REPORT ON THE 36TH INTERNATIONAL MATHEMATICAL OLYMPIAD YORK (TORONTO) : 13 - 25 JULY 1995 AND ON RELATED NATIONAL EVENTS WITHIN THE UK

We hope this report will be of interest to all who enjoyed this year's

- **British Mathematical Olympiad** *for those in their last years at school,*
- **International Intermediate Invitational Mathematical Challenge** *(Years 9-11)*
- **UK Junior Mathematical Olympiad** *(Years 7-8).*

We ask teachers to make copies available to all those who might be interested.

General Background

What is the IMO? And why is it held? Each July young mathematicians from all over the world meet to contest the *International Mathematical Olympiad* (IMO) - a kind of "World Junior *Mathletics* Championships". This year's event, hosted by Canada in Toronto, attracted a record 73 participating countries, each of whom was allowed to bring a team of up to six students.

As in the 'real' Olympics, competition is fierce, demanding both preparation and commitment. But whereas the Olympics involves 'pursuit of excellence' in arbitrary physical disciplines (hence the initial hilarity at the advent of synchronised swimming!), the Mathematical Olympiad is a part of the discipline of mathematics. Thus the IMO is not an end in itself, but aims to encourage, stimulate and challenge bright young mathematicians from all countries. It also provides an opportunity for students from many countries to meet. Both aims are important. The IMO began in Eastern Europe in 1959; at first it was restricted to Iron Curtain countries. In the mid-late 60s, countries from the West were gradually invited to join: the UK first took part in 1967.

Interaction between young students from different cultures - from East and West, from Occident and Orient - is not without its tensions. This year saw participation from Bosnia, from Croatia, and from Serbia-Montenegro; from Greece and from Macedonia; from China and from Taiwan! Such interactions help idealistic youngsters to realise they have more in common than they imagined.

Candidates sit two 4½ hour papers on successive days, with three problems on each paper. Very few students (15 this year) solve all 6 problems correctly; thus the very best students might hope to solve each problem in $1\frac{1}{2}$ - 2 hours. Mathematicians develop in many different ways. Some blossom early and need to be stretched. For most talented mathematicians the crucial years are those between the ages of 18 and 25. But all able youngsters can benefit from the experience of grappling with hard *Olympiad* problems - whether or not they will ever be in contention for the UK IMO team. *[The 1995 problems are on page 5!]*

Increasingly, countries who take part in the IMO can be classified as *amateurs* or *professionals*. The professionals train hard - with residential camps for 6-12 weeks prior to the IMO, staffed by academics who know the material well and who try to prepare their students for every conceivable type of problem. The amateurs (constrained by lack of funds, lack of time, lack of competence, or an old-fashioned view that problem-solving loses its appeal if it becomes predictable) prepare their students as best they can - by correspondence, with one or two weekends thrown in. At present, the UK remains strictly amateur. We try to ensure that students who attend the *IMO* find that the experience contributes positively to their mathematical development. The *IMO* should encourage and stimulate; it is not a guarantee of future success.

How does the IMO help the mass of bright students? As in sport, effective encouragement of talented youngsters requires a pyramid of activities for large numbers of pupils in different age groups. The real value of the IMO lies in this infrastructure and its impact *on the masses,* much as the World Cup inspires ordinary footballers who will never make their national squad.

National mathematics 'competitions' developed originally in Hungary, where they have been going strong for over a 100 years. Hungary now has a range of events, and everyone who is interested in Mathematics can get involved in some way. Most important of all, they started a *problem journal for students* in 1894. This journal - known by its abbreviation *KöMal* - is still going! The important thing is that these events are not just for a few brilliant freaks, but challenge and encourage large numbers of ordinarily bright youngsters.

One of the most obvious effects of this Hungarian 'pyramid' is that since 1900 Hungary, with a population of around 10 million, has produced an astonishing number of brilliant mathematicians, and an equally striking number of very good mathematicians of the second rank. (A successful system has to produce more than just Nobel prizewinners!) The Hