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2014 Chern Medal Winner – Phillip Griffiths

Century-old geometry inspired his advancements

Phillip Griffiths, a professor emeritus at the Institute for Advanced Study, says receiving the Chern Medal from the International Mathematical Union at SEOUL ICM 2014 was the "most moving experience professionally I have had." Recalling the late Chinese mathematician Shiing-Shen Chern as a "mentor and a friend," Griffiths says Chern had influenced him in many ways including how to think about mathematics.

"When I was a graduate student, my advisor said since I was interested in differential geometry, I should go to Berkeley for the summer and study under Chern because he was the master," said Griffiths. "Chern's training came especially from Elie Cartan, but he was also influenced by the Hamburg School. Cartan was a towering mathematician in the late 19th century and the first half of the 20th century. However, his work in differential geometry was primarily local. The Hamburg School was instrumental in developing global differential geometry, and Chern blended these two approaches and that was what I learned from him – not just about differential geometry but about geometry in general."

Known for his emphasis on mathematics education, Griffiths remembered Chern's classes as a delight.

Phillip Griffiths, the recipient of the Chern Medal at SEOUL ICM 2014, talks to reporters on Friday at COEX.

"He wouldn't start by saying that we were going to develop this or that general theory, but rather by saying, 'Here's an interesting problem, and we are going to see how one might go about developing the techniques to understand and at least solve a part of it.' The course began with a question and a problem and not with the goal of developing a theory. Frequently what became a general theory, such as exterior differential systems, emerged from the methods used to address the specific problem," recalled Griffiths.

Griffiths joined reporters on Friday at COEX to talk about himself and his work.

Q. In reformulating old mathematical work, did you go back and read all the papers? Doctoral students usually don't read papers more than few years old.

A lot of what I learned as a graduate student was reading classics, especially the works of French geometers such as Darboux, Monge, Picard and Poincaré. The way they thought about geometry was very elegant and very appealing. It was generally not so complicated technically, but there was a geometric idea and then a nice theorem followed by an argument and computations explaining why the result should be true. The approach was not so much what we now think of as a formal proof. More recently, there is sometimes a formal proof but not an explanation of why the result is true. I wanted to know why something should be true and then attempt to get the details in place, especially the details that come out through computations. Although Solomon Lefschetz wasn't directly my teacher at Princeton, his work influenced me greatly. It was sometimes said that he never stated a false theorem nor gave a completely correct proof.

See CHERN, Page 4

Achievements

When Phillip Griffiths was a Miller Fellow at the University of California, Berkeley, with a new Ph.D. from Princeton University in 1962, he met Shiing-Shen Chern (1911-2004), after whom the Chern Medal is named. One of the towering figures of 20th-century mathematics, Chern was a geometer of wide interests and deep insights. He also had a profound sense of responsibility for developing the culture and community of mathematics. He made a lasting impression on the young Griffiths; the two became collaborators and lifelong friends.

For more than 50 years, Griffiths has been a leader in research in several areas, most notably in algebraic geometry and differential geometry. He is best known for pioneering new approaches, for developing connections between areas that seemed unrelated and for opening new lines of research.

Robert Bryant of Duke University, the chair of Chern Medal committee for 2014, said Griffiths also has the ability, despite the formidable technical machinery used in his work, to hold fast to the intuitive heart of the problem at hand.

"Even when mathematicians discuss very abstract geometric concepts, they often speak as though there are tangible objects being represented and attach an almost physical sense to them," said Bryant. "This sort of metaphorical sense ... is frequently the hallmark of great insight. Griffiths has an amazingly strong ability to invoke those kinds of intuitions and to communicate them to others."

Griffiths sees this intuition in the work of past masters, such as the Italian school of algebraic geometry of the late 19th and early 20th century and Élie Cartan (1869-1951), and reinterprets it in modern terms. "There was a kernel of beautiful geometric ideas that ran through these classic works and once you got through the old-fashioned language and notations, an extraordinary relevance to modern problems," said Mark Green of the University of California at Los Angeles. "Griffiths is a great believer in the power of deep geometric ideas, and he encouraged his students to engage with these classic books and papers."

