposes two great lacunae on the neurons: the incapacity of proliferation and the irreversibility of intra-protoplasmatic differentiation. It is for this reason that, once development ends, the sources of growth and regeneration of the axons and dendrites dry up irrevocably. In the adult brain the nerve channels are fixed, complete, immutable. Everything can die; nothing can be regenerated… It is up to science in the future to change, if possible, this cruel decree."

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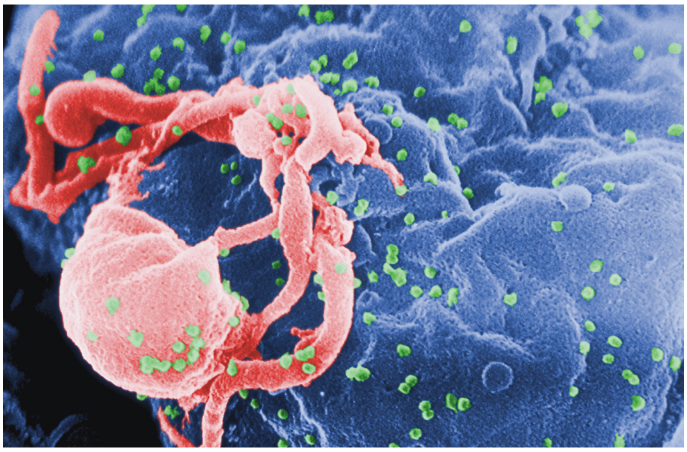
AIMS opening at the Congress Palace of Madrid

Differential equations against HIV

Every two years, the American Institute of Mathematical Sciences organizes the international conference on “Dynamical Systems, Differential Equations and Applications”, which was recently held again between July 7th and July 11th 2014 in Madrid. Among the numerous subjects addressed in the talks at the conference, there were many devoted to the modeling and dynamical analysis of complex patterns in biological systems, where it was shown that differential equations provide a tool for the fight against one of the pandemics of our century, HIV.



CDC of USA

Andrea Jiménez. Although aids was first detected decades before it ravaged different areas of Africa, the first clinical cases of this disease were recorded in the early 1980s in North America before sowing panic right across the world.

At that time, little was known about this disease that slowly undermined the immune system of those infected, except that it was transmitted by bodily fluids and that its cause, the human immunodeficiency virus, better known as HIV, was indestructible. Those who caught the disease were well aware of their fate; their bodily defenses would gradually collapse before other infectious diseases whose effects would eventually reduce them to skin and bone, with no known cure to save them from their inevitable end.

To date, no known treatment has been found to wipe out this lethal virus, which in recent decades has claimed more than thirty million lives. However, progress in research has enabled aids to be controlled by substantially improving the quality of life of sufferers thanks to the administration of drugs that attack the reproductive process of the virus at different points, thereby blocking its activity.

One of the great challenges facing the scientific community is to find an effective vaccine against this agent that is so lethal that, according to data from the World Health Organization, last year alone it infected 2.3 million people throughout the world. While research goes on to find a possible vaccine, alternative treatments currently consist of pharmacotherapy capable of slowing down the effect of the virus so that it causes no resistance to the medication in the patient.

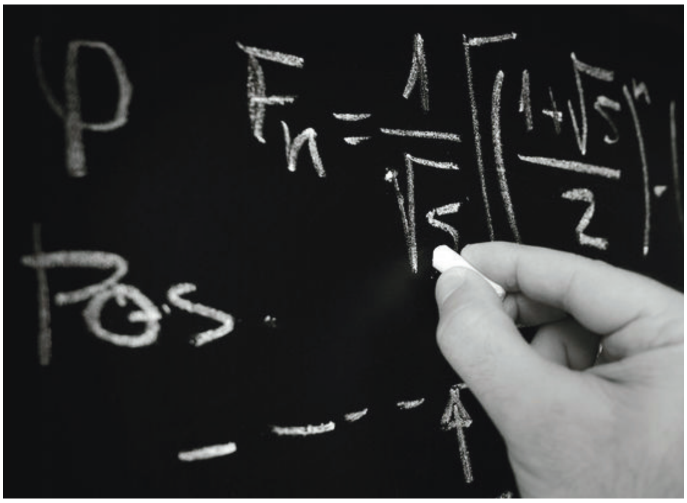
Doctor Nicoleta E. Tarfulea is involved in this fight against HIV, but using an approach that is somewhat different from that employed in conventional laboratories. She is an associate professor in the Department of Mathematics at Purdue University Calumet (USA), and the weapons she is using to tackle HIV are nothing less than differential equations.

Her mathematical developments enable very specific experimental situations to be reproduced numerically and therefore at a much reduced cost. These situations consist of testing the effect of a combination of drugs, observing their short- and long-term effect of interrupting the treatment on the rate of mutation of the virus, comparing the effectiveness of early and late treatment, and even studying the effect of a potential vaccine on infected patients.

She does this by means of mathematical models for studying the dynamics of the virus and the dosage in the treatment with antiretroviral drugs. She presented her latest results last June at the American Institute of Mathematical Sciences (AIMS) Conference on Dynamical Systems, Differential Equations and Applications, which she has attended regularly in recent years. As this mathematician explains, “there’s a great deal of information about the individual processes involved in the dynamics, evolution and treatment of HIV, but there’s still a lot more to do. Integrating these results into a qualitative model in order to describe how the body reacts when it is infected by HIV can help us to tackle the virus more effectively.”

“A qualitative model in order to describe how the body reacts when it is infected by HIV can help us to tackle the virus more effectively”

Tarfulea’s research work is focused on the characteristic speed with which the virus mutates and becomes resistant, one of the most puzzling issues that HIV poses to science, since it constitutes the main obstacle for the development of an effective vaccine. Her models enable the dynamics of HIV and the evolution of resistance it sets up in the body to be explored, as well as studying the different possible strategies of treatment for the virus.



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Resistance takes algebraic forms

Tarfulea points out that, "resistance to treatment has its origin in different factors, among which is failing to take the medication exactly as it was prescribed." Skipping a dose or a poor absorption of the medication leads to a reduction in the antiretroviral drugs found in blood samples and allows the virus to reproduce and mutate more freely.

While the appearance of each new mutation of the virus in the organism means stopping one treatment and trying another, in the experiments with mathematical models it is not necessary to change the whole initial formula, but rather add it to all the mutations as if it were forming an increasingly longer tail to the equation. As Tarfulea points out "From the moment when a mutation is introduced and we have observed its behavior, we can deduce the dynamics of the second one, and so on successively."

> "By adjusting the variables and the concentrations, I can also investigate the different strategies in the treatment"

This researcher goes on to say that, "I first introduce into the models a mutation into the system, bearing in mind the wild-type strains so that the original drug is assigned to them, and after that the mutant strains. By adjusting the variables and the concentrations, I can also investigate the different strategies in the treatment."

In addition to providing an infinite variety of scenarios in which to analyze the behavior of the virus, the mathematical models enable ethical questions to be addressed that would not be possible using real patients. As Tarfulea explains, "HIV is a very delicate subject, especially in the United States. It's very difficult to find volunteers willing to subject themselves to experimental therapies with drugs. That's the advantage of our models from all points of view. Thanks to these models a large amount of money and resources can be optimized, as well as solving many of the technical problems that arise in most biomedical studies in general, and particularly in HIV."

