

# IMO 2016, Hong Kong - UK Deputy Leader Blog

Dominic Yeo<sup>1</sup>, University of Oxford

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The UK Maths Trust<sup>2</sup> organises competitions, mentoring and other enrichment activities for talented and enthusiastic school-aged mathematicians. One strand is a training programme for the country's top young problem-solvers to introduce them to challenging material, enjoyable in their own right, but also the focus of international competitions.

The International Mathematical Olympiad is the original and most prestigious such event, now in its 57th year. About a hundred countries send teams of up to six contestants, and this year I led the training for the UK team to take part at the IMO in Hong Kong. The following report, which tries to strike a balance between mathematics and travelogue, describes our experiences at the final training camp, and the competition itself. It originally appeared in four instalments with some pictures on my blog<sup>3</sup>.

## Friday 1st July

It's my last morning as an Oxford resident, and I have to finish the final chapter of my thesis, move out of my flat, print twenty-four boarding passes, and hurtle round town collecting all the college and department stamps on my pre-submission form 3.03 like a Pokémon enthusiast. Getting to Heathrow in time for an early evening flight seems very relaxed by comparison, even with the requirement to transport two boxes of IMO uniform. Because I wasn't paying very much attention when I signed off the order, this year we will be wearing 'gold', but 'lurid yellow' might be a better description. Hopefully the contestants might have acquired some genuinely gold items by the time we return to this airport in two weeks.

## Saturday 2nd July

Our flight passes rapidly. I proved an unusual function was locally Lipschitz, watched a film, and slept for a while. Others did not sleep at all, though I suspect they also did not prove any functions were locally Lipschitz. The airport in Hong Kong is truly enormous; for once the signs advertising the time to allow to get to each gate have a tinge of accuracy. We have plenty of time though, and there is substantial enthusiasm for coffee as we transfer. Cathay Pacific approach me with a feedback form, which turns out to include 130 detailed questions, including one concerning the 'grooming' of the check-in staff, while we all collectively tackle an inequality from the students' final sheet of preparatory problems.

Before long though, we have arrived in Manila, where Jacob is uncontrollably excited to receive a second stamp in his passport, to complement his first from Albania at the Balkan Olympiad last month. As we bypass the city, we get a clear view of the skyscrapers shrouded in smog across the bay, though the notorious Manila traffic is not in evidence today. We pass through

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<sup>1</sup>[dominic.yeo@worc.ox.ac.uk](mailto:dominic.yeo@worc.ox.ac.uk), for now.

<sup>2</sup><http://www.ukmt.org.uk>

<sup>3</sup><http://eventuallyalmosteverywhere.wordpress.com>

the hill country of Luzon Island, the largest of the Philippines, and get caught in a ferocious but brief rainstorm, and finally a weekend jam on the lakeside approach to Tagaytay, but despite these delays, the fiendish inequality remains unsolved. I'm dangerously awake, but most of the students look ready to keel over, so we find our rooms, then the controls for the air conditioning, then let them do just that.

## Sunday 3rd July

We have a day to recover our poise, so we take advantage of morning, before the daily rain sets in, to explore the area. We've come to Tagaytay because it's high and cool by Philippine standards, so more conducive to long sessions of mathematics than sweltering Manila. We follow the winding road down the ridge to the shore of Taal Lake, where a strange flotilla of boats is docked, each resembling something between a gondola and a catamaran, waiting to ferry us to Taal Volcano, which lies in the centre of the lake. The principal mode of ascent from the beach is on horseback, but first one has to navigate the thronging hordes of vendors. Lawrence repeatedly and politely says no, but nonetheless ends up acquiring cowboy hats for all the students for about the price of a croissant in Oxford.

Many of us opt to make the final climb to the crater rim on foot, which means we can see the sulphurous volcanic steam rising through the ground beside the trail. From the lip we can see the bright green lake which lies in the middle of the volcano, which is itself in the middle of this lake in the middle of Luzon island. To the excitement of everyone who likes fractals, it turns out there is a further island within the crater lake, but we do not investigate whether this nesting property can be extended further. After returning across the outer lake, we enjoy the uphill journey back to Tagaytay as it includes a detour for a huge platter of squid, though the van's clutch seems less thrilled. Either way, we end up with a dramatic view of an electrical storm, before our return to the hotel to await the arrival of the Australians.

