I. Main duties of the research unit in 2018

The fundamental goal of the Alfréd Rényi Institute of Mathematics is to pursue research of high international standing in pure mathematics. The Institute is an important center of mathematics internationally. Fellows of the Institute received several Hungarian and international recognitions in 2018. One researcher was elected member of the Academia Europaea. Another received the Széchenyi Prize. The highest award of the János Bolyai Mathematical Society, the Tibor Szele memorial medal, was given to a member of the Institute this year, another member got an Academy Prize, while an emeritus research professor was decorated with the Officer’s Cross of the Order of Merit of Hungary. Several younger researchers received various honors: the Erdős Prize and the Turán Prize from the Mathematics Section of the Hungarian Academy of Sciences, a Young Researcher Prize of the Academy, two others obtained the Grünwald medal from the Bolyai Society. It is an outstanding international recognition that four members of the Institute got an invitation to speak at the International Congress of Mathematicians in 2018. Researchers of the Institute continued to successfully apply for grants from the European Research Council. In 2018 the awarding of a Synergy grant with high financial support was announced. In 2018 four research groups in the Institute were funded by the ERC. A consortium led by the Institute launched research in the mathematical foundations of artificial intelligence, funded by the National Research, Development, and Innovation Office.

Researchers of the Institute published 168 scientific papers during the year. The most important results have appeared in the most significant international mathematical periodicals (Advances in Mathematics, Journal of the European Mathematical Society, Annals of Probability, Journal für die reine und angewandte Mathematik, etc.). A book was also published this year.

The scientific tasks of the Institute concentrate on fundamental research. However, significant efforts were devoted to some topics in applied mathematics as well. The main applied areas investigated in the Institute are artificial intelligence, the theory of large networks, cryptography, financial mathematics, as well as bioinformatics. Mathematical statistics has also been applied in several related areas (e.g., in astronomy and in environmental science).

The Institute is organized in the framework of 8 scientific departments, 6 Momentum research groups, one ERC research group, and the research group on mathematics education. The research topics of the Institute are continuously adjusted to the most recent developments in mathematics.
II. Outstanding research and other results in 2018

a) Outstanding research results

Low Dimensional Topology Momentum Research Group

They continued their study of invariants of knots, and extended earlier techniques. They obtained new results by associating to a knot in the 3-sphere its double branched cover, and considering the invariants of this object. The involution provided by the deck transformation results in a new array of invariants, motivated by work on involutive Heegaard Floer homology, and they hope that these new ideas can be fruitfully used in studying pairs of knots which differ by mutation. They applied properties of Heegaard Floer homology to questions about the three-dimensional rational homology cobordism group, such as when an element has infinite order or when a collection of elements is linearly independent. They have obtained a complete classification of which positive integral surgeries on positive torus knots bound rational homology balls.

In studying moduli spaces of irregular Higgs bundles they clarified the case when the corresponding Hitchin fibration has a unique singular fiber. In this case novel constructions of various elliptic fibrations with specific singular fibers have been found. Using similar methods, they defined convenient coordinates on an open subset of the moduli space of logarithmic connections.

In a further project they clarified transversality properties of motivic Chern classes. This allows one to calculate the motivic Chern classes of certain (Schubert type) subvarieties of GIT quotients.

Automorphic Forms Momentum Research Group

Members of the research group gave a nearly optimal upper bound – in the case of a certain arithmetic hyperbolic surface and a 3-manifold – for the square mean of the error term in the prime geodesic theorem. In another direction, they studied the value distribution of automorphic forms and automorphic \( L \)-functions, which arises naturally in number theoretic investigations. They initiated the study of nonholomorphic Siegel modular forms of degree 2 with the aim of bounding their Whittaker functions and global maxima. They started to work out a variant of the Selberg pretrace formula, which may be capable of bounding non-spherical Hecke-Maass cusps forms on \( GL(2) \) over an arbitrary number field. They have also succeeded in verifying certain subconvex bounds of the corresponding automorphic \( L \)-functions by a better understanding of the Michel-Venkatesh method. In a third direction, they put multivariable \((\varphi, \Gamma)\)-modules into a new context using Scholze's perfectoid spaces. The result is an equivalence of categories between \( p \)-adic representations of products of local Galois groups and multivariable \((\varphi, \Gamma)\)-modules.
Groups and Graphs Momentum Research Group

They investigated the cost and weak containment for point processes over locally compact groups. They showed that the cost vanishes for products and that the Poisson process has maximal cost among free point processes.

They studied the growth of mod-$p$ homology in sequences of locally symmetric spaces, proving that this invariant vanishes for higher rank simple Lie groups for any proper sequence. They studied the question of torsion growth in higher homology groups of $SL(n,\mathbb{Z})$ and other lattices in Lie groups.