Life in equations

In Madrid she spoke about her latest achievements. "We've improved on the existing models and arrived at some very relevant conclusions." One of the main questions that has been studied is the role played by cells in the immunological system when responding to the virus. "We've shown that their presence reduces the concentration of infected T cells – those that coordinate the immune response and which are attacked specifically by the virus - with the result that concentrations of the virus stabilize at the lowest level and enable the healthy cells to increase."

The most ambitious part of her project consists in setting up a low-cost virtual laboratory capable of handling large quantities of data in order to continue exploring new models that may improve our understanding of the dynamics of HIV and its treatment. Says Tarfulea "I'm optimistic, and believe that this research will lead to a better understanding of the dynamics of the disease as well as bringing us closer to the development of new strategies of treatment. But I'm also aware that we still have a long way to go and that a cure for aids will not be found in the immediate future."

Her research work also forms part of her teaching duties. "This kind of research in biology shows young scientists the highly important applications of mathematics and the challenges it provides for them. That's why I always have at least two projects in which my students can participate." Her models cover practically all fields of life sciences, ranging from studies on salmonella to population dynamics and the monitoring of fish migrations.

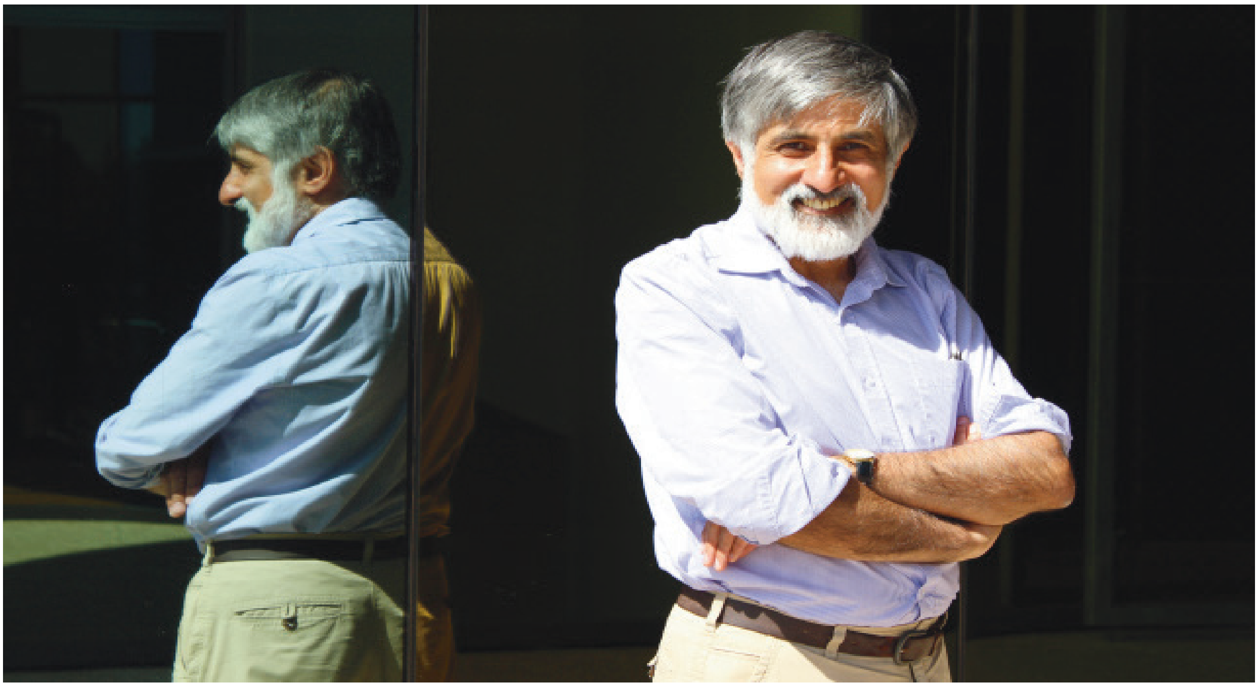
Tarfulea says that "Most of my students have jobs as well as studying at university, and to see them finding the time from their tight working schedules to do research with such passion is both wonderful and very reassuring." This motivation, added to the good results they are obtaining, provide even greater encouragement to this mathematician in her profession.

Wisinconsin University

Doctor Nicoleta E. Tarfulea professor in the Department of Applied Mathematics at the University of Wisconsin (USA).

Interview: Philip K. Maini, Professor of Mathematical Biology at Oxford University

"Cancer therapy inspired by mathematical models may appear in the next five years"



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Philip K. Maini, Professor of Mathematical Biology at Oxford University

Inmaculada Sorribes.

Philip Maini (Northern Ireland, 1959) is one of the leading experts worldwide on the applications of mathematics to the study of cancer. His models for tumor growth provide new perspectives for the understanding the development of certain types of this disease and may prove vital for designing new forms of therapy. A graduate in Mathematics from Oxford University, where he also obtained his PhD, since 1992 Maini has been the head of the Wolfson Center for Mathematical Biology. We had the opportunity of talking to him at the 10th Conference of the American Institute of Mathematical Sciences, which was held between July 7th and July 10th at the Campus Cantoblanco, Autonomous University of Madrid.

Question: What would you say has been the most important contribution to date of mathematics to cancer research?

Answer: Statistics has helped to identify what factors that make certain people more prone to suffering from some diseases from a genetic point of view. A good example of this type of statistical data is the relation between tobacco and cancer. Furthermore, mathematical biology is just starting to provide an understanding of what happens during certain biological processes. The work I'm doing in collaboration with researchers at the Wolfson Center for Mathematical Biology and the Experimental Center in Arizona is opening up new perspectives for understanding how certain types of cancer are propagated.

Q: What does this involve?

A: Cancerous cells and healthy cells are regarded as a system of internal interaction, which we are trying to understand. So we are looking for ways to change or influence these dynamics and favor the healthy cells rather than concentrating solely on tumor cells. We take into account the whole picture.

Q: Could this lead to new types of treatment?

A: Potentially it could. We want to develop new types of therapy that can be completely understood, although there's still a long way to go.

Q: What other applications do you think mathematics might provide in this field in the future?

A: There are models that evaluate different types of therapy; for example, for controlling the development of resistance or intolerance to the drugs administered, and then analyzing the optimum way of managing the doses. But these are subjects on which mathematicians work alongside biologists, and there's a big jump from here to clinical work. We're gradually moving closer to that, and maybe types of therapy against cancer that really have been motivated and stimulated by mathematical models may appear in the next five or ten years.

"Mathematical biology is just starting to provide an understanding of what happens during certain biological processes"

Q: What are the main challenges facing mathematicians in cancer research?

A: There are many challenges, the first of which is learning about and understand the biology involved. A mathematician has to know as much about biology as the biologists he or she is working with, if not even more. So far, mathematicians have mainly been stimulated by physics. But biology is a very different matter; it requires its own mathematics. When tackling a problem in mathematical biology we try to use certain tools that have been created for solving a specific problem, but the situation is completely different and gives rise to new questions.

Q: Can you give us an example?