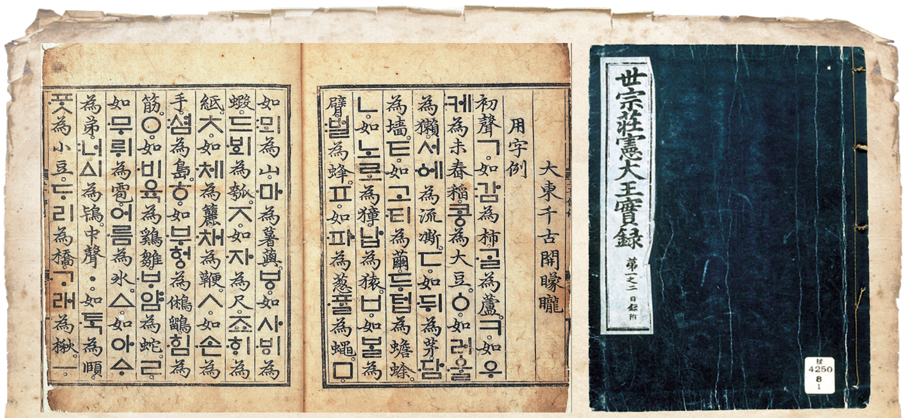
Griffiths has also been an outstanding teacher; he has had 29 Ph.D. students, many of whom have gone on to outstanding careers themselves.

Compiled by
Jun-Muk Hwang
Korea Institute for Advanced Study

Rediscovering Mathematics in Korean Cultural Heritage

Observatory, hangul show mathematical insights

Hangul, the Korean alphabet, is mathematical in form, and its consonants and vowels combine to create a wide range of permutations. Hangul was devised in 1444, during the period when the most valuable mathematics works and applications of Asian scholarship were being published. Eight centuries earlier, Cheomseongdae, an observatory built during the Silla Dynasty, also demonstrates diverse mathematical secrets in its astronomy, depictions of the seasons and architectural structures. Let's take a look at the mathematical structures and aesthetic values in Korea's cultural heritage.



Hunminjeongeum Haeryebon, explaining the underlying principles and applied examples of Hangul (left), the cover of the Annals of King Sejong, the photographic edition (right).

King Sejong, representing the 'will of Heaven' with Hunminjeongeum

Hangul is the only writing system in the world that can be accurately dated, has an actual creator, and is supported by a list of underlying principles. One character usually has one sound only and the few exceptions are regular, making the use of the alphabet simple and practical.

King Sejong applied mathematical order to create Hunminjeongeum ("The Proper Sounds for the Education of the People"), the official name of the alphabet. Hangul can be viewed as a mathematical operation which actively reflects sound variations in the forms of its characters, which are built using phonetic symbols for consonants and vowels. In that way, it is analogous to the laws of chemistry, where atoms are combined into molecules, and molecules are combined to form a wide range of materials.

Hangul has a symmetric structure involving spots, lines, and circles. For instance, the character "가"(pronounced "gah") consists of a consonant and a vowel. By rotating the vowel in "가" in steps of 90 degrees, (가, 구, 거, 고) characters can be created. This is the minimum number of characters in the least space with the most possible words made, using the principles of topology. By using letter combinations to form characters, each of one syllable, Hangul can be easily read vertically or horizontally. The alphabet is also one of the easiest in the world to optimize for keyboards.

A mathematics book presented by a noble to the Joseon king

In the "Annals of the Joseon Dynasty," it is said, "The governor of Gyeongsang Province presented the king with 100 copies of the 'Yanghwisanbeob' (Yanghui Suanfa)."

The copies of that book are designated Treasure No. 1755. The Chinese work is a seven-volume tome on mathematics with contents similar to modern algebraic equations. Shin Inson, the provincial governor, found the collection in China and obtained it with some difficulty. The contents were carved onto wooden boards for reproduction, a technique that was a forerunner of Joseon's invention later of moveable type.

In today's world, it is easy to copy a book. But then, transforming a tome into wooden plates and then to paper was a daunting task. It is a credit to the intellectual spirit of the time that a vassal presented the king with a mathematics text.