They solved a problem of Bhargava on optimally equidistributed sequences in rings of integers of number fields. They finished and wrote up their results on the local convergence of eigenvectors for locally symmetric spaces. They finished writing up the results on the uniform limit multiplicity theorems for noncompact lattices in Lie groups. The Benjamini-Schramm convergence of the largest connected component of the critical Erdős-Rényi graph was also examined.

They finalized and submitted for publication their results on maximal size matchings. In this work they verified some of the observations of Liu, Slotine and Barabási from 2011. They strengthened their result on the concentration of the matching ratio of random graphs given by the random configuration model.

A well-known conjecture of Babai states that $\text{diam}(G)$ (the maximal diameter of a connected Cayley graph of $G$) is bounded by a polynomial of the logarithm of the size of $G$ in case $G$ is a non-abelian finite simple group. For finite simple groups of Lie type the best available bound for $\text{diam}(G)$ was due to Biswas and Yang. The group improved this bound considerably. Furthermore, the same new bound was shown to hold even for $\text{diam}(H)$ where $H$ is an arbitrary subgroup of $G$. A structure theorem for finite completely reducible linear groups was also given.

Large Networks Momentum Research Group

In the topic of large networks, graph limits and random structures they put down the foundations of a unified graph limit theory which also works for graphs of intermediate density. This theory extends to more general operators, and using it they could prove new results on the eigenvectors of random matrices.

In higher order Fourier analysis the group continued the nilspace approach and they solved various open problems in ergodic theory. They proved inverse theorems for the Gowers norms on compact abelian groups and on nilmanifolds.

In the mathematical foundations of artificial intelligence they worked on a system to classify chronic wounds. They also further developed their algorithm to reconstruct incomplete data sets.
Financial Mathematics Momentum Research Group

The research group studied the ergodic behaviour of Markov chains in random environments. They proved the stochastic stability for such systems in cases which are not covered by existing literature (e.g. discretized diffusions), and established an ergodic theorem. These processes subsume models of queuing systems where the service time is stationary, as well as popular financial models such as the fractional stochastic volatility model. They have improved the known convergence rate estimates for the stochastic gradient Langevin method in the case of log concave target densities, and verified that the obtained rates are essentially optimal.

The value of information for creating arbitrage opportunities for investors has been studied and characterizations have been obtained. Utility maximization under transaction costs was treated in the setting of model uncertainty and the existence of optimizers has been established in the case where investors prepare for the worst-case scenario.

Random Spectra Momentum Research Group

They have introduced the so-called Directed Landscape, the scaling limit of last passage percolation. This object is the central one in the important KPZ universality class. Among other things, this construction shows that the shape of the longest increasing subsequence in a random permutation converges to a random function whose graph has Hausdorff dimension 4/3.

They have given mathematical proofs for heuristic results about the controllability of large random networks, published earlier by other researchers in the journal “Nature”. Their proofs are based on graph limit theory and well-known techniques about converging graph parameters.

For an arbitrary Cayley graph with one end they were able to construct an invariant random one-ended spanning tree. This is a strengthening of a widely used earlier result that showed the existence of a spanning tree with one or two ends.

Shearer’s inequality bounds the sum of joint entropies of discrete random variables in terms of the total joint entropy. They gave another lower bound for the same sum in terms of the individual entropies when the variables are functions of independent random seeds. The proof method yields inequalities for other measures of randomness, including covariance.

Noise-sensitivity Everywhere ERC Research Group

In real-life applications of most scientific fields, it is a common phenomenon that a function of many variables needs to be computed, but the input is noisy, and it can only be hoped that the noise does not influence the result to a great extent. However, some functions that are crucial for applications are sensitive to very little noise: a tiny perturbation in the input makes the result totally unpredictable.

An important question related to noise sensitivity is the following: if we know a vanishing proportion of the input bits for a function in which each input bit plays the same or very similar role, can we reconstruct the output of the function? The group has proved that, for random input bits that are completely independent from each other, the answer is negative: there is no sparse reconstruction. Presently, the case of dependent random input bits is being investigated on the usual models of statistical physics.

The group solved an almost 20-year old conjecture of Gaboriau on Kazhdan groups (important objects in group theory, dynamical systems and number theory), using percolation theory (part of statistical physics). The group has disproved a conjecture of Kalai by constructing functions that are noise stable despite almost always having an input variable whose change would significantly change the output.
Didactics Research Group

In the framework of the Content Pedagogy Research Program of the Hungarian Academy of Sciences the research group investigated the possibilities of nurturing outstanding talents, worked on the modernization of curriculums for special mathematics high school classes. They continued to teach a new experimental program for weaker students.