## Monday 4th July

Morning brings the opportunity to meet properly the Australian team and their leaders Andrew, Mike and Jo. We've gathered in the Philippines to talk about maths, and sit some practice exams recreating the style of the IMO. The first of these takes place this morning, in which the students have 4.5 hours to address three problems, drawn from those shortlisted but unused for last year's competition.

After fielding a couple of queries, I go for a walk with Jo to the village halfway down the ridge. On the way down, the locals' glances suggest they think we are eccentric, while on the ascent they think we are insane. About one in every three vehicles is a 'jeepney', which is constructed by taking a jeep, extending it horizontally to include a pair of benches in the back, covering with chrome cladding, and accessorising the entire surface in the style of an American diner. We return to find that the hotel thinks they are obliged to provide a mid-exam 'snack', and today's instalment is pasta in a cream sauce with salad, served in individual portions under cloches. Andrew and I try to suggest some more appropriate options, but we're unsure that the message has got across.

I spend the afternoon marking, and the UK have started well, with reliable geometry<sup>4</sup> and a

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<sup>4</sup>It appears to be an extra axiom of Euclid that all geometry problems proposed in 2015/2016 must include a parallelogram...

couple of solutions to the challenging number theory problem N6, including another 21/21 for Joe. Part of the goal of this training camp is to learn or revise key strategies for writing up solutions in an intelligible fashion. At the IMO, the students' work will be read by coordinators who have to study many scripts in many languages, and so clear logical structure and presentation is a massive advantage. The discussion of the relative merits of claims and lemmas continues over dinner, where Warren struggles to convince his teammates of the virtues of bone marrow, a by-product of the regional speciality, *bulalo* soup.

## Tuesday 5th July

The second exam happens, and further odd food appears. Problem two encourages solutions through the medium of the essay, which can prove dangerous to those who prefer writing to thinking. In particular, the patented 'Agatha Christie strategy' of explaining everything only right at the end is less thrilling in the realm of mathematics. It's a long afternoon.

We organise a brief trip to the People's Park in the Sky, based around Imelda Marcos's abandoned mansion which sits at the apex of the ridge. In the canon of questionable olympiad excursions, this was right up there. There was no sign of the famous shoe collection. Indeed the former 'palace' was open to the elements, so the style was rather more *derehlicte* than *chic*, perfect for completing your I-Spy book of lichen, rust and broken spiral staircases. Furthermore after a brief storm, the clouds have descended, so the view is reminiscent of our first attempt at Table Mountain in 2014, namely about five metres visibility. A drugged parrot flaps miserably through the gloom. Even the UK team shirts are dimmed.

There is a shrine on the far side of the palace, housing a piece of rock which apparently refused to be dynamited during the construction process, and whose residual scorchmarks resemble the Blessed Virgin Mary. A suggested prayer is written in Tagalog (and indeed in Comic Sans) but there is a man sitting on the crucial rock, and it's not clear whether one has to pay him to move to expose the vision. Eventually it clears enough to get a tolerable set of team photos. Joe tries to increase the compositional possibilities by standing on a boulder, thus becoming ten times taller than the volcano, so we keep things coplanar for now. Harvey finds a giant stone pineapple inside whose hollow interior a large number of amorous messages have been penned. He adds "Geoff  $\heartsuit \triangle s^5$ ", in homage to our leader, who has just arrived in Hong Kong to begin the process of setting this year's IMO papers.

## Wednesday 6th July

After starting the third exam, Mike, Jo and I go for a walk through some of the smaller villages on the other side of the ridge. Along the way, we pick up a bunch of local rascals who ask us, via their English-speaking henchman, many questions about basketball, and the colour of Mike's shoes. Jo asks him why they aren't in school, but this remains shrouded in mystery. Partly as a means of escape, we take a detour through a grove of the famous Tagaytay pineapples, which are indeed a striking crimson just before they ripen fully. I'm nervous about beard tanlines so am looking for a barber, but it seems I'm one of only two people in the Philippines with facial hair. (The other is Neel, who is adamant that his school endorses the 'Wild man of Borneo' look.)

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<sup>5</sup>Top tip: turn off images before googling 'heart in L<sup>A</sup>T<sub>E</sub>X'.

We return to find that the students have been issued with cake. Its icing is impossible to manage without a fork. It is also entirely purple, and Lawrence describes it as ‘tasting of air’. None of this has distracted the UK students, who all solve the first two problems perfectly, which bodes well for the IMO itself, now less than a week away. To fill some time and provide a brief variation from the constant problem-solving, I give a talk about correlation and graphs, based on a subsubsubsection of my thesis and for now, fortunately no-one finds any logical holes.