A: Yes, in physics there's a clear difference between spatial and temporal magnitudes. We can employ sufficiently large and well-differentiated units of measurement, and use them to simplify the equations. But this doesn't happen in biology, so we've got to use the original equations, which are sometimes unmanageable. The number of variables, factors and parameters to take into account is such that we find systems that are so large, broad and complicated that they are impossible to deal with. Furthermore, unlike physical systems, biological systems are different in the sense that each cell is different. It's extremely necessary to find the mathematical structure that enables us to deal with that.

Q: In your experience, what's the relation between mathematicians, biologists and clinicians?

A: I think we're moving in the right direction. My research group is closely related to biologists and clinicians, and now researchers in hospitals want to talk to us about their problems to see if we can make some contribution or come up with a different approach. This is a completely different situation to that which existed ten years ago, when this simply did not happen. Even if it was you who tried to talk to them, they didn't really trust you.

"Now researchers in hospitals want to talk to us about their problemes"

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Maini with some others guests at the AIMS 2014 dinner.

Q: What do you think has brought about this change?

A: Many of them have realized that mathematicians can provide a new outlook on a problem or suggest new ideas. Biologist colleagues have often mentioned that we as mathematicians think in a different way and this leads to new approaches, because we come from a different background. Everybody has their own background and this is also what brings biologists to validate their hypotheses by experimentation without recourse to any deeper work.

"Mathematicians have mainly been stimulated by physics. But biology is a very different matter; it requires its own mathematics"

Q: How does this go down with a "pure" mathematician?

A: There are mathematicians who say that they chose their discipline because it concerns pure knowledge, in which results are either true or false. In biology, something may be true one day and false on another. And there are biologists who say they do biology because it doesn't involve any mathematics. Of course, bringing together two people from very different cultures is going to take time, but that's already beginning to happen.

"I hope to be the first of many women presidents of the IMU"

Ingrid Daubichies, former chair of the International Mathematical Union

Ágata Timón.

Ingrid Daubechies (Belgium, 1954) is a professor of mathematics at Duke University (USA). She is the first, and at present the only female chair of the International Mathematical Union. Although her term comes to an end in 2014, the International Congress of Mathematicians provided a fitting finale to her work over the last four years. It was there that we had the opportunity to talk to her about the Institution itself as well as international mathematics and her own research work, to which she is eager to return again full-time when she steps down from her current position.

Question: What has been for you the greatest achievement of this International Congress of Mathematics (ICM)?

Answer: On the one hand, we wanted the plenary talks to be accessible to all the mathematicians, and so we provided the speakers with some means for this to happen. I also had the idea of including short videos in the inaugural talk of the prize-winners, and that generated a debate in the Executive Committee and was eventually viewed in a positive light, since the videos added a nice dimension to the ceremony.

Another novelty was that for the first time a MENAO (Mathematics in Emerging Nations: Achievements and Opportunities) Symposium in developing countries was held one day before the start of the Congress itself. And thanks to a great initiative by the local organizers of the congress, travel grants were provided for researchers coming from developing countries. In addition, a fund-raising campaign, DonAuction (http://donauction.org/), was set up to help the training of young mathematicians.

Q: This is also the first time that a woman has been awarded the Fields Medal. What would you like to say about that?

A: I'm extremely happy. We knew this was going to happen at some time, and it's great it did so while I was in the chair. I hope it won't be too long before there are more.

Q: What do you think it means for the mathematical community?

A: I think that the image of Maryam Mirzakhan receiving the prize from Park Geun-hye, the woman president of South Korea, is one we won't forget in a long time. But I'm sure that the Republic of Korea doesn't want Park to be the only woman president, just the first. Both I and the whole mathematical community wish for the same; that Mirzakhani will be the first of many women winners of the Fields Medal; in the same way that I hope to be the first of many women presidents of the IMU. Let's hope we get to the point where a female Fields Medal winner is no longer front page news.

Q: Why has it taken so long for a woman to be awarded the prize?

A: At the IMU we believe that mathematical talent is distributed randomly over the whole population and across all genders. Nevertheless, in many countries the number of women mathematicians is much lower than men, so we believe that there are cultural questions and issues of equal opportunity that influence the situation. In response to this, and for other reasons, organizations of women mathematicians have been created all over the world with the aim of promoting activities to help young women to pursue a career in mathematics.

> "I've been working on tools and techniques that are useful for art historians and curators"

Q: What's the role of the ICWM (International Congress of Women Mathematicians) in all this?

A: It brings together organizations of women mathematicians from all over the world to share their experiences and to show that they are not alone. All of we who attend the ICWM are minorities in our countries of origin, so it's very nice to get together. Let's hope there comes a time when there are so many women mathematicians that we won't need to gather together in a separate group.

Q: The stance of the IMU regarding women's rights seems clear, but it made no pronouncement in the debate on the exoneration of Alan Turing. What's the position of the institution on that issue?

A: The fact that the subject was debated seemed important to us; restoring the reputation of Alan Turing has a symbolic value, but we also give priority to defending the rights of living people. What's more, we were very busy with the organization of the ICM at that time. In any case, I'm sorry we passed it over.

Q: What advice would you give to Shigefumi Mori, the next Chair of the IMU?

A: He'd already belonged to the IMU Executive Committee, but he told me that he finds that the institution has changed a lot. I think I'd advise him to be very organized, but since he's already been the head of a research institute he'll know very well what to do. Maybe I'd also advise him to look for a good assistant for the next IMU. I made the mistake of doing without one, and that's something I regret.

Q: Now that you're stepping down, will you stay in contact with the IMU?

A: Yes, I'm going to continue working on the things that were most important to me in the past, the things that I'd miss the most; for instance, building up a digital mathematical library, or the situation of mathematicians in developing countries.

Q: On the other hand, what do you think you won't miss?

A: I won't miss the lack of time to do my own mathematics. I'm looking forward to having that time again.

Q: One of your lines of work is the collaboration with the Prado Museum in Madrid. What can you tell us about that?

A: In recent years I've been working on image analysis; specifically, on tools and techniques that may be useful for art historians and curators. On one of these projects we realized that many X-ray images of paintings on wooden panels showed cross bars. This surprised us, because although these types of cross bars appear on canvases too, due to the stretchers, we didn't expect to find them on wooden panels. Then we realized that it was in fact a widely used method of preservation and support. The problem is that this type of conservation technique makes analysis difficult; in order to see the condition of the panting in all its details, experts have to remove this support (called a "cradle") with extreme care. We thought that maybe we could devise a tool to do this digitally.

A woman pioneer in mathematics

One of Ingrid Daubechies' (Houthalen, Belgium, 1954) most outstanding scientific achievements is the mathematical development of wavelets and their applications to many fields, such as data compression, digital communication and image processing. Wavelets enable a mathematical object (an image, a wave, etc) to be decomposed into more simple packets of information, which are easier to transmit and therefore provide a new scientific approach to data compression.

The underlying ideas of the wavelets she constructed have been incorporated into the JPEG 2000 standard and into a great many technologies, including efficient audio and video transmission and medical imaging.

In 2012 she was awarded the Frontiers of Knowledge Prize by the BBVA Foundation for Basic Science in recognition of her work, which she also shared with mathematician David Mumford. She was the first woman to receive this award, which was an addition to her personal list of landmarks: she was the first female professor at Princeton University and is the only woman to have received National Prize of the Academy of Mathematical Sciences. She has also been the only woman president of the International Mathematical Union to date.