They organized and taught on more than 20 weekends in mathematics camps for talented students. They were the main organizers of two one-week summer math camps, where the most talented Hungarian students participated, and participated on the special mathematics class section of the main conference for Hungarian mathematics teachers.

Department of Algebra

It is well-known that results on zero-sum sequences over a finitely generated abelian group can be translated to statements on generators of rings of invariants of the dual group. Now the direction of the transfer of information between zero-sum theory and invariant theory was reversed, and bounds on the catenary degree of a block monoid were derived from a known degree bound for syzygies of rings of invariants. For this purpose, the notion of weighted catenary degree was introduced. Along the way it was shown how a presentation by generators and relations of the ring of invariants of an abelian group acting linearly on a finite dimensional vector space can be obtained from a presentation of the ring of invariants for the corresponding multiplicity free representation. A Gröbner basis version of this result was also developed.

A noncommutative version of the classical Hilbert-Nagata Theorem asserts that the algebra of invariants of a linearly reductive group acting on a Lie nilpotent relatively free algebra is finitely generated. This result was made constructive this year. It was shown that there is a canonical way to associate another representation to the representation inducing the action on the relatively free algebra, such that once the generators of the corresponding commutative ring of invariants are given, one can write down explicit generators for the sub algebra of invariants in the relatively free algebra. In the corresponding classical theory Weyl’s Theorem on polarizations plays an essential role. This statement has been extended to the present context. They proved a lattice theoretic criterion for the existence of a faithful representation of a finite group.

A classification of irreducible representations of both the Leavitt and the Cohn path algebras is established for arbitrary directed graphs. Their presentations are also given; therefore a class of finitely presented irreducible representations has been determined. Furthermore, both their endomorphism rings and associated primitive ideals are computed.

The cohomology ring structure of generalized real flag manifolds was studied. In particular, the incidence coefficients of the Schubert cells in the Vassiliev complex of real flag manifolds were determined, extending a theorem of Kocherlakota. A topological extension of the Borel-Haefliger theorems to $U(1)$- and $Sp(1)$-actions were given and applied to determine the cohomology ring of the even real flag manifolds and the quaternionic and octonionic flag manifolds. Furthermore, a geometric description of the coefficients of equivariant formal group laws was investigated. In particular, the coefficients were expressed in terms of Milnor hypersurfaces.
Department of Algebraic Geometry and Differential Topology

The members of the department continued the ongoing research in the theme of the Ghys conjecture: they studied the finite subgroups of the homeomorphism groups of topological manifolds.

They studied the “L” invariant, introduced by Ekholm (as an important ingredient in formulae valid for the Smale invariant). They provided a direct proof for the equivalence of the different definitions of $L$ available in the literature, and also proved a formula which expresses the $L$ invariant of the immersion associated with a finitely determined complex germ. They found the relation between $L$ and the vertical indices, which were used for the gluing functions of the boundary of the Milnor fiber.

They have generalized Yves André's theory of solution algebras and solution fields to arbitrary characteristic and to difference equations. The theory has important applications to the transcendence theory of special values of Mahler functions.

The members of the department developed a new theory regarding the Abel map associated to a normal surface singularity, and finished the first three manuscripts of a planned series of articles on this topic.

Department of Analysis

New results were obtained in connection with the well-known problem on uniform approximation of multivariate continuous functions by homogeneous polynomials on the boundary of symmetric star-like domains. It was verified that the boundary of each symmetric star like domain contains an exceptional set such that only continuous functions vanishing on this set admit approximation by homogeneous polynomials. The exceptional set of the intersection of star like domains was described. New convex and star-like domains were found for which the above Weierstrass type approximation holds in the case of homogeneous polynomials.

Nearly sharp Turán-Erdős type inequalities were verified in a certain norm on the boundary of general convex domains. More precisely, it was shown that for the derivatives of complex polynomials of degree $n$ with all zeros in a given convex domain $K$ a simple inequality holds on the boundary of the domain.

Bernstein-Markov type upper bounds were given for weighted derivatives of univariate algebraic polynomials in case of nonsymmetric weights. Convergence properties of a new Hermite-Fejér type linear operator were studied on the half axis.

New interesting relations were found between the slope and Ljapunov exponent of the isentropic curves of a given 2-parameter family of curves. Using this result, an effective method of establishing the Ljapunov exponent for the given family of functions was given. In connection with the Haight-Weizsäcker type problem and Hincsin conjecture, new results were given concerning the convergence of series of the shifts of nonnegative functions.