### Thursday 7th July

To add variety, today the two teams have set each other a paper, which they will spend the afternoon marking. It transpired late last night that the hotel has no means of printing or photocopying documents, and we haven’t brought copies of tomorrow’s final exam. So today’s paper has been painstakingly written on whiteboards, and some of the adults set off round Tagaytay in search of a working printer. The mode of transport is the ‘tricycle’, a small motorcycle with one place behind the rider and two in a bone-shaking pillion enclosed within a lace curtain. Availability of tricycles is infinite, availability of photocopiers is positive but small, and availability of printers is zero. We’ll be going for the handwritten, personal touch.

Both teams have chosen their papers so as to get some fiddly answers, and both teams have helped the exercise by writing some rubbish. Mostly it is all correct on close inspection, but much requires serious digestion, and gives the students at least a flavour of what Andrew and I have to endure on a daily basis. The Australians have rephrased a combinatorial problem in terms of Neel wandering through security checks at an airport, and the UK boys have proved that whatever happens here, a gold medal at the International Metaphor-Extending Olympiad seems inevitable.

Courtesy of Australian student Wilson, a penchant for fedoras has swept through the camp. Joe and Harvey arrive for dinner looking like extras in an ultra-budget production of *Bugsy Malone*. Our mock coordination has taken most of the afternoon, so we have not been tracking the imminent supertyphoon Nepartak as carefully as we ought, but at least the new headwear fashion offers some protection from the elements.

### Friday 8th July

This morning is the final training exam, and in keeping with tradition is designated the *Mathematical Ashes*. Whichever team wins gets to keep an impressive urn, filled with the charred remains of some old olympiad scripts. The urn is quite heavy, so for the Cathay Pacific weight restrictions, it would be convenient for me if Australia won this year. The lack of an actual Ashes this year renders the competition all the more important in some people’s eyes, though if there were a test match here today, the covers would be on all day as the typhoon squalls.

The Ashes paper is the original<sup>6</sup> Day Two paper from IMO 2015. The problems are supposed to be secret until after this year’s IMO (exactly because of events like the one we are running) but the entire shortlist has been released overnight on the internet. Fortunately none of the students have been checking the relevant forum over breakfast, but ideally people will curb their admirable enthusiasm and follow the actual rules in future years. I mark the second problem, a

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<sup>6</sup>Potted summary: some copies of this paper were accidentally released before they should have been, and so the paper had to be re-set.

fiddly recursive inequality, which invites many approaches, including calculus of varying rigour. Whatever the outcome, both teams have done a good job here.

For dinner, we are hosted by Dr Simon Chua, and some of his colleagues involved in the Philippines maths enrichment community, who suggested this location, and helped us set up this camp. We are treated to various Philippine dishes, including suckling pig and squid in its own ink, with a view of sunset across the lake as the storm clears. We're very grateful to Simon, Joseph and their colleagues for tonight and their help and advice in advance.

We finish the marking after dinner, and the UK has consolidated our position on the third question, including a superb 21/21 for Warren on a genuinely hard paper, and we have won 82-74. It is late, everyone is tired, and there is packing required, so the celebrations are slightly muted, though it gives Jacob an excellent opportunity to lose his room key again, an alternative competition in which he is certainly the unique gold medallist. We transfer to the main event in Hong Kong early tomorrow, so it's an early night all round.

### **Saturday 9th July**

After a disturbed night, it has been vociferously recommended that we leave at 6am to beat the Manila traffic, with the result that we have four hours at the airport. I try to remain stoic, with difficulty. Joe practises sleeping on a wide range of horizontal surfaces while the rest of us have a sudden enthusiasm to solve N8 from last year's IMO shortlist. It turns out the UKMT travel agent has outdone themselves, and booked half the group in premium economy, and half in regular economy, though the only real difference seems to be armrest width.

We are met in Hong Kong by Allison, our local guide for the week, and escorted onto coaches across from the airport on Lantau island to the University of Science and Technology in the New Territories. The check-in process is comprehensive: I sign and initial to confirm that they have correctly provided us with seven laptop sleeves, and then repeat for an infinite supply of other branded goods. Finally, we are allowed out to explore the spectacular campus, which stretches steeply down to Clearwater Bay. It is something of a novelty to take elevators up a total of 37 levels, and arrive on something called 'Ground Floor'.