Q: What stage is the project at now?

A: The algorithm is ready, and the idea now is to turn it into a Photoshop tool. We have to speak to the people at the Prado and see if it's possible to do this. We'd like to be able to make it a tool that all curators can use; that's why we also want to develop an Open Source version to facilitate mathematical analysis and develop an algorithm to enable anyone to adapt it to their needs, as well as to encourage museums to work together with local mathematicians and engineers.

Q: What else are you working on?

A: I'm collaborating with biologists to differentiate surfaces and define distances between surfaces; for example, the surfaces of bones and teeth; you need to compare them in order to classify them.

Q: What do you think the most important applications of mathematics will be in the future?

"There are many fields that are being developed without necessarily thinking about applications, but nevertheless applications come out of them"

Q: Did it work?

A: The first example we tried it with worked, but we needed more. Here the Prado has helped us a lot because they've given us access to many paintings damaged by this means of conservation. They're physically removing the cradles from a very small collection of paintings, but we have to make sure that our results are correct; that is, to find out if the result of removing the lines digitally is the same as when they are removed manually.

A: I don't know what the next great mathematical application will be, but so far I've found no branch that cannot somehow be applied. I think there'll be a lot of applications. A wonderful thing about mathematics is that there are many fields that are being developed without necessarily thinking about applications, but nevertheless applications come out of them. Since the ideas are already there, we know where to look when we need tools for specific problems. It's also important that we have people with open minds, ready to listen to others who may need mathematics.

Interview: Mats Gyllenberg, researcher in biomathematics at the University of Helsinki

"The new challenges in biomathematics are in molecular biology"

Blanca Fiz del Cerro.

Almost 2,500 mathematicians from all over the world were able to enjoy the hot weather in Madrid when they attended the 10th American Institute of Mathematical Sciences (AIMS) Conference on Dynamical Systems, Differential Equations and Applications, which was held at the Autonomous University of Madrid Cantoblanco campus between July 7th and July 10th. Mats Gyllenberg was one of the speakers, and his profile fits perfectly within the concept of interdisciplinarity and transfer that the conference was designed to encourage. "As a biomathematician you may not necessarily think about important questions. It's vital to maintain a permanent dialogue with those who really know biology", said. The talk that Gyllenberg gave at the conference (on models for populations that are structured according to one of their physiological traits, such as age or sex) reflects his work with the research team of biomathematicians at the University of Helsinki, where they model biological processes and phenomena mathematically at both a molecular level and for the study of populations. In order to get to know his work as a biomathematician better as well as how he tackles the challenges that this poses, we spoke to him after the plenary talk given by Cédric Villani at the AIMS2014

Mats Gyllenberg, researcher in biomathematics at the University of Helsinki

Question: What kind of problems do you work on?

Answer: As a biomathematician I've worked on problems involving the dynamics of populations with applications to ecology and evolution by natural selection. I've also worked on physiological models such as those concerning respiration and snoring in humans, and on microbiological applications to the growth of bacteria and their classification. From the mathematical point of view, I use theories of dynamical systems as well as functional analysis and, in particular, the theory of semi-groups of linear operators and delay integral equations.

Q: How did you become a biomathematician?

A: I've always been interested in biology. In fact, when I was a student I took some courses on microbiology and biochemistry, and in the summer I worked in the microbiology laboratory at the university. I realized later that I could use mathematical modeling to understand bacterial growth, and that's how I got started.

Q: What do you like most about being a biomathematician?

A: Translating a real-world system into mathematical language. When you've done this, you can become a pure mathematician and do research into the equations you've arrived at, draw conclusions and translate them back into biological language to see what they mean in that world. I like this interaction between biology and pure mathematics. I collaborate with biologists, microbiologists and medical doctors, because if I try to do it by my own as a biomathematician, maybe I don't think about the important questions or don't even formulate the correct ones. It's very important to have this dialogue with people who really know biology well.

Q: Is it difficult for them to understand your work?

A: Yes, there's a big communication problem, because those who have been trained as biologists don't have enough mathematical knowledge to understand what's really happening in the models. As I mentioned before, I've studied microbiology and biochemistry so I understand what they're talking about, as well as the difficulties they have for understanding the mathematical results. I think this is a challenge, and today, when the world of life sciences has become much more mathematical, university education in courses like biology ought to include this discipline more.

Q: Mathematicians are expected to provide new tools to tackle the great challenges in biology. Which of these challenges would you mention in particular?

A: The new challenges are in microbiology. There are interesting topics on DNA, how to understand folding in three dimensions, codification and so on, for which you need different mathematical fields such as topology. In phylogenetics, in the construction of genetic trees, you work with algorithms, but there's still a lack of a rigorous mathematical basis.

Q: You use the well-known rock-scissors-paper game to explain the theory on the dynamics of ecology. Can you explain how you do this?

A: This is related with a specific problem in evolution by natural selection. There's a very common misunderstanding: people think that evolution optimizes something, and that in some way human beings are the optimal result in nature. That isn't true.

"I think this is a challenge, and today, when the world of life sciences has become much more mathematical, university education in courses like biology ought to include this discipline more"

Q: So how does it work?

A: There is no function that must be maximized or minimized to arrive at an optimal result. However, we can take a cycle rock (A) – paper (B) – scissors (C), which means that A has a better physical form than B, B better than C and C better than A. In this way there's a principle of optimization, but it could also work in the opposite direction.

Q: Do you think that using this kind of analogy helps people to understand your work better?

A: yes, I think so. In fact, it's absolutely necessary because all modeling has to do with analogies and metaphors. As I said before, you translate reality. You've got a system you're interested in; you describe it and start with an original model that enables you by metaphors to use a common language. That's already an improvement, and you can relate it to the real system by means of the research you're conducting through something you know better.

Q: How important do you think mathematics is for the other sciences?

"... there's still a lack of a rigorous mathematical basis (in biology)"

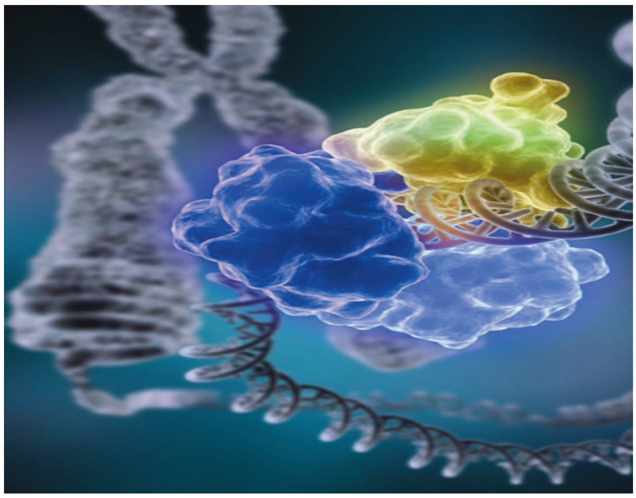
A: Mathematics is what makes science what it is, as Emmanuelle Kant said. Physics has always gone hand in hand with mathematics, at least since the time of Galileo Galilei. Now mathematics is becoming an important part of life sciences, and is even used in the humanities, in the analysis of texts, for example. Classification algorithms based on rigorous mathematics are used to find the original texts of ancient documents that have been copied and modified. These copied texts also present analogies with phylogenetics; they contain errors and these errors correspond to mutations in biology, so when trying to find the original document you find the ancestor of the species. In this way you construct the genealogical tree.