An abstract method for operator extension was found, which allows the introduction of operations of parallel summation and parallel subtraction in settings different from Hilbert space operators. These operations are important for the description of mappings which preserve absolute continuity and singularity. It was shown that the structure of mappings can be rather complicated even when the Waserstein space is isometrically rigid.

It was shown that the arc length of almost every (prevalently many) homeomorphisms of $[0,1]$ equals 2.
Department of Discrete Mathematics

They determined the domination number of the containment bipartite graph of the $k$ element and $l$ element subsets of an $n$ element set.

They determined the Turán number of a wide class of graphs and hypergraphs, which may lead to the proof of the Erdős-Sós-Kalai conjecture.

They studied the maximal number of vertices of the $n$ dimensional hypercube a ball of radius $r$ can contain. The full solution of the problem – especially in the case of 30-40 dimensions – would imply important statistical applications.

They solved the conjecture of Monod and Rordam about amenable, purely infinite actions. They worked out the qualitative limit theory of graphs, described the basic properties of the weak equivalence theory of continuous actions.

The members of the department continued the research on swap Markov chains defined on the realizations of graph degree sequences. They proved the fast mixing of the swap Markov chain on a large part of degree sequences of bipartite graphs.

They determined sufficient conditions for the following: if we partition the edge set of the complete graph into edge sets of isomorph graphs then we can orient them isomorphically so that their union is the transitive tournament.

Studying Ramsey-type questions, they determined the minimum number of colors that we can color the edges of the complete graph of $n$ vertices avoiding monochromatic paths of four vertices, and in any four vertices one of the four vertex paths should rainbow. Based on the connection between the Ramsey number and the Shannon capacity of a graph, they proved a lower bound on the Shannon capacity of the 4-chromatic Myczielski graph. Investigating the structural properties of the 4-chromatic Schrijver graph, they characterized the vertex color critical edges of them, i.e. the edges whose deletion decreases the chromatic number.

They proved sharp estimates on the number of hyperedges in 3-uniform hypergraphs not containing any induced Berge 4-cycle.

Investigating the tilings of the plane with non-homothetic triangles, they answered the question of Nandakumar by proving that such a tiling is impossible using triangles of equal area and circumference.

They determined the order of magnitude of the maximum number of paths such that the union of any two paths contains a 4-cycle. This solves a problem of Cohen, Fachini and Körner and the method improves the earlier results concerning longer even cycles.

They found a sub-exponential algorithm to find independent sets in graphs not containing an induced path of length $k$, where $k$ is fixed but can be arbitrarily large.

They proved the missing cases of the hypergraph version of the Erdős-Gallai theorem on cycles. They proved sharp theorems on the existence of cycles avoiding a given vertex but containing other prescribed vertices in claw-free graphs. Several theorems were proved on the generalized Turán number of a graph not containing an even cycle of given length. They asymptotically determined the maximum size of $r$-uniform connected hypergraphs not containing any path of a given length. They determined the Turán number of some ordered cycles in ordered graphs. They improved the estimates on the pebbling number of the square grid and estimated the pebbling number of graphs with given diameter.

They determined that given $n$ points in the plane in general position, what is the maximum number of triples constituting an epsilon-regular triangle.
Department of Geometry

The members of the department proved that for a connected Riemannian manifold the following properties are equivalent: (1) the manifold is locally harmonic, (2) the volume of a tube of small radius about a regular arc depends only on the length of the arc and the radius, and (2’) the volume of a tube of small radius about a geodesic segment depends only on the length of the geodesic and the radius. It was obtained as a corollary that if the dimension of the manifold is at least 4, then the above properties are also equivalent to the following two conditions: (3) the total scalar curvature of a tube of small radius about a regular arc depends only on the length of the arc and the radius, and (3’) the total scalar curvature of a tube of small radius about a geodesic segment depends only on the length of the geodesic and the radius.

They obtained new results for semialgebraic graphs. In this special case they managed to solve a 100-year old problem of Issai Schur, and they got improved bounds for some Ramsey numbers.

It was shown that any \( n \) points in the plane determine almost \( n \) pairwise crossing segments. This improves a 25-year old bound of root \( n \).

With linear algebraic methods they further improved the bounds on the upper density of planar point sets that do not determine a unit distance. They investigated the limit shape of convex polygons determined by random planar point sets with normal distribution.

The members of the department obtained improved upper bounds on the area of a part of a convex disc that can be covered by a given number of translates of another, centrally symmetric convex disc.

They investigated projective metric spaces and it turned out that in the important cases the ellipse and the hyperbola are quadratic curves only in the classical spaces, and the metric conditions for triangles hold only in the classical spaces. They showed that projective metric spaces are symmetric if they are symmetric in finitely many points.