After a confusingly-managed dinner at the student cafeteria, a few of us head out to look at the nearby neighbourhood of Hang Hau. We pass the olympic velodrome, which gives Lawrence a good opportunity to explain gearing to those among his colleagues who do not naturally seek out applied mathematics. We return to find that Harvey decided to go to sleep before working out how to turn on his air conditioning. In humid hindsight, this was a poor strategy, as this was one of HK's hottest days since records began. We have arrived back at the perfect time to watch the awesome thunderstorm from safety, which hopefully isn't an omen of terrible things to follow in the contest.

### **Sunday 10th July**

I'm awake at 6am and there's nothing to do, so take a short run along the edge of the bay. I meet an old lady singing along to a walkman (yes, really) while doing taichi. She encourages me to join and it seems rude to refuse. Suffice it to say I'm as grateful no video evidence exists as she should be that no audio recording was made. Six-hundred mathematicians queueing for powdered eggs seems like an unwelcome start to the day, so we are self-catering. The guides

have been commanded to show every student how to find their place in the exam hall, and I approve of Allison's contempt for the triviality of this task.

The main event of the day is the opening ceremony, held at the Queen Elizabeth stadium in the centre of Hong Kong Island. To no-one's surprise, this involves a lot of time waiting around in the stifling UST plaza, which the students use to take a large number of photographs. The UK and Australian boys are smartly turned out as usual, but the polyester blazers are rather ill-suited to these tropical conditions, so we invoke *Red Sea rig* until air conditioning becomes available. The Iceland team are particularly keen to seek out the English members for reasons connected to a football match of which Neel proudly claims total ignorance. I picked up an EU flag for next-to-nothing last Friday, and now Jacob and Warren prove very popular as they circulate inviting our (for now) European colleagues to join us behind the stars.

The deputies are segregated in an upper tier and obliged to watch a rehearsal of the parade. Some of the organisers have a confused interpretation of the IMO roles. I still have some of the uniform with me, but an official says it is literally impossible for me to give it to the team. She is small and Joe Benton can catch flying ties as well as colds, so it turns out to be literally entirely possible, but for my trouble I get called 'a very bad boy'.

Many hours after we left our rooms, the ceremony starts, and is actually very good, with a handful of well-chosen speeches, a mercifully quickfire parade of teams, and musical interludes from a full symphony orchestra, with various traditional and non-traditional percussion. The new IMO song *Every day in love we are one* involves a B section accompanied by a mélange of watercooler bottles, but despite its catchy conclusion about maths, friendship and beyond, I suspect it may not trouble the top of the charts.

## Monday 11th July

It's the morning of the first IMO paper<sup>7</sup>, and you can feel both the excitement and the humidity in the air. Some of our boys are looking a bit under the weather, but we know from past experience that the adrenaline from settling down in a room of 600 young contestants who've been preparing for exactly this can carry them through anything. I skip an excursion in order to receive a copy of the contest paper. Security is tight, and the deputies who have chosen this option are locked in a lecture theatre for two hours, and our bathroom visits monitored with commendable attention to detail. I guess that the combinatorial second problem is most likely to provoke immediate discussion, so I spend my time working through the details of the argument, just in time to meet our contestants when their 4.5 hours are up.

Q3 has been found hard by everyone, and Q2 has been found hard by other countries. Harvey's kicking himself for drawing the wrong diagram for the geometry, an error that is unlikely to improve Geoff's mood when he receives the scripts later today. Apart from that, we have a solid clutch of five solutions to each of the first two problems, and various nuggets of progress on the final problem, which is an excellent start. Several of the team are itching to keep trying to finish Q3, but the campus is likely to be a hotbed of spurious gossip all day, so Allison and I take them out. The very convenient MTR takes us under the harbour while the students and I debate the usefulness of the square-free case, and how well it is preserved under rescaling so that the circumcentre is a lattice point.

As we emerge above ground, Jacob is entranced by the live-action *Finding Dory* playground at Causeway Bay, and we toy with buying a pig's trotter from a nearby market, but not

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<sup>7</sup>The problems can be found here: <https://bmos.ukmt.org.uk/home/imo-2016-day1.pdf>

even Lawrence is feeling adventurous enough with another exam tomorrow. We travel over to Kowloon via double-decker tram and ferry then, fortified by ice cream, take lots of photographs of the unique HK skyline, where even the giant waterfront office towers are dwarfed by Victoria Peak, which the contestants will visit while I'm marking. On our return journey, some of the team are impressed by the HK rush hour, indicating that they've clearly never tried to change line at Leicester Square around 6pm on a Friday...

