Mathematical minds

Hyam Rubinstein*

Gazette: What led you to become a mathematician?

Rubinstein: I discovered numbers at a young age, influenced by my mother Gertrude (Masters degrees in Chemistry and Zoology) and eldest brother Martin (I am third of six boys) and recall doing lots of arithmetical exercises and deciding very early that mathematics was my career choice. It is a fortunate life to do what you love as a profession.

At Melbourne High School, I had some exceptional teachers: George Rowney in physics, Trevor Stanning for applied mathematics and Roy Maher for pure mathematics. Melbourne High School valued all forms of activity, science and arts, music and politics as well as the ubiquitous sports. I formed a triumvirate with Albert Langer and Arthur Kaletzky. Albert became a well-known political agitator during and after the Vietnam period. At university, he skipped most classes to engage in organising and stirring and used to borrow my notes, two weeks before exams, and still got first class honours in mathematics.

Gazette: Students usually find arithmetical exercises tedious. Why did they captivate you?

Rubinstein: I loved the patterns of numbers and found mental arithmetic fun. At Melbourne High, Albert was reading very advanced mathematics and I tried to catch up, starting with linear algebra. My eldest brother Martin (a contemporary of Terry Speed and Frank Barrington) had gone off to Berkeley to study mathematics and sent me Kurosh's books on groups and Dieudonne's on analysis. Kurosh was a real revelation — full of beautiful ideas and introducing me to the formal approach to mathematics.

Gazette: After high school, was mathematics still your main interest?

Rubinstein: I was always interested in politics and, through my mother and brothers, music and literature. But mathematics was my real passion. I went to Monash University and was influenced there by many people, especially Terry Speed, Emmanuel Strezlecki and George Virsik. Terry had shifted from Melbourne University to Monash University to do his PhD and told me that the program at Monash was more exciting than at Melbourne, which was going through a lean period. George had come out from Czechoslovakia during the brief spring period in 1968 and taught us beautiful, rather abstract courses on algebraic topology and differential geometry. I was hooked and spent a year going through Spanier's book on algebraic topology, even doing the hundreds of exercises!

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I took many courses in pure mathematics, applied mathematics, statistics and physics at second year, but by third year I decided that pure mathematics and statistics were my main interests as these areas appealed to me the most. Monash University had so many interesting courses and it was impossible to do them all. It is regrettable that Australian universities no longer have such rich offerings. I never thought of doing anything except mathematics until later on, although I did seriously consider majoring in statistics rather than pure mathematics at graduate level.

Gazette: Where did you do your PhD?

Rubinstein: I followed my brother Martin to the University of California at Berkeley and had a wonderful mathematical education. Monash had prepared me well for most of what I needed. Initially my intention was to do algebraic topology but I found the current research (at the time) rather technical and liked more geometrical ideas. I dabbled in dynamical systems — Berkeley was a top centre with Smale and his colleagues — but I had started reading some of Stallings' classic papers on geometric topology and when he returned from extended leave, I became his student. He gave me an interesting problem to work on, which took about 18 months and several failed attempts to solve.

Gazette: Most graduate students would find it demoralising to fail to solve this interesting problem. Was it? Why did you persevere?

Rubinstein: Stallings was very encouraging — the smallest amount of progress was always discussed enthusiastically to give me more confidence. Stallings was most likely the reviewer of a wonderful paper by Laudenbach in the *Annals of Mathematics*, which was the basis of my thesis problem. I really enjoyed reading and rereading Laudenbach's paper and I finally found the trick required to adapt his method to the new situation.

Gazette: What led you back to Australia?

Rubinstein: After Berkeley, my wife Sue was homesick, so I applied for jobs all around Australia. It was the time of the recession after the first oil shock and only Melbourne University offered me a short-term postdoctoral position, due to the recommendation of Simon Rosenblat. Simon was working on bifurcations in fluid dynamics and thought that a geometric topologist might help. I was again fortunate, even though I never did contribute to this, and held on to get a lectureship. At one stage I did contemplate changing careers, perhaps to engineering, since the job situation was very difficult.

At this time, Jim Cross was the sole other person in Melbourne working in geometry (or topology) and I appreciated talking to him. By chance, Tom Price from Iowa came to Melbourne and showed me a fascinating problem about a three-dimensional spherical space form, that is, the quotient of a finite group of isometries acting on the three-sphere, without fixed points. This three-manifold appears naturally, when studying embeddings of the projective plane in four-dimensional Euclidean space, as the boundary of a small neighbourhood of the surface. This led to many interesting problems and my research took off.

Gazette: What areas of mathematics do you work in?

Rubinstein: I became very interested in minimal surfaces. There had been a 'parallel' development of ideas in three-dimensional manifolds and minimal surfaces, which was brought together by the great work of Meeks, Schoen, Simon, Yau and then picked up by many geometric topologists such as Hass, Freedman, Scott. A fortuitous study leave was spent at Princeton in 1982. Yau asked me to report to him on a recent PhD thesis of Frank Smith, supervised by Leon Simon. Yau thought I should already know about this, but in fact, at that stage had not followed all the lectures on geometric measure theory at Melbourne University. So I had to catch up quickly and found the thesis a fantastic piece of work. It became a centrepiece of my ideas.