Q: What advice would you give to a future scientist?

A: Go right ahead. It's very nice being a scientist. I'd also like to point out that any future scientist shouldn't be afraid of mathematics, because even though your main field might be chemistry, biology, or even literature, you might need mathematics for your work. If you don't like doing mathematics yourself, you should look for mathematicians to collaborate with you.

Q: Why are events like the AIMS 2014 important for a scientist?

A: This congress is enormous. There are around three thousand people and so many talks that it's impossible to attend all of them. I'd say that the most important thing is the social side aspect: meeting up again with old friends, talking about mathematics, and the sessions. Of course, I've also enjoyed the plenary talks. Normally, from the scientific point of view, I prefer the small meetings where you can get precise information, but from the social point of view, the big talks are very pleasant.


Tom Ellenberger - NIGMS

" Any future scientist shouldn't be afraid of mathematics, because even though your main field might be chemistry, biology, or even literature, you might need mathematics for your work"

Profile of Jerry Bona, Professor of Mathematics at the University of Illinois, Chicago

Jerry Bona, Professor of Mathematics at the University of Illinois, Chicago

"It is hard enough to make progress even if you love what you are doing"

Jerry Bona was born in 1945 in Little Rock, Arkansas. He studied mathematics at Harvard University, and obtained his PhD from there in 1971 under the supervision of Garrett Birkhoff. Currently, he is Professor of Mathematics at the University of Illinois at Chicago.

Question: Why did you choose mathematics ahead of any other subject?

Answer: Actually, I did not choose mathematics. I was a computer science major as an undergraduate and went off the graduate school in Applied Physics at Harvard. I realized that most of what I was doing was mathematics in one form or another and shifted to Mathematics for my Ph.D.

Q: Besides mathematics, which activities do you like most?

A: Reading fiction, traveling, sports, walking/hiking, cinema, theatre, art history, cooking, drinking wine; no order intended.

Q: A movie, book or play you'd recommend?

A: Too many to think about, but one novel I read recently that struck me was Carlos Ruiz Zafón's "The Shadow of the Wind". Another was Ken Follett's "Pillars of the Earth" series and the subsequent, related tales.

Q: How was your first encounter with mathematical research?

A: I was given a problem in Operations Research to study by my undergraduate advisor, Leon Cooper, at Washington University, Saint Louis. This turned into my honor's thesis.

Q: What did you like most about your early experiences with mathematical research?

A: I was really only interested in mathematics because it allows us to say precise things about the world around us. It was Galileo who said something like "The Book of Nature is written in the Language of Mathematics".

Q: Which scientist impressed you most during your career?

A: Again, too many to choose; however, the person who had the largest influence on me personally was T. Brooke Benjamin.

Q: If you could have a one hour blackboard discussion with an ancient mathematician, whom would you choose to meet and what would you discuss

A: Not sure what 'ancient' means in this context. If Leibniz qualifies as 'ancient' I would like to discuss calculus with him. If we go back further, it would be a lot of fun to talk about the same topic with Eudoxus.

Q: Do you have a particular theorem or formula you especially like?

A: No.

Q: What is your favourite mathematical book?

A: This is like asking, "do you want cookies or cake or …..?".

Q: How would you describe/sketch your research interest in a few lines?

A: I have been concerned with issues that arise in the real world. The major thrust of my effort goes into turning such matters into mathematical problems. The particular areas that have attracted me include fluid mechanics and especially water waves, economic theory and certain parts of biology and medical science. The particular mathematical techniques used depend upon the problem of course.

Q: Which recent results in your field would you highlight?

A: There has been a lot of progress lately in understanding the relationship between various mathematical models for water wave propagation.

Q: Which particular mathematical problem do you consider especially challenging?

A: There are many, many challenging problems. This is fortunate for the future of our subject!

Q: Which subjects in mathematics outside your field would you like to learn more about?

A: I have always had an abiding interest in certain parts of topology.

Q: In the future, where do you think the interaction between different branches of mathematics may be more fruitful?

A: During my career, I have watched an increase in the conversations between various branches of mathematics and between mathematics and its application areas.

Q: Do you have any message or advice you would like to share with young mathematicians?

A: Find things to work on that you enjoy. It is hard enough to make progress even if you love what you are doing.

Profile of Mª Ángeles García Ferrero, young researcher at ICMAT

“It’s surprising what happens at the frontier between mathematics and physics”

Lucía Durbán.

Mª Ángeles García Ferrero was born 23 years ago in León. She studied Physical Sciences in Valladolid and Madrid and is currently engaged on her doctorate from the Complutense University of Madrid (UVM) at the Institute of Mathematical Sciences (ICMAT) under the supervision of ICMAT researcher Alberto Enciso. Although she had already been at the ICMAT on a CSIC JAE Intro Grant, she returned to the Institute just three months ago to work on her thesis, which concerns “global approximation theorems in partial differential equations and their application to geometrical analysis and physical mathematics”

Question: When did you decide that mathematics was really your vocation?

Ansuer: I think mathematics chose me and not the other way. It’s been following me all my life. Even as a little girl I loved it; for me it was a game full of fun and I went in for all kinds of competitions, such as the Olympiads, the mathematical babysitter, and so on. But in the end I studied physics, and really the national Olympiads that I won were in physics and chemistry!

Q: And how does one move from physics to mathematics?

A: Actually, my thesis and I are right at the frontier between mathematics and physics, and it’s surprising what happens there. I studied physics because I admired the phenomena in nature and was very interested in biophysics. But when I was doing my degree I realized that I enjoyed subjects that involved a lot of mathematics most, so whenever I could I collaborated with teachers who gave those lectures and when I finished my degree I decided to do a PhD in mathematics. And what fascinates me most about mathematics is just that - the possibility of developing tools capable of describing natural processes.

Q: Didn’t you consider any other profession?

A: No, not as a profession; I think I would always have opted for research. At one time I thought about studying medicine, although I would never have gone in for clinical medicine; I’m more of a laboratory person.

Q: How did this vocation for research come about?

A: I’ve always been curious. The motivating force was probably a subject on mathematical physics in the second year of my degree course; I enjoyed it so much that I volunteered to help the professor in the following year, and that set the ball rolling with collaborations with mathematics always in my sights. I worked in the field of self-adjoint operators and exceptional orthogonal polynomials, and during that same summer of my third year I got a CSIC Intro JAE (Junta para la Ampliación de Estudios) Grant. That was the first time I came to the ICMAT. I learned a lot about partial differential equations and had the chance to attend the summer courses at the Institute, where two things became clear to me: I didn’t know as much about mathematics as I thought and wanted to learn more.

Q: Did that provide you with an introduction to the work you’re doing now at the ICMAT?

A: In order to understand the dynamics of research, yes; but as a field of research my thesis has nothing to do with what I’d done before. Now I’m working on global approximation theorems in partial differential equations and their application to geometrical analysis and physical mathematics. I find these subjects fascinating, but I still find them difficult to understand. I knew that the first steps would be to read and read, because I need to learn a lot of mathematics and sometimes it’s a bit scary. But when you struggle with a paper and you manage to understand a lot of things you feel that you’re in the right place.