## Tuesday 12th July

Another morning, another trek uphill to a 4.5 hour exam. Time passes rapidly, especially now I've worked out how to order coffee without the ubiquitous condensed milk. The security arrangements concerning the deputies' copies of the paper have been increased even further, but the IMO photographers have outdone themselves, and published on Instagram some pictures of the exam room with a level of crispness such that it's clear the paper includes no geometry, and after finally getting hold of a proper hard copy, it looks like a paper<sup>8</sup> which the UK team should really enjoy.

As so often after IMO papers, there is a range of reactions. Lawrence is unsure whether he presented his exemplar polynomial in a form that actually works. Joe knows and I know that he could easily have scored at least 35 on these papers, but after over-thinking himself on Q5, this isn't his year. Like Aeneas gazing on the ruins of Troy, *sunt lacrimae rerum*, but also plans for new foundations. By contrast, Harvey has atoned for yesterday's geometric lapse with what sounds like a perfect score today. Warren and Neel seem to be flying overall. There's plenty to think about, and Geoff has now arrived bearing yesterday's scripts and several novels' worth of anecdotes from the leaders' site.

Before getting down to business, it feels sensible to walk off the *Weltschmerz*, and provide an outlet for joy in the nearby Clearwater Bay country park. There's a long trail all over the New Territories, and we join it for a brief but purposeful stroll up through the light jungle and along the ridge. Harvey is not an Englishman, so by elimination must be a mad dog. We're fairly confident we didn't find the global maximum, but we find a couple of local maxima with great views out around the coastline, which seems to have Hausdorff dimension slightly greater than 1. We see some enormous spiders (though the Australians are substantially less impressed) before ending up an uncontroversial minimum where Jill has bedded in with merciful bottles of water on the beach. To say we are sticky doesn't even begin to cover it. Crucially though, we are no longer consumed by the morning's events.

The UK boys are now masters of the complicated UST food court ordering process, and Warren endears himself to Geoff by producing a steaming bowl of spicy ramen as if by magic. The contestants have a 'cultural night', which apparently includes a greater number of hedge fund representatives than one might have expected. For me, it's a night in with green tea and the scripts for Q2, while Geoff digests Q1. Joe and Neel have filled fourteen pages between them checking a construction in glorious detail, a step which Harvey has described in its entirety with the words 'glue them together'. Overall, they are complicated but precise, and I have few concerns, so it's only necessary to burn the candle at one end.

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<sup>8</sup><https://bmos.ukmt.org.uk/home/imo-2016-day2.pdf>

## Wednesday 13th July

It's time for coordination, where Geoff and I agree the UK marks with a team of local and international experts. The scheduling has assigned us the Q1 geometry early in the morning, which is a clear case of five perfect solutions, so we move to Q2. Coordinator Stephan seems very well-prepared for the UK scripts, so again we are finished in a matter of minutes. This allows us to bring forward our discussion of Q4. Jacob has made several small errors, all of which could be fixed by attacking his script with a pair of scissors and some glue. I believe the mark scheme should award this  $4 + 2$ , and coordinator Juan thinks it should be  $5 + 1$ . We are both open to each other's interpretations, and have at least basic proficiency in addition, so again there is little need for debate.

The early evening brings the main challenge of the day, Q6, at which the UK has excelled. Geoff has listed marks for five of our attempts, but the final script belonging to Joe has generated only the comment 'magical mystery tour'. His solution to part a) diverges substantially from the most natural argument, and indeed involves wandering round the configuration, iteratively redirecting lines<sup>9</sup>. I am eventually convinced by the skeleton of the argument, though unconvinced I could complete the details in the finite time available.

We discuss the script with Lisa Sauermann, who explains some of the main challenges<sup>10</sup>. After a short pause for thought, we're convinced by Lisa's suggestion of equivalence with a point on the conventional markscheme. It would have been nice to have had more time to think about the subtleties myself, but this was some really interesting maths and we pack up for the day feeling very impressed with the quality of coordination here so far.