They investigated coupled expanding circle maps in the thermodynamic limit, and proved that for weak interaction the system state converges to a Lebesgue absolutely continuous invariant measure, while for strong coupling convergence to a point mass can occur. They also proved that for four coupled maps, in case of sufficiently strong coupling, there are several invariant ergodic invariant measures.

In spaces of constant curvature they characterized the pairs of sufficiently nice closed convex sets with interior points, for which the following implication holds. If some of their congruent copies have a compact intersection, then this intersection is centrally symmetric. For the compact case the two sets are congruent balls.

Department of Set Theory, Logic and Topology

Improving an earlier deep result of theirs, they proved that if in a regular space \( X \) every open set is uncountable and \( X \) is (countable extent)-generated then \( X \) is omega-resolvable. Furthermore, they proved the surprising fact that any connectedness preserving map defined on a non-trivial product of connected \( T_1 \) spaces is automatically continuous.

They proved that wide classes of cardinalities can be sequences of cardinalities of the Cantor-Bendixson levels of locally compact scattered spaces. They showed that Väänänen's generalized Cantor-Bendixson theorem is equivalent to the kappa-perfect set property for closed sets and is therefore equiconsistent to the existence of an inaccessible cardinal.
They solved the most important problem of the theory of Haar meager sets: they proved the existence of a Haar meager but not strongly Haar meager set.

They exhibited infinitely many finite non-representable loop-polygroupoids. Using this result, they proved that there are continuum many varieties between the variety of coset-relation algebras and that of relation algebras. They proved that within a discriminator variety, dense extensions of members of a subvariety do not variety-generate new maximal algebras. By the use of this, they proved that the relation algebras obtained from the previously constructed non-representable finite polygroupoids are all outside of the variety generated by the completions of representable relation algebras. This answers an open problem of Maddux.

From a small slice of the new axiom system of general relativity, they proved that there are no observers moving faster than light. They proved that two commonly used versions of definitions of local property of general relativistic spacetimes do not coincide.

Department of Number Theory

They worked on adapting a recent large prime gap result to primes in arithmetic progressions. They investigated binary problems for primes (Goldbach Conjecture, Twin Prime Conjecture) and they investigated problems in connection with the estimate of the size of the exceptional set in Goldbach's problem. They studied the Prime Geodesic Theorem belonging to the full modular group. The problem is to find an estimate on the number (more precisely on a weighted sum) of hyperbolic conjugacy classes having norm less than a given number.

They studied uncertainty inequalities for finite abelian groups. Such an inequality gives an estimate for the sum of the number of zeros of a nonidentically 0 function and its Fourier transform. In the case when the order of the group is a prime number ($p$), a completely satisfactory answer is known. However, for the direct product of the group of $p$ elements with itself, the problem is open. They proved several results for this group, essentially improving earlier results in certain cases.

They gave lower and upper estimates for the greatest common divisors of the values of two polynomials with integer coefficients. These two estimates agree asymptotically.

They continued the examination of Kloosterman sums over higher dimensional matrix groups and proved bounds on sums over $GL_n$ (for any $n$) by elementary methods. They tried to locate the purity locus of these sums and computed the dimension of $l$-adic cohomology groups.

They studied the uniform distribution of random walks and orbits of dynamical systems. The convergence speed of a family of discrete random walks on the circle to the uniform distribution was found up to a constant factor. The best-known estimates of the discrepancy of the same random walks were improved. They proved that there are no irregularities of distribution phenomena for continuous curves.

They proved the equivalence of the Riemann hypothesis to an average form of the Goldbach conjecture with remainder term.

The members of the department disproved a conjecture of Erdős and Szemerédi about sums and products along the edges of a graph.

They wrote a survey on the Kakeya conjecture, and its analogues and equivalent forms expressed in terms of additive-combinatorial number theory.

They found new results for Radon-partitions of point sets in general position.
Non-central limit theorems for non-linear functionals of vector valued stationary Gaussian fields have been obtained. To this end, a theory describing non-linear functionals of vector valued stationary random fields has been worked out. For Gibbs samplers on finite product spaces, under Dobrushin's uniqueness condition, an estimate was derived for the logarithmic Sobolev constant which improves on earlier results. The proof is based on the theorem of strong entropy contraction.

A quenched central limit theorem for random walks in divergence-free random drift-field under the notable “$H(-1)$” condition has been proved, relying on a non-trivial extension of a classical result of John Nash on moment bounds for diffusion processes. Superdiffusive bounds for random walks on the randomized Manhattan lattice have been obtained. An invariance principle for particle trajectories in the random Lorentz gas has been shown. This has been the first significant progress in more than 30 years for this notoriously difficult problem of classical non-equilibrium statistical physics.