"When you struggle with a paper and you manage to understand you fell thar you're in the right place"

Q: In the first three months of your thesis, do you remember the first day when you felt satisfied?

A: About four weeks ago I managed to read a paper by Albert Enciso from beginning to end in one sitting, and not only did I understand it, I really enjoyed it! I went home that day very excited and very satisfied, but I still have a long way to go before I can work more or less on my own.

Q: What challenges face you in the near future?

A: Well, I've just landed really and everything is a challenge for me. I want to solve some of the problems that Albert Enciso, my thesis supervisor, has set me. I want to complete a good thesis in less than four years, and I hope to have published a paper in two years.

Q: Where would you like to be in 10 years' time?

A: I'd like to be in a research center working on cutting-edge mathematics, such as the ICMAT. And I'd like to work on a subject with many possibilities, like the one I'm studying for my doctoral thesis.

Q: Are you interested in another field in mathematics?

A: I'm fine working on what I'm doing right now, but as far as learning is concerned I enjoy numerics a lot.

Q: What other interests do you have apart from mathematics?

A: I love reading and also going to the cinema, but I also spend part of my free time on voluntary social work. I think this type of activity puts you in your place. I usually work with the same organization, the Red Ìncola Foundation, giving support classes to school children at risk of social exclusion.

Q: Do you read books about mathematics? Would you recommend one to the young people you work with?

A: I read a lot of books on mathematics. I've only been doing my thesis for three months and my day-to-day work at the ICMAT is read, read, read. But if I had to recommend an inspiring book, I think it would be "Surely You're Joking, Mr. Feynman!" The passion with which he recounts things would arouse anyone's curiosity!

Q: If you could travel in time, which scientist would you ask for advice?

A: I'd love to attend a master class by Leonhard Euler to learn how so many results were achieved at that time. And I'd certainly ask him to tell me how he managed to combine such a successful scientific career with daily life.

Scientific review

Mathematics for better livestock management

Title: Control strategies for a stochastic model of host-parasite interaction in a seasonal environment
Authors: Antonio Gómez Corral (ICMAT-UCM) and Martín López García (University of Leeds)
Source: Journal of Theoretical Biology 354, 1–11
Date of Publication: August, 2014

The gastro-intestinal nematode (or roundworm) is one of the most common types of parasite found in lambs of less than one year old. It attaches itself to the small intestine of these lambs when they ingest fodder or forage contaminated by the droppings of animals already infected by the parasite. While this process is inevitable, it varies according to geographical location and the season of the year; greater rainfall gives rise to more forage, but also increases the amount of water in the forage, and all lambs carry this parasite to a greater or lesser extent. These roundworms may cause diseases that lead to loss of weight, and even death if the infection is not kept below a certain level. In order to control it, cattle breeders can use different strategies that are often combined, for example, with the use of anthelmintics, transfer of the lambs to less contaminated areas or complete isolation.

Each of these strategies carries a cost and should be put into practice at the right time in order to ensure their effectiveness. Antonio Gómez Corral (ICMAT-UCM) and Martín López García (University of Leeds) have studied these different strategies for controlling the parasite Nematodirus spp. by means of a probabilistic host-parasite interaction model, and have compared their results with those obtained experimentally. The nonlinear, stochastic model proposed in the Journal of Theoretical Biology employs non-stationary Poisson processes to describe the acquisition of parasites, the parasite-induced host mortality, the natural (no parasite-induced) host mortality, and the reproduction and death of the parasite itself in the host. "The aim is to improve the quality of health of the animal, for which it is necessary to quantify the level of infection at each time instant t, and to decide on what treatment to administer and when",

Scientific review

says Antonio Gómez Corral, researcher at the Complutense University of Madrid and member of the ICMAT.

The probabilistic model leads to a bi-objective optimization problem; on the one hand, the goal is to improve the health of the animal, and on the other to minimize the cost of the treatment. The healthier the lamb the greater the investment required for treatment, while the less spent on treatment the worse will be the animal's state of health. In order to quantify the effectiveness of the strategy, these two researchers have defined probabilistic functions that depend on the time *t(0)* at which the intervention is carried out. The cost of the type of treatment administered at time *t(0)* is also defined using probabilistic functions, while in order to describe the evolution of the amount of parasites in the host both before and after t*(0)*, stochastic processes come into play, which in turn depend on seasonal factors, the age of the animal, its weight and the food it eats.

Two basic ideas exist for selecting *t(0)*: minimizing the cost of intervention and maintaining a minimum level (as high as possible) of effectiveness; or maximizing effectiveness and establishing the maximum affordable cost. For selecting the appropriate *t(0)*, the researchers present two control strategies that balance the effectiveness and the cost of the intervention. Their approach is based on simple probabilistic principles and enables them to determine the seasonal fluctuations of the number of gastro-intestinal nematodes carried by the lambs. The analytical results are obtained on the basis of the transient distribution of the number of parasites infecting the animal at a time instant *t*. Depending on the strategy under study, a transient solution is required for some inhomogeneous-time versions of the birth-death process with killing , where the birth, death and killing rates are all non-stationary functions, and they depend on the state of the animal.


2000 Revista Agro

The researchers

Antonio Gómez Corral obtained his PhD in Mathematics from the Complutense University of Madrid (UCM), where he obtained the post of Associate Professor at the Department of Statistics and Operations Research in 1998, a position he has held since that time. His current areas of research are focused on mathematical biology, in particular, the use of stochastic models in epidemics and population dynamics, fields in which he has published articles in journals such as Advances in Applied Probability, the Journal of Mathematical Biology, Journal of Theoretical Biology, Physica A, Stochastic Models, etc. Furthermore, he is an Associate Editor with the journals Applied Mathematical Modelling, Asia-Pacific Journal of Operational Research and Top. Together with Jesús R. Artalejo, he is the co-author of the book "Retrial Queueing Systems: A Computational Approach", Springer-Verlag, 2008.

Martín López García completed his degree in Mathematics at the University of Alicante in 2009. He did his doctoral thesis under the supervision of Antonio Gómez Corral at the Complutense University of Madrid. Completing his PhD on 2103, he obtained a post as a post-doctoral researcher with the Mathematical Biology and Medicine team at the University of Leeds as part of the project "Vascular Receptor-Ligand Programming: Stochastic Modeling of Cellular Fate", funded by the Leverhulme Trust. He is also a member of the UCM Stochastic Modelling Group and collaborates with the project on "Stochastic Models for Epidemics and Populations", funded by the Spanish Ministry of Economy and Competitiveness and led by Antonio Gómez-Corral.