We and the coordinators are also very impressed with the quality of Harvey's art. As a result, we now have an answer to the question 'What should you do if you finish the IMO two hours early?' Harvey's answer at least is to draw a diagram of the Q6 configuration in the case  $n = 3$ , where at each of the intersection points with the outer boundary stands a member of the current UK team. Precisely UNKs 1, 3 and 5 are wearing a frog. The real life sextet have been taken to Disneyland today, so some are potentially now wearing a princess. But while the contestants can let it go now, it's off to work I go, as there's still two sets of scripts left to ponder.

## Thursday 14th July

I have now spent a while thinking about square-free  $n$  in Q3 after rescaling, and I still don't know what the markscheme should award it. I therefore request that Joe and Warren receive the same score as each other, and any other contestant who has treated this case. In my opinion this score should be at most one, mainly as a consolation, but potentially zero. However, we are offered two, and after they assure me this is consistent, I accept.

There is brief but high drama (by the standards of maths competitions) when we meet Angelo the Australian leader, who confirms that he has just accepted one mark for almost the same thing by his student Johnny. A Polish contestant in a similar situation remains pending, so we all return for a further meeting. I'm unconvinced that many of the coordinators have read all

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<sup>9</sup>The mechanism for this redirection is neither canonical nor explained, and even in the best setup I can come up with in an hour or so of trying a huge class of diagrams, exactly half of the indices in the resulting calculation are off by  $\pm 1$ . The pressure of IMO Day Two can indeed derail even the most well-prepared contestants.

<sup>10</sup>There is a non-trivial difficulty when the area enclosed by our path is concave, as then some intersection points on the path arise from lines which are also part of the path. Handling the parity of such points looks easy once you've been shown it, but is definitely not obvious.



the scripts in question, but they settle on two for everyone, which is consistent if generous. The only drama on Q5 is the ferocious storm that sets in while I'm making final notes in the plaza. Again though, coordinator Gabriele has exactly the same opinion on our work as Geoff and I, apart from offering an additional mark for Lawrence's now slightly damp partial solution.

And so we are finished well before lunch, with a total UK score of 165 looking very promising indeed. I'm particularly pleased with the attention to detail - Jacob's 6 on Q4 is the only mark 'dropped', which is brilliant, especially since it hasn't come at the expense of the students' usual styles. We'll have to wait until later to see just how well we have done.

It would be nice to meet the students to congratulate them in person, but they are with Jill on the somewhat inaccessible Victoria Peak, so instead I take a brief hike along the trail down the centre of HK Island, ending up at the zoo. This turned out to be free and excellent, though I couldn't find the promised jaguar. There was, however, a fantastic aviary, especially the striking flock of scarlet ibis. A noisy group of schoolchildren are surrounding the primates, and one lemur with an evil glint in his eye swings over and languidly starts an activity which elicits a yelp from the rather harried teacher, who now has some considerable explaining to do.

With 1000 people all returning to UST at roughly 6.30, dinner is not dissimilar to feeding time at the zoo, and afterwards various leaders lock horns during the final jury meeting. Two countries have brought an unresolved coordination dispute to the final meeting, and for the first time since I became deputy leader, one of them is successful. Congratulations to the Koreans, who now have a third student with a highly impressive perfect score. Andy Loo and Geoff chair the meeting stylishly and tightly, and although there are many technical things to discuss, it doesn't drag for too long. Eventually it's time to decide the medal boundaries, and the snazzy electronic voting system makes this work very smoothly. I feel the gold and bronze cutoffs at 29 and 16 are objectively correct, and the 50-50 flexibility at silver swings towards generosity at 22. We can now confirm the UK scores as:

	Q1	Q2	Q3	Q4	Q5	Q6	$\Sigma$	
Joe Benton	7	7	2	7	2	1	26	Silver
Jacob Coxon	7	1	0	6	7	3	24	Silver
Lawrence Hollom	7	7	0	7	3	0	24	Silver
Warren Li	7	7	2	7	7	3	33	Gold
Neel Nanda	7	7	0	7	2	7	30	Gold
Harvey Yau	0	7	0	7	7	7	28	Silver

This is pretty much the best UK result in the modern era, placing 7th and with a medal tally tying with the famous food-poisoning-and-impossible-geometry IMO 1996 in India. But obviously this is a human story rather than just a  $6 \times 6$  matrix with some summary statistics, and Harvey in particular is probably looking at the world and thinking it isn't fair, while Warren's gold is the ideal end to his four years at the IMO, two of which have ended one mark short. The American team are pretty keen to let everyone know that they've placed first for the second year in succession, and their remarkable six golds will hopefully allow scope for some good headlines. There is much to talk about, celebrate and commiserate, and this continues late into the night.