King Sejong in turn handed out these books to agencies that would use them efficiently, including the department where Joseon's greatest young scholars gathered to study mathematics with Chinese and domestic classics. The investment in the transportation and printing of the book indicates that the king fully understood the links between mathematics and the people's welfare. Governor Shin was later promoted to Minister of Defense and given the title of *daejehak*, or "great scholar."

No copies of the book exist in China; the only known copy extant today has been in Japan since the Japanese invasion of Korea in the late 16th century.

The queen's Cheomseongdae

The Cheomseongdae Observatory (National Treasure No. 31) is a good example of ancient Korea's mathematical capabilities. The observatory was built based on mathematical and numerological formulas from a publication called "Joobisangyung." It is built of 27 rings of stones, atop which is another ring carved with the Chinese character 井 that symbolizes the movement of the 28 constellations. The 12 stones forming the first level of the observatory represent the 12 months of a year. From the first level to the sixth level, the number of stones goes down in a sequence representing the number of days from the winter solstice through the first few of the two-week "seasons" traditionally used by Koreans even today.

Consisting of 366 stones in total and with base stones designating the four cardinal directions, the observatory window faces due south. At the spring and autumn equinoxes and when the sun is also due south, sunlight shines directly onto the floor of the observatory, which is level with the base of the window. (The lower part of the observatory is filled with earth.) At the winter solstice, there is no sunlight at all on the floor.

Other elements of the observatory show the dynasty's familiarity with π and with the Pythagorean theorem. Queen Seondeok reigned over Silla from 632 to 647, the second female sovereign in recorded East Asian history.

Mathematics applied: Seokguram

The city of Gyeongju still abounds with Silla's sophisticated level of mathematical creations. The Gyeongju Seokguram is National Treasure No. 24 and was built in 751 CE. It was listed as a UNESCO World Heritage Site in 1995. At the exact moment when the sun rises from the sea, a ray of sunlight is reflected off at one point on the statue of Buddha there and falls upon the rebirthed who pray before the statue. This stunning effect would not be possible without accurate measurements of height and angle.

Seokguram has ideal proportions in every space, and without the knowledge of mathematical principles such as π, this type of architecture could not have existed. The width of the Seokguram Buddha's face is 2.2 *ja* (a unit of measurement: 30.3 cm.), its chest width is 4.4 ja, the shoulder width is 6.6 ja, and the space between the knees is 8.8 ja, creating a 1:2:3:4 ratio. That base measure of 1.1 ja is one-tenth of the total height of the Buddha.

Silla was already aware of the ratio, which symbolized stability and beauty, so it applied the concept to every space in Seokbulsa for ideal proportions.

If you geometrically analyze the entirety of Seokguram, spaces are made up of horizontal-to-vertical (or vice versa) rectangles of a 1:2 ratio. The mathematical calculations that split the round ceiling accurately into 10 segments remain a mystery of mathematics in Silla. Cheonwoo Nam, a Korean physicist, says, "Silla people already knew a more accurate value of π than 3.141592. They had the skills concerning the dodecahedron and the law of sines to exactly compute the sine of 9 degrees."

Cheomseongdae (top), an observatory based on the most sophisticated mathematics and astronomy of the 7th century. The cave Seokguram (above) includes architecture demonstrating a number of mathematical principles including π (bottom).

Jang Joo Lee
(Sungkyunkwan University)

Nevanlinna Prize Winner – Subhash Khot

Computer scientist resolves mathematical enigma

When Subhash Khot, then a graduate student at Princeton University, came up with the early idea of what later would be the Unique Games Conjecture in 2001, nobody, including himself and his mentors, had any idea of the theory's implications.

Now, few would deny the impact it has made on mathematics and in particular on computational complexity theory. The International Mathematical Union awarded the Rolf Nevanlinna Prize to the Indian scholar during the opening ceremony of the International Congress of Mathematicians in Seoul on Wednesday.