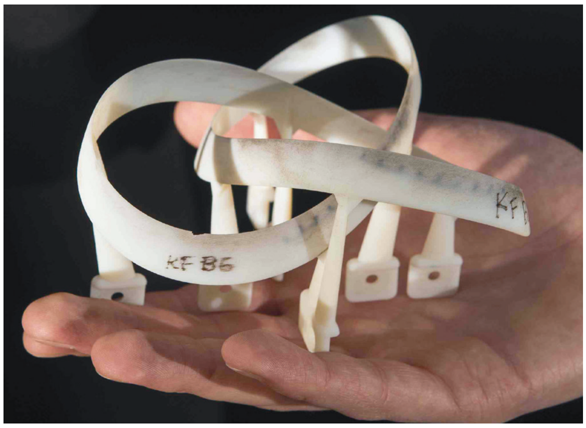
Mathematics Today

ICMAT News

Alberto Enciso and Daniel Peralta prove a conjecture posed by Lord Kelvin 140 years ago

Two ICMAT researchers, Alberto Enciso and Daniel Peralta Salas, have solved an important mathematical enigma that has challenged the scientific community for 140 years. The problem was posed in 1875 by the Scottish physicist Lord Kelvin (creator, among many other things, of the Kelvin temperature scale) as a step towards understanding the atomic structure of matter. He conjectured that knotted tubes could appear in stationary fluids, which he applied to explaining the composition of matter, which would be formed by loop-shaped structures (atoms) that floated in the ether. The different types of atoms were determined by variations in the geometry of these knots.

Although Kelvin's conception was erroneous, the structures he envisioned did indeed correspond to the configuration of fluid matter, and this is what the result achieved by Peralta and Salas proves mathematically: fluids in equilibrium, such as water flowing constantly through a pipe, to which a simple behavior would be attributed, may conceal donut-shaped structures twisted in a complex way. These shapes, known as knotted vortex tubes, are also related to turbulence.



Steve Koppers

The "hydrofoil" used at the experiment.

The first person to identify these structures in the 19th century was the physicist James Maxwell, but it was not until last year that precise experimental results were obtained. These complex structures in fluids were successfully reproduced in the Irvine Laboratory of the James Frank Institute at the University of Chicago, and constitute an experimental confirmation of Salas and Peralta's work. As these two researchers say; "physicists had observed these phenomena before, but we have provided solid information; we have now proved that they are mathematically possible."

In order to arrive at the sought-after solution, the authors have developed new tools adapted to the difficulties posed by the problem. "This is a very sophisticated proof and has required a detailed analysis of the equations of fluid mechanics," they say. "They are concepts we've been working on for the last 10 years." The novelty of the ideas employed in their proof has prolonged the process of verification for two years and has required the effort of leading experts in the field. The result was accepted last October by the prestigious journal "Acta Mathematica", published by the Mittag-Leffler Institute of the Swedish Royal Academy of Science. Experts consider the result as the most important in the history of fluid geometry.

The ICMAT is now the European center of mathematics with the most recognition from the European Research Council

ICMAT

Alberto Enciso, researcher at ICMAT.

The European Research Council (ERC) Starting Grants are awarded to the best Young scientists to enable them to set up their own research groups in European institutions. The calls for these grants are among the most competitive, and this year only 328 projects have been funded in the whole of Europe, 20 of them in Spain. Ramón y Cajal researcher and member of the ICMAT, Alberto Enciso, is one of the only two mathematicians to receive one of these ERC Grants, the other being Francisco Gancedo, a researcher with the University of Seville and regular collaborator to the ICMAT. They are the only two mathematicians on the Spanish list.

With the Starting Grant awarded to Alberto Enciso, the ICMAT has now received nine awards, which makes it the leading center in mathematics in Europe, ahead even of other institutions such as Oxford University. As ICMAT director, Manuel de León points out: "The high number of ERC projects is unmistakable proof of the quality of our researchers and the excellence of the Institute on the international scene."

The aim of Enciso's project is to make progress in fundamental questions in the field of geometry arising from the analysis of partial differential equations. As this mathematician explains "This is a project of an interdisciplinary nature combing analysis, geometry, dynamical systems and mathematical physics. The applications include problems in fluid mechanics, elliptic equations and geometrical analysis, Einstein's dispersive and metric equations, and spectral problems." Enciso's work has received recognition from various institutions. Just a few months ago he was awarded the 2014 Príncipe de Girona Prize for Scientific Research, and was previously chosen as the most outstanding Spanish applied mathematician by the Sociedad Española de Matemática Aplicada (SEMA – Spanish Society of Applied Mathematics) in 2013, and the best young Spanish mathematician by the Real Sociedad Matemática Española in 2011.

The ICMAT collaborates with two new didactic units

The "Mathematics of Planet Earth" didactic unit, published by the Spanish Foundation for Science and Technology (FECYT), and the iStage2 book "Smartphones in Science Teaching", presented in Berlin by the Science in Action and Science on Stage scientific dissemination platforms, are the two latest educational publications with which the ICMAT has collaborated in 2014. Both were presented last December and are aimed at the teaching profession for the purpose of aiding them in their daily work and for stimulating interest in science among their students.

The "Mathematics of Planet Earth" didactic unit is aimed at secondary school and baccalaureate teachers and can already be downloaded free of charge at the FECYT website. This material has been coordinated by the ICMAT and provides tools for including the latest developments in mathematical research in the classroom. Furthermore, this edition has been produced with the collaboration of the SM publishing company, which has drawn up an extra notebook of activities.

Subjects included in the "Mathematics of Planet Earth" are mathematics that make possible systems of geolocation, the study and prediction of earthquakes and volcanic eruptions, weather forecasting, models for the spread of epidemics, the understanding and evolution of biodiversity, cyber security, and even interplanetary travel!

"Smartphones in Science Teaching" takes a rather different approach and will make the Smartphone no longer off-limits in science classes, since it constitutes the only complement required for carrying out the ten experiments set out in the iStage2 book.

Measuring the position of the Sun and the stars using the mobile phone as an astrolabe; calculating distant points by measuring angles; comparing the harmonic frequencies of musical instruments; measuring the circumference of the Earth with the help of other students positioned at other geographical points of the globe; using the Smartphone as a colorimeter or making a noise map at school are just some of the experiences proposed in this didactic unit.

iStage2 has been produced with the collaboration of 25 teachers from 14 European countries and has been developed digitally. It is available in English and can be downloaded free of charge at the Scienceonstage website. Science in Action, which consists of scientific institutions such as the ICMAT, has participated in the development of the unit, and most of the activities translated into Spanish can be found at its own website.

BBVA Foundation grants for the development of ecological models

ICMAT researcher Kurusch Ebrahimi-Fard has obtained one of the 56 grants awarded for Researchers, Innovators and Cultural Creators in the first call issued by the BBVA Foundation. The purpose of this initiative is to provide recognition and support for highly creative and productive individuals who are half way through their academic courses. Thanks to this grant, worth 40,000 euros over a twelve-month period, Ebrahimi-Fard will enjoy greater freedom and flexibility in the management of the project "Mathematical models for ecology and industrial management (MMEGI)"; this is the only mathematics-based project chosen among the 1,664 submissions received as a result of the call.

The mathematical models developed by Ebrahimi-Fard are focused on the proper management of ecological resources. He is exploring techniques of combinatorial algebra for their subsequent application to the control of ecological systems; for example, to modify the population sizes of certain species of fish for economic reasons, and the maintenance of ecosystems.

Water temperature, the availability of food, the number of predators, harvesting, and the presence of diseases or pollutants are just some of the factors that determine population sizes, and given that some of these variables can be controlled by humans it is possible to increase or reduce the size of a population. However, the models that enable such predictions to be made require new mathematical developments, and this is what Ebrahimi-Fard is investigating in his research work. As he says: "Innovative mathematical thinking leads to new applications in many areas of science."