## Friday 15th July

Our morning copy of the *IMO Newsletter* includes an interview with Joe, with the headline 'Meh'. Frank Morgan has rather more to say, which is good news, since he's delivering the IMO lecture on *Pentagonal Tilings*. He discusses the motivation of regular tilings where  $\frac{\text{Perimeter}}{\text{Area}}$  is

minimised, starting from questions about honeycombs raised by the Roman author Varro! We move onto more mathematical avenues, including the interesting result of L'Huilier that given a valid set of angles, the associated polygon with minimal  $\frac{\text{Perimeter}}{\text{Area}}$  has an incircle, and the corresponding result for in- $n$ -spheres in higher dimension. A brief diversion to the beach on the way home is punctuated with attempts to project the hyperbolic plane onto the sand.

The day's main event is the closing ceremony, held at the striking Hong Kong Convention Centre. As usual, the adults and our students have been vigorously separated for the journey. As I arrive, it seems the UK boys have been directing a massed gathering behind the EU flag on stage, while the non-European teams are divided into two sides in a giant paper aeroplane dogfight. All attempts by the organisers to quash this jocularly are being ignored, and after bringing everyone here two hours early, I have minimal sympathy. Geoff sits on a secluded bench, and agrees to the many selfie requests from various teams with regal if resigned tolerance.

The ceremony is started by a fantastically charismatic school brass band, and proceeds with some brief speeches, and more astonishing drumming. Then it's time to award the medals. Lawrence and Jacob get to go up together among the clump of 24-scorers, while Kevin from Australia does an excellent job of untangling his flag and medal while keeping hold of the ubiquitous cuddly koala. Neel has been threatened with death if he appears on stage again with an untucked shirt, but no direction is required for his and Warren's smiles as they receive the gold medallists' applause.

Afterwards, there is a closing banquet. We get to join British coordinators James and Joseph for a climate-defying carrot soup, followed by a rare diversion onto Western carbohydrates accompanying what is, for many of us, a first taste of caviar. Both Geoff and the American team are forced to make speeches at no notice. It is all generally rather formal, and fewer photographs are taken than usual. An attempt to capture Joe and Harvey looking miserable results in one the biggest grins of the evening. The UK and Australian teams have a thousand stickers and micro-koalas to give out as gifts, and some of the attempts at this descend into silliness. All clothing and body parts are fair game, and Jacob makes sure that Geoff is fully included. The UK and Australian leaders, variously coated, retreat from the carnage to the relative safety of our top-floor balcony as the IMO drifts to an end, until midnight, when it seems sensible to find out what the students are up to.

## Saturday 16th July

This is what the students are up to. When we arrived at UST last week, everyone was given food vouchers to redeem at the campus's various restaurants. Very very many of these are left over, and, despite the *haute cuisine* on offer earlier, people are hungry. They have therefore bought McDonalds. And I mean this literally. Animated by Jacob and American Michael, they have bought the entire stock of the nearest branch. If you want to know what 240 chicken nuggets looks like, come to common room IX.1, because now is your chance. Fortunately our team have made many friends and so after the Herculean task<sup>11</sup> of getting it to their common room, pretty much the entire IMO descends to help. Someone sets up a stopmotion of the slow erosion of the mountain of fries, while the usual card games start, and a group around a whiteboard tries to come up with the least natural valid construction for  $n = 9$  on Q2. Around 3.30am everything is gone, even the 30 Hello Kitties that came with the Happy Meals, and we're pre-emptively well on the way to beating jetlag.

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<sup>11</sup>I make no comment on which Herculean labour I feel this most resembles.

I wake up in time to wave Geoff off, but he's been bumped to an earlier bus, so the only thing I see is Lawrence and colleagues returning from a suicidal 1500m round the seaside athletics track. Our own departure is mid-morning, and on the coach the contestants are discussing some problems they've composed during the trip. They'll soon be able to submit these, and by the sounds of it, anyone taking BMO and beyond in 2018 has plenty to look forward to. Jacob has already mislaid his room key and phone, and at the airport he's completed the hat-trick by losing one of the two essential passport insert pages. Fortunately, it turns out that he's lost the less essential one, so we can clear security and turn thoughts towards lunch.