Khot, an associate professor at the Courant Institute of Mathematical Sciences, is a researcher in theoretical computer science, a discipline to which he has devoted his whole academic life. He spoke on Thursday at COEX, at an interview moderated by Sang-il Oum, a professor of mathematical scineces at KAIST.

Subhash Khot, the winner of the 2014 Nevanlinna Prize, at an interview on Thursday at COEX.

Q. You won two medals at the International Math Olympiad during your high school days. Why did you choose computer science, not mathematics?

Well, it has to do with the place where I grew up, India. Maybe things are different now, but when I grew up there was little awareness of mathematics. Of course, everybody respected mathematics, but somehow it was not taught as a real career option. So it was due to the lack of awareness in some sense. You didn't have the big picture of what the choice would lead to.

How different is computer science from mathematics?

At some level, these differences are artificial. I consider theoretical computer science as real mathematics. If you have a computer science problem, the question is how fast you can solve it, or how many steps it takes to solve the problem. This aspect of efficiency and time makes computer science special. Of course, there are many questions, and I think answering these questions is mathematics. I don't see how it is any different from geometry or any other mathematical discipline. Over the last 10 years or so, the interaction between computer science and mathematics has been growing to the extent that now more people would accept my view.

There are many instances where computer scientists were able to solve problems that mathematicians cared about. The fact that computer scientists were able to solve these problems for them was important.

You are from Asia, which with Africa and Latin America lag Western countries in mathematics. The organizing committee of the SEOUL ICM 2014 is focused on developing countries. What's the best way to help them?

Raising awareness of the importance of mathematics and its potential career paths is the key. I am from a part of India where awareness was zero. By luck, I met a mathematics researcher, he knew other people, and so on. Otherwise, I probably would be following my parents' occupation, medicine.

There are many ways to raise awareness. For example, I don't know the details of this NANUM program, but I believe this is about raising awareness, and inviting mathematicians from developing countries who probably otherwise wouldn't have opportunities to see what an ICM is.

Achievements

The Rolf Nevanlinna Prize is awarded every four years for contributions in the mathematical aspects of information sciences. While contributions in mathematics are usually theorems proven, outstanding conjectures or problem statements sometimes provide enormous new insights and creative new research directions.

This year's Nevanlinna Prize winner is Subhash Khot, a professor at the Courant Institute of Mathematical Sciences, whose main contribution is the Unique Games Conjecture.

To explain this work, one must start with the fundamentals of complexity theory. Though it is not yet known whether $P \neq NP$, it is generally believed by experts that not all NP problems can be solved in polynomial time. Problems to which every NP problem can be reduced are called NP-hard, and so if $P \neq NP$, then no NP-hard problem can be solved in polynomial time.

Satisfiability (SAT) — determining the existence of assignments to satisfy a Boolean formula — is the first problem proven to be NP-hard; this is known as the Cook-Levin theorem. Thousands of problems have been shown to be NP-hard through reduction to SAT. The P vs. NP conjecture is equivalent to saying that SAT can not be answered exactly in polynomial time.

In 1992, theoretical computer scientists showed that some problems are not only difficult to solve exactly, but are also hard to approximate within some factor by using the PCP theorem. Irit Dinur and Samuel Safra showed in 2002 that unless P=NP, there is no polynomial-time algorithm to find an approximate solution of a minimum vertex cover in a graph within a factor of 1.36. (A minimum vertex cover problem is to find a minimum set of vertices in a graph to meet all edges.) But this tool is difficult to apply to some situations. There is a simple factor-2 approximation algorithm for the minimum vertex cover problem. Can this gap between 1.36 and 2 be closed?

Khot proposed that for a problem called the unique game, it is not only difficult to find an exact solution, but is also hard to approximate one. In a nutshell, the Unique Games Conjecture states that the unique game is difficult to approximate. This problem was formulated in 2002, while Khot was a graduate student at Princeton University and thinking about new ideas on the hardness of approximation. He found that many approximation problems could be reduced to that of the unique game. If the unique game problem could be shown to be hard to approximate, then so would many other problems. His advisor, Sanjeev Arora, thought this conjecture was worth writing about, but recalls, "We had no idea it would become so central." The first evidence of its importance came in 2003, when he and Oded Regev proved that if it holds, the minimum vertex cover cannot be approximated within a factor of $2-\varepsilon$ for any $\varepsilon>0$.