According to a recent report issued by the United Nations, fish make up 16.6% of the animal protein consumed by the human population worldwide, so the conservation of fish populations and the development of tools for the management of fishing resources are key factors in a sector that contributes approximately 218 billion dollars to the global GDP every year. Thus the importance of mathematical innovation when it comes to controlling populations according to environmental and industrial parameters.

The ICMAT and the CBA collaborate on the organization of an OuLiPo


CBA

Literature and mathematics came together during the first joint collaboration between the ICMAT and the CBA (Círculo de Bellas Artes). A workshop on potential literature OuLiPo, from the French "Ouvroir de Littérature Potentielle") aimed at a general public was held between December 1st-4th in the framework of the ICMAT's "Initiative for Mathematics and the Arts".

Those who attended this first workshop on literary experimentation had the opportunity to discover the creative potential to be found in applying constrained writing techniques, based mainly on arithmetic "restrictions", by creating their own work with the help of the directors of the course: mathematician and scientific popularize, Marta Macho-Stadler (University of the Basque Country), and Francisco González Fernández (University of Oviedo), doctor in philology and expert on the influence that mathematics has had and continues to have on modern and contemporary literature.

The OuLiPo group, created in 1960 by the writer Raymond Queneau and the mathematician François Le Lionnais, has for the last fifty years been compiling an endless box of literary "assembled games" that anyone can use and to which anyone can make a contribution. They lay down no rules, but rather creative procedures with no guidelines other than those formulated by the participants themselves as they play at writing mathematically. According to Marta, "this technique is a highly addictive game for those who take part in it." And in the words of the creators of this pioneering movement, an Oulipiano author "is a rat that constructs for itself the labyrinth from which it must find its own way out."

The ICMAT provided 10 grants for this activity, which in addition opened with two talks that were open to all free of charge; "Mathematics and Literature: A Round Trip" by Marta Macho-Stadler, and "Oulipo: Numbers and Letters: Origins, History and Poetics of the OuLiPo" by Francisco González.

28 European secondary school students visit the ICMAT in the framework of the Comenius educational program

Twenty-eight 14 to 16 years old secondary school students from France, Italy, Poland, Greece, Romania and Spain paid a visit to the Institute this year on November 5th as part of the European Comenius program, an educational initiative whose aim is to strengthen the European dimension in primary and secondary education. In particular, the project to which the visit to the ICMAT belongs concerns multiple intelligences and the search for alternatives for the innovatory learning of mathematics.

The Head of the Institute's Unit of Mathematical Culture, David Martín de Diego, gave the students a view of the day-to-day of a center of excellence such as the ICMAT, after which the students had the opportunity to experience at first hand the mathematical work conducted there during the "Chaos and Mathematics" workshop given by Florentino Borondo, a professor at the Autonomous University of Madrid and member of the ICMAT. This activity included demonstrations ranging from chemical reactions, electronic circuits, pendula and social networks to the well-known "six degrees of separation" theory.

Agenda

SCIENTIFIC ACTIVITIES

Workshop on Harmonic Analysis, Partial Differential Equations and Geometric Measure Theory

Dates: January 12 - 16, 2015

Stochastic Systems Simulation and Control 2015 Workshop

Dates: March 9 - 13, 2015

Research Term on Analysis and Geometry in Metric Spaces

Dates: April 1 - June 30, 2015

Place: ICMAT, Madrid (Spain)

DISSEMINATION ACTIVITIES

"Matemáticas en la Residencia"

Sylvia Nasar

Dates: April 16, 2015

"4º ESO + Empresa"

Dates: March 23, 24 and 25, 2015

Place: ICMAT

ICMAT News

Five activities in Science Week for discovering the "other mathematics"

Experimental, useful mathematics, fluids and young people were the subjects chosen by the Institute of Mathematical Sciences in the five activities organized during the Science and Technology Week that was held last November in collaboration with Alcobendas City Hall and the Beatriz Galindo Secondary School.

The talks, experiments and round-table discussions were aimed at showing secondary school and baccalaureate students the relation of mathematics with the "real world". The purpose of the main talk, given by María Pe Pereira, post-doctoral ICMAT researcher and 2012 José Rubio de Francia prize for the best young Spanish mathematician, was "What do mathematicians do and why is it useful?"

Fernando Chamizo, full professor at the Autonomous University of Madrid (UAM) and ICMAT member, and Dulcinea Raboso, pre-doctoral researcher at the Institute, showed that, in addition to calculations and logical demonstrations, experiments are essential for the statement of theories and for testing the validity of mathematical models. To that end, they performed experiments with numbers that lead to conjectures, and others of a more visual nature with Möbius strips and related to physics that included experience with everyday objects. Ramón y Cajal researcher at the UAM and ICMAT member, Ángel Castro, who in 2013 was awarded the José Rubio de Francia prize for the best young Spanish mathematician, stressed this relation between physics and mathematics, which is vital for understanding the motion of fluids.

Finally, a round-table discussion was held in which four ICMAT researchers, Diego Alonso Orán, a master grant student at the Institute; PhD students Tania Pernas and Eric Latorre, and Marina Logares, a post-doctoral researcher at the Institute, shared their experiences in mathematical research. "Activities such as this, which enable young people to have first-hand contact with professional scientists who are passionate about their work, can help to awaken a scientific vocation among students," said Pe.

The ICMAT opens up new avenues of collaboration with Chinese mathematics

Some thirty Chinese mathematicians of international renown attended the first ICMAT-China Exploratory Congress, held between November 17th and November 21st, 2014. The aim of this meeting was to open up new avenues of collaboration between the Institute and leading Chinese research centers: the Academy of Mathematics and Systems Science (AMSS); the International Center for Mathematical Research in Beijing; the Chern Institute of Mathematics, and the Tsinghua University Mathematical Sciences Center. The first three had already signed up to a preliminary collaboration agreement in the field of "mathematics and its applications" which has existed between the ICMAT and China since 2011, while the fourth signed a second agreement in 2013.

Mathematicians and institutional representatives from both countries gave a total of 40 talks in which they presented their latest research results. This joint venture seeks to establish common ground on which to develop research projects together (of a bilateral nature and with funding from the European Horizon 2020 scheme), as well as to lay the foundations for the development of training and specialization programs.

China is already a leading world force in mathematics, second only to the United States, and is committed to this basic science as an essential factor for technological development. "China has already made a multi-million dollar investment in the creation of infrastructures, training and the appointment of researchers, and will continue to do so, but it requires support for training of excellence in order to sustain its rapid growth, and this is where we can collaborate to good effect," says ICMAT director, Manuel de León. "Furthermore, we also wish to open up opportunities for young researchers, and China is a good place to do a post-doctoral stay."

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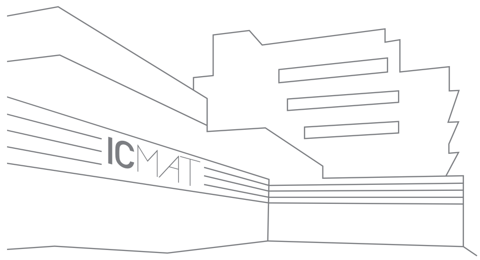

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