Jill has given me free licence to choose our *dim sum*, so the trip ends with pork knuckle and chicken feet. Our aim is to stay awake for the whole flight, and Neel helps by offering round copies of a Romanian contest from 2010, while I start proof-reading. By the time they finish their paper, many rogue commas have been mercilessly expunged. It should be daylight outside, but the windows are all shut, and by the ninth hour time starts to hang drowsily in a way that combinatorial geometry cannot fix, and so the mutual-waking-up pact kicks in, aided by Cathay Pacific's unlimited Toblerone. Winding through Heathrow immigration, Joe unveils his latest airport trick of sleeping against vertical surfaces. We diverge into the non-humid night.

## Reflection

There's a great deal more to life and mathematics than problem-solving competitions, but our contestants and many other people have worked hard to prepare for IMO 2016 over the past months (and years). So I hope I'm allowed to say that I'm really pleased for and proud of our UK team for doing so well! The last three days of an IMO are very busy and I haven't had as much time as I'd have liked<sup>12</sup> to talk in detail about the problems. But I personally really liked them, and thought the team showed great taste in choosing this as the British *annus mirabilis* in which to produce lots of beautiful solutions.

But overall, this is really just the icing on the cake of a training programme that's introduced lots of smart young people to each other, and to the pleasures of problem-solving, as well as plenty of interesting general mathematics. I have my own questions to address, and (unless I'm dramatically missing something) these can't be completed in 4.5 hours, but as ever I've found the atmosphere of problem discussion totally infectious, so I hope we are doing something right.

Lawrence and Warren are now off to university. I'm sure they'll thrive in every way at this next stage, and hopefully might enjoy the chance to contribute their energy and expertise to future generations of olympiad students. The other four remain eligible for IMO 2017 in Brazil, and while they will doubtless have high personal ambitions, I'm sure they'll also relish the position as ideal role models for their younger colleagues over the year ahead. My own life will be rather different for the next two years, but our camp for new students is held in my no-longer-home-town Oxford in a few weeks' time, and I'm certainly feeling excited about finding some new problems and doing as much as possible of the cycle all over again!

## Final words

Training a UK team and taking them to the IMO requires a huge amount of effort from a large number of people. Thanks are particularly due to:

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<sup>12</sup>For a report on a recent competition in Albania with a full discussion of the problems, see <https://www.imo-register.org.uk/2016-balkan-report.pdf>.

- All the staff at our camps this year in Oxford, Hungary, Cambridge and Tonbridge. Nothing can quite compare to getting so many teenagers with the same interest in the same places, and watching them learn together, and we couldn't do this without all the volunteers happy to give up their time to support this. Thanks also to Bev at the UKMT office, who sorts out all the arrangements for the IMO trip and our events during the year so tirelessly!
- Dr Simon Chua and Dr Joseph Woo, who found the location for our pre-IMO camp in the Philippines, and helped us with a huge amount of local organisation. Also thanks to Sky Travel, and especially Julie de Menezes who offered lots of assistance at the start and end of the trip.
- IMO 2016 was a well-run competition, and especially the important academic components were managed very sensibly. Thanks to the organisers for putting on an excellent week, and to HKUST for hosting us at their stunning campus.
- The UK was fortunate to have Allison Fok as our guide. She looked after our team well, showed them lots of interesting things in Hong Kong during our free time, and did a good job of getting them places after they were supposed to arrive, but before they needed to. We wish her every success for the remainder of her studies!
- Our Australian colleagues, Andrew, Mike and Jo, who were great company academically and personally during our training camp. I remember well the first such joint training camp, in Sydney during the freezing 2007 winter, but this now the tenth instalment, and it seems to be an ideal arrangement, which will hopefully continue to flourish.
- Jill, who as always managed to corral eight mathematicians to where we needed to be with minimal fuss and great style; and Geoff, who leads so many aspects of the IMO itself both during and between the competitions, while still maintaining the time and energy to peruse the UK scripts, share his expertise on Asian ornithology and many other topics, and enliven the students with stories from the IMO and beyond.
- Our UK team, Joe, Jacob, Lawrence, Warren, Neel and Harvey, who were well-liked by everyone throughout the trip, had a positive attitude to the competition, and kept me dangerously on my toes at all times mathematically. Their success at this year's competition was richly deserved.