In 2007, Khot and his collaborators proved that if the conjecture holds, then the max-cut problem cannot be approximated within the factor of $0.878...+\varepsilon$ for any $\varepsilon>0$, thus matching the approximation ratio of the best known approximation algorithm by Goemans and Williamson. This is surprising because the Unique Games Conjecture provides an exact boundary on the best approximation ratios that can be achieved by a polynomial-time algorithm.These results might seem like an illusion; if the conjecture doesn't hold, then all the results mentioned above would collapse. However, Khot has shown some theorems to be independent of the correctness of the Unique Games Conjecture, even though motivated by it. By using insights obtained from the Unique Games Conjecture, Khot and his collaborators have also proven several theorems in other areas of mathematics, including geometry and Fourier analysis.

Compiled by
Sang-il Oum
KAIST

The NANUM program echoes vision of the CDC

The International Mathematics Union's Commission for Developing Countries and its predecessors have long worked to support mathematicians in developing countries. At every ICM, the committee has supported the attendance of 150 to 200 mathematicians who would not otherwise be able to attend. But at SEOUL ICM 2014, the committee suspended the program because the congress's organizing committee arranged to support 1,000 mathematicians from poorer countries.

Dreams and Hopes

Herbert Clemens, the policy secretary of the Committee for Developing Countries and a professor at Ohio State University, at first thought that was far too ambitious a goal. He talked with Math&Presso on Thursday at COEX about the outcome and other topics.

Q. The NANUM program echoes the vision of the CDC. When you heard about the program, what did you think of it?

I had worked at the previous two ICMs with much smaller resources for inviting about 100-200 mathematicians from developing countries where it's unthinkable that they would have the resources to come on their own. Our program was quite small, and only got into a systematic application system in 2000. When I first heard about the NANUM program, I was a bit skeptical that 1,000 mathematicians could be identified in any sort of systematic way. I was very impressed that it actually was carried out so successfully, with selection committees from each part of the developing world, each inviting hundreds of mathematicians

The CDC hosted the first MENAO Symposium at SEOUL ICM 2014. Will there be another one in Brazil in four years?

There are no plans at this moment to try something that big next time. In fact, people from other countries said that we didn't mention anything in this MENAO about partnerships with the United States and several other large developed countries. They said, "So next time, why don't you do that?" MENAO was most appropriate this time because of the NANUM program. I truly don't know if there'll be a next time.

There is the issue of cost. For example, even though I am a secretary of the CDC, I try to keep my travel and things like that to absolute minimum because a few resources go a very long way in the developing world. The amount that it would cost for me to fly from the United States to Cameroon, for example, would

Secretary for Policy Herbert Clemens of the IMU Committee for Developing Countries.

support two mathematics graduate students study for an entire year. We spent about €100,000 in direct costs on this one-day MENAO Symposium here. That's a lot of mathematics graduate students for a lot of years in many parts of the world. So one has to balance that. Our goal was that, for every euro spent on that meeting, it should generate 10 euro in support. Originally we expected or hoped that those 10 euro would come from government agencies, foundations and high-tech companies: people that use all the products of good mathematical training. It turned out so far that maybe seven or eight of those 10 euro have come in, but they've come in from the mathematical community itself. I expected a little more from the other sectors. For example, a lot of the Silicon Valley companies were invited, but they are not focusing their giving in this direction. It was really the math community itself that understood the connection of the subject to social and economic progress, so that's where we are seeing the interest. An exception was Korean companies, however. They were very generous in supporting NANUM.

How do you feel about that?

When I got my Ph.D. close to 50 years ago, I taught in South America for some years. This whole issue of the value to society of mathematics, research and graduate study, was not something that was obvious to the non-mathematical community. Of course you could say it's a question of enlightened self-interest for the mathematics community. But the understanding of the connection between mathematical development and social and economic advancement was an issue many years ago when I finished graduate school, and it's still an issue today.