Following up on earlier results concerning consensus algorithms on networks using communication with packet loss they have greatly generalized their findings, now applying it to random matrix products, and also identifying the speed of convergence. In parallel projects they analyzed the mixing rate of random walks of different cases when a graph is slightly perturbed, leading to much more efficient mixing. There is ongoing work on improving the bounds for the independence ratio of 3-regular random graphs with a constructive, algorithmic approach.

**Applied research**

The research carried out at the Rényi Institute has focused on exploratory (theoretical) research. On the applied research projects the research groups of the previous years have continued their work in cryptography, bioinformatics and other mathematical methods applied in life sciences, e.g., in neural networks.

The Deep Learning Research Group, operating partly in the framework of the *Large Networks Momentum/ERC Research Group* – beyond the theoretical results detailed in the report of the research group – has reached the following main results:

- In the field of generative modeling, they investigated the latent representations emerging in variational autoencoder (VAE) models. They have identified in several ways the weaknesses of the deep variational method, which manifest most in the system's inability to utilize the available capacity for information transmission. They worked on various possible improvements. There are initial and promising results, but no breakthrough has been achieved yet.

- The gradient-based regularization method developed by the team in 2017 was further studied and successfully applied in training with more complex data sets. The method is well-tested in case of classification problems where there is very little training data available.

- In the second half of the year, they started to work on the application of machine learning in the field of automatic theorem proving. The primary goal of their project is to train a system that guides automatic theorem provers, thereby drastically reducing the search space. Learning is partly based on human proofs and partly on the system's own exploration. These studies are still at an early stage, but they already demonstrated in the case of simple arithmetic problems, that once a proof has been found, the system can generalize and find proofs of similarly structured problems.
The team led the work to create the scientific and technical material for the “Exploring the Mathematical Foundations of Artificial Intelligence” grant of the National Excellence Programme (2018-1.2.1-NKP-2018-00008). Since they won the grant, which started in September, they have organized a one-day (NKP Kickoff Workshop) and a one-week (Budapest Workshop on Reasoning and Machine Learning) workshop.

The team has successfully applied for NVIDIA's GPU Grant Program and attained a total of 1.5M HUF hardware donation.

The Cryptology Research Group of the Rényi Institute mainly focused on further generalizations of previous results on secret sharing in 2018. A general bound for the complexity of graph-based secret sharing schemes is the so-called Stinson bound. They determined the smallest family of graphs where this bound is sharp. This asymptotic result was extended for the worst case and the average case as well. They determined the complexity of graphs with many leaves, an interesting family of graphs. Furthermore, they examined the complexities of unicycle graphs and planar graphs. Furthermore, they worked on optimization algorithms, especially on vertex numeration. It is about vertex enumeration, an important tool in finding new constraints, for example, for optimal size of secret sharing schemes. The described method extends the best presently available algorithms to significantly higher dimensions. Acknowledging their expertise in secret sharing, one group member has been appointed as a PhD examiner at the National University of Bogota, Colombia.

The researchers of the Bioinformatics Research Group of the Rényi Institute conducted collaborations with Davidson College and published a paper on approximating the number of most parsimonious Single Cut and Join genome rearrangement scenarios on a star tree. The results have been published in the journal Advances in Applied Mathematics.

Career advancement of researchers

In 2018 four young researchers received the PhD degree, another one obtained a nostrification of his foreign degree. At the end of the year 7 members of the Academy, 29 doctors of HAS, 52 researchers with PhD or CSc worked at the Institute. 33 researchers have not yet obtained a degree. Besides the regular employees 20 emeritus research professors (9 academicians, 11 with DSc title) take part in the scientific work of the Institute. The Institute puts great emphasis on involving young talents – working towards their PhD or just obtaining the degree – into the research work of the Institute. In 2018 a further 4 young researchers were employed in new positions offered by the Academy. Altogether 22 young researchers worked in the Institute in 2018. The Institute has an agreement with the Central European University (CEU). In this framework 28 doctoral students were supervised by members of the Institute.
b) Science and society

Unfortunately, most of the research topics in pure mathematics are not suitable for discussions for the general public. On the other hand, the international success of the researchers has underlined the importance of the research conducted in the Institute even in the media.

The researchers of the Institute play an important role in popularizing mathematics, giving lectures for high school and university students. The Institute regularly organizes an open house during the Festival of Hungarian Science, where high school students and their teachers can get information about the mathematics profession. A young fellow gave several talks on popularizing mathematics and took part in the FameLab science communication competition – he was the only mathematician among the participants.