Frank had extended a previous thesis of Jon Pitts. Pitts and I ended up working together, with Leon's encouragement and produced a general way of finding explicit minimal surfaces in Riemannian three-manifolds using a minimax or sweepout method. This can be viewed as the mountain pass lemma in the space of embedded surfaces. Later, Bus Jaco and I developed a useful polyhedral theory of minimal surfaces, which removed some of the need for difficult analysis/geometric measure theory and I found a polyhedral sweepout technique, which is now called *almost normal surface theory.*

Another fortunate occurrence was a visit of G. Tsagas, a fine analyst from Thessaloniki. He and I worked through Hamilton's great first paper on Ricci flow for three-manifolds of positive Ricci curvature. In 1992 I met Perelman at Berkeley and we chatted about different approaches to geometrisation, including Ricci flow.

Around 1987, I started working with Doreen Thomas on shortest networks, which are one-dimensional minimal surfaces. We made contributions to the solution of the Steiner ratio conjecture, by introducing both local and global methods from the calculus of variations. The network group expanded, with Jia Weng, Marcus Brazil, Nick Wormald and Peter Grossman joining. Under the influence of David Lee, we turned our attention to problems in the design of access to underground mines. This has been a challenging but worthwhile enterprise lasting for more than ten years. We have built software based on new algorithms for shortest networks in three-dimensional space, satisfying restraints on curvature and gradient, with barrier avoidance and weightings on different components, measuring haulage and development costs. We hope to license this to a mining software company, so that it can be supported and widely distributed.

Gazette: Your work in underground mines seems very 'applied' and atypical of your other research interests. Is it?

Rubinstein: Underground mining is a superb area, both for the interesting mathematical challenges and also the issue of producing something which people want to use, that is, something that is relevant to real operations, not just idealised ones.

Gazette: On the subject of postgraduate students and collaborators...

Rubinstein: I have had many superb postgraduate students and this has been a highlight of academic life in Melbourne. Iain Aitchison and Craig Hodgson were

Masters students who became colleagues. I have had a long and productive collaboration with Iain on polyhedral differential geometry. There have also been many collaborators and research fellows who I have enjoyed working with, including Bus Jaco and Marty Scharlemann. Bus and I share an appreciation for triangulations and algorithms in low-dimensional topology, plus good red wine. Marty and I worked on a method to compare two handlebody decompositions, which proved to be a very effective tool. Currently Joel Hass and Abby Thompson are visiting from Davis for six months and we are having a lot of fun thinking about difficult problems.

Gazette: Do you prefer working independently or with others?

Rubinstein: I really prefer collaboration to working alone. Bouncing ideas around is very much the practice I like to follow. Often two or three collaborators can bring completely different viewpoints which is much more effective. Also, being rather inefficient, if I have a collaborator I feel guilty and am more likely to get projects finished!

Gazette: In which direction is your research going now?

Rubinstein: There continue to be opportunities to explore different uses of mathematics. Recent examples include: some network analysis for a paper with some French physicists on confinement of quarks, Lie group methods with Peter Hall and Peter Bajorski on principal component analysis, and a connection between hyperplane arrangements and compression schemes in statistical learning theory with my son Ben who has just graduated from Berkeley, following the family tradition.

Gazette: You were the Chair of the working party of the National Strategic Review of Mathematical Sciences Research, which delivered its report in 2006. What do you think about the present state and the future of mathematics in Australia?

Rubinstein: The various reviews of mathematical sciences have raised awareness about the challenges facing mathematics and statistics, but a coordinated action plan from government still seems a distant hope.

We produce outstanding mathematical talent in Australia but there is no deep appreciation of the power of mathematics and statistics to contribute to all areas of society. I remain cautiously optimistic that eventually the mathematical sciences will get the support they need, but it is vital that we continue to communicate with engineers, economists, actuaries, computer scientists, biologists etc. and help them wherever possible.

Gazette: Of which achievement are you most proud? What has been the highlight of your career so far?

Rubinstein: Certainly the solution of the three-sphere recognition problem and being invited to talk about this at the International Congress of Mathematicians in Zurich in 1996. At the time I did not realise that this was so significant, but there has been much subsequent development of algorithms to solve problems in low-dimensional topology.

Gazette: Why do you do mathematics?

Rubinstein: My wife says that I am addicted and so I should not retire, as I would just continue doing mathematics. Seriously, mathematics is a wonderful occupation and there are endless new interesting developments to learn as well as problems to tackle. Moreover, the mathematics community is full of interesting characters.

Hyam is Chair of the National Committee for Mathematical Sciences and was the Chair of the working party of the 2006 National Strategic Review of Mathematical Sciences Research. He is interested in geometric topology, differential geometry, shortest networks, machine learning and design of underground mines. He has been a Professor at Melbourne University since 1982 and has supervised more than 20 masters and PhD students.