Monday, August 18

09:00 - 12:30	Plenary Lectures	**Hall D1**
	09:00 - 10:00 *Integrable probability* **Alexei Borodin,** Massachusetts Institute of Technology, USA	PL-10
	10:15 - 11:15 *Random geometry on the sphere* **Jean-François Le Gall,** Université Paris-Sud, France	PL-11
	11:30 - 12:30 *Minimal surfaces - variational theory and applications* **Fernando Codá Marques,** IMPA, Brazil	PL-12
12:30 - 14:00	Lunch	
14:00 - 15:00	Lecture by Mark Green on the work of the Chern Prize Winner, Phillip Griffiths	**Hall D1**
15:00 - 18:00	Invited Section Lectures	
	1. Logic and Foundations	317ABC
	4. Algebraic and Complex Geometry *	307ABC
	5. Geometry	Hall E1-4
	6. Topology *	300
	7. Lie Theory and Generalizations *	308ABC
	8. Analysis and its Applications	Hall E5-6
	12. Probability and Statistics *	318ABC
	13. Combinatorics *	327ABC
	15. Numerical Analysis and Scientific Computing	301AB
	* ends at 18:45	
15:00 - 16:30	Invited ICM Panel Discussion 1: Why STEM?	**402**
16:30 - 18:00	Invited ICM Panel Discussion 2: How should we teach better?	**402**
15:00 - 18:00	Short Communications	
	2. Algebra	309
	3. Number Theory	310AB
	5. Geometry	316
	6. Topology	312
	8. Analysis and its Applications	320AB
	9. Dynamical Systems and Ordinary Differential Equations *	324AB
	10. Partial Differential Equations	319
	11. Mathematical Physics	323
	12. Probability and Statistics	322
	13. Combinatorics	321AB
	14. Mathematical Aspects of Computer Science	326
	15. Numerical Analysis and Scientific Computing	325AB
	16. Control Theory and Optimization	311AB
	17. Mathematics in Science and Technology *	313
	* ends at 19:00	
12:00 - 18:00	Poster Sessions	**C1**
	13. Combinatorics	
	14. Mathematical Aspects of Computer Science	
	15. Numerical Analysis and Scientific Computing	
	19. History of Mathematics	
18:00 - 19:30	IMU Panel Discussion 1: Mathematical Massive Open Online Courses	**402**
19:30 - 21:30	U.S. Reception	**101**

The London Mathematical Society will host a society meeting open to all ICM participants on Tuesday, Aug. 19, from 17:00 to 18.00 in the COEX Grand Ballroom 101. The speaker will be Jean-Pierre Bourguignon (ERC/IHES), whose lecture is titled "The Life of a Mathematician May Have Several Sides."

CHERN, from Page 1

Did you have difficulties in reading these old texts?

Algebraic geometry, for example, is one of my main interests. To me, the subject that I enjoyed the most as a student was complex function theory, which is elegant and very deep. The way that Picard approached algebraic geometry was through complex function theory. He and his contemporaries didn't speak about algebraic varieties; they spoke about algebraic functions and their integrals. The books that Picard and Simart wrote were about what we now think of algebraic curves and algebraic surfaces, but they thought of an algebraic curve as given by multi-valued, algebraic function. Of course they knew very well what a geometric object was; it's just that they studied it using complex analysis and that was the way I learned to think about it.

Later, I found you had to use commutative and homological algebra, a discovery that was not easy for me, as the connection to geometry isn't as intuitive as through complex analysis.

Would you recommend the same approach, going back to the classics, to students now?

Modern books would be better now, because there are excellent sources with new ones appearing frequently. There are some that are more geometric, some that are more algebraic and some that take an analytic approach. If you are going to work on this subject you need to study the available books because that's where you can learn the techniques.

You'll never learn Grothendiek's version of duality from the classics. Earlier scholars would understand the explanation and would see why the result is interesting and why it might be true. But to actually work in the subject you need tools that you'll find in the many good books that are now out there. I do think, though, that students should sometimes go back and look at the classics to get a sense of how the subject evolved historically.