Members of the Institute take part in fostering mathematical talents. In 2018 they have organized several mathematical camps and other events for students interested in the subject. The Institute plays a role in giving scientific background for the teachers of specialized mathematics classes in high schools.

III. A presentation of national and international R&D relations in 2018

National relations

A consortium led by the Institute in 2018 applied to “The mathematical foundation of artificial intelligence” call of the National Research, Development and Innovation Office under the framework of the National Excellence Programme. During the formation of the consortium, and later, during the preparation of the application and start of the joint work, the Institute has developed fruitful cooperation with the members of the consortium: with the research groups of artificial intelligence/neural networks of Institute for Computer Science and Control of the Hungarian Academy of Sciences, Mathematical Institute of the Faculty of Sciences at Eötvös University, Faculty of Informatics and Sciences of the University of Szeged, and the Faculty of Information Technology and Bionics of the Péter Pázmány Catholic University.

Within this context, the Institute is a founding member of Artificial Intelligence Platform, founded in fall 2018, which is intended to connect the national development and application platforms of the topic with strong governmental support.

Researchers of the Institute teach part time at many universities both in Budapest and in other cities (Eötvös University, Budapest University of Technology, Péter Pázmány Catholic University, University of Szeged, Pannon University, etc.). They play an important role in doctoral schools and in Masters programs. 12 fellows of the Institute are core members of doctoral schools in various universities, and they supervise 53 doctoral students. Especially important is the collaboration between the Institute and the Department of Mathematics and its Applications of the Central European University. The lecturers and the supervisors of the Masters and doctoral programs of CEU mainly belong to the Institute, including the department chair and the leader of the doctoral program. Also, a large number of lecturers of the Budapest Semesters in Mathematics English language study abroad program for North American students belong to the Institute. This program helps to bring the fame of Hungarian mathematics to American universities, and serves as a role model for other international programs. For the Institute the close contact with the new generation of mathematicians is of foremost importance. In this spirit 57 members of the Institute (47 percent of all researchers) were active in teaching at universities in 2018; that included supervising 4 student research projects, 21 BSc and 15 MSc theses.
As part of the renewal program of the Academy, the Institute restarted its guest researcher program, which enables university professors and lecturers to spend one or two semesters in the Institute freed from their teaching duties. As part of this program, four people from Eötvös University and two from the University of Szeged joined the research teams of the Institute in 2018.

The weekly seminars in the Institute are attended regularly by researchers from other institutions, among them some people from universities outside Budapest as well. This way these seminars influence the whole mathematical scene in Hungary.

Members of the Rényi Institute traditionally take part in various Hungarian scientific committees well over proportion. In particular, the Section of Mathematics of the Hungarian Academy of Sciences (MTA) and its committees, the Hungarian Research Fund (NKFIH), and the János Bolyai Mathematical Society (BJMT) can be mentioned. The chairman of the Mathematics Committee of the MTA, one of the vice-chairmen of the Bioinformatics Committee of the MTA, the president and the deputy secretary general of the BJMT, the chairman of the Scientific Section of the BJMT, and the vice-chairman of the Applied Mathematics Section of the BJMT are all researchers of the MTA Rényi Institute.

International relations
The researchers of the Institute have very extensive international relations. Among the coauthors of the members of the Institute one finds mainly foreign mathematicians. Joint projects and jointly organized conferences are also typical.

In 2018 thirty-one people from the Institute were involved in organizing international conferences, some of them even on several occasions. In 2018 the Institute gained the right to organize two conferences belonging to international series (10th FoIKS and 34th SoCG). There were six workshops held in the Institute and researchers from the Institute played a crucial role in organizing the Building Bridges II conference.

The visits in the framework of the bilateral exchange programs between the Hungarian Academy of Sciences and its partner institutions successfully contributed to the cooperation with foreign partners. With the help of these programs fruitful joint research projects, useful exchange of information, and conference participations were made possible.

Researchers of the Institute took part in altogether 12 international scientific committees. Names of the Institute’s researchers can be found 172 times on the list of editorial boards of various international journals. In 2018 the researchers gave altogether 322 talks at international meetings, and many of these were given as an invited or plenary lectures.

In 2018 nine researchers spent more than half a year abroad at the following institutions: University of Chicago (USA), City University of New York (USA), Auburn University (USA), École Polytechnique Fédérale de Lausanne (Switzerland), Lancaster University (England), University of Toronto (Canada), and Universität Hamburg (Germany). Financed by the ERC and Momentum grants or from other sources, 17 foreign researchers worked in the Institute for a longer period, and a further 11 foreign researchers spent 1–7 months in the Institute (altogether that makes up 29 months). They came from the Czech Republic, Italy, Poland, Slovenia, Vietnam, Australia, Egypt, USA, Iran, China, Georgia, Brazil, Turkey, and Finland. The number of foreign visitors of the Institute – not counting the conference participants – was 87 in 2018.
IV. Brief summary of national and international research proposals, winning in 2018

National grants

The Rényi Institute, similar to the practices of the previous years, successfully participated in the national NKFIH researcher-initiated project proposals. In 2018 a further 4 research projects won support and two young research fellows started their NKFIH postdoc research project. The Institute was successful as well on the newly introduced excellence driven NKFIH project calls. In the call for proposals for research teams with significant achievements of internationally outstanding impact two members of the Institute won support. In the call “SNN_18 (research proposals based on Hungarian-Slovenian cooperation) one further project was funded.

The Institute was very successful in the previous years as well in the researcher-initiated project applications of NKFIH. Still, the financial impact of these projects among the incomes of the Institute has varied; e.g., the income of year 2016, almost trebling the previous year’s one, got halved in year 2017, and almost reached the 2016’s level again in year 2018. The variance is not due to the average of the yearly gained support, but rather due to the increasing delay in the acceptance of the research reports as well as in the prefinancing of the running projects. Still, due to the prefinancing of the research costs and the continuity of the winning projects, this variance poses no problem in continuing the financed research.

A further significant grant is “The mathematical foundation of artificial intelligence” submitted by a consortium led by the Institute in 2018 – and declared winning in the middle of the year - to the call of the National Research, Development and Innovation Office under the framework of the National Excellence Programme. The total funding of the project is close to 1 billion Forints, out of which the Institute’s share is 466 million Forints for a three year period starting September 2018. The purpose of this project is to create a knowledge center for research in the field of artificial intelligence and its applications that will promote Hungary into the forefront of this area. In order to achieve this goal, it is necessary to concentrate the human resources available in Hungary, and furthermore, structuring and strengthening them. Through the partnership of the two institutes of the Academy and the three universities a new collaboration will be created, whose results will overarch from the most theoretical aspects of artificial intelligence to the most practice oriented ones. The researchers will not work isolated on the particular problems, but rather they will closely cooperate ensuring the flow of information between the theoretical and practical components of the project.

In the project calls of the Hungarian Academy of Sciences one young researcher received a Premium Post Doctorate Research grant and – due to the high number of ERC projects – the Institute was very successful in the EUHUNKPT project call. Altogether these projects with the running Momentum course pedagogy projects kept close to the earlier record of the financial support level of Academy and other national (non-NKFIH) projects.

International grants

The most promising and successful international calls for the explanatory (theoretical) research projects of the Rényi Institute are EU European Research Council (ERC) calls and the mobility (Marie Sklodowska Curie) calls of the European Union. In 2018 one ERC Synergy grant proposal won (submitted in 2017 by a consortium led by the Institute) to investigate the structure and dynamics of networks. The consortium, consisting of, apart of the Institute, the Central European University (Budapest, Hungary) and Charles University (Prague, Czech Republic) receives 9,315,424 EUR for 6 years, out of which the Institute’s share is 3,484,324 EUR. The research funded by the grant is due to start in the second half of 2019. It is worthwhile to mention that this is the only funded project grant in the recent Synergy call from the E-13
countries and the only research project in mathematics among all of the so far winning Synergy grants.

In 2018 one further ERC Advanced grant and five MSC-IF grant applications were submitted, none of which has been finally evaluated yet, though the Advanced Grant proposal advanced to Step 2.

Following the two earlier ERC projects terminated in 2017, one additionally got into its final stage in 2018, while the projects started in 2018 were still in their team building phase, resulting in a decline in the overall EU grant spending level of the Institute. This is foreseen, however, to increase again, however, it requires the cofinancing from Institute resources of the Full Time Equivalent of the salaries of those researchers who are employed on EU projects but not full time. With the overhead of the terminated ERC projects the Institute had no cash flow problem to financing the last phase (not prefinanced by the EU) of the expenses of the terminating projects.

Altogether the total research grant income of the Institute in 2018 was very close to two years ago (the highest level), mainly due to the new Hungarian research and development (National Excellence Programme) grant and the increase in the Hungarian NKFIH research grant levels. Though the different type of grant incomes can vary year by year, on average, even considering only the running grant support, this income of the Institute is considered to be stable for the next few years.

The following diagram shows the amount of project support received during the last 5 years.
V. List of important publications in 2018


http://real.mtak.hu/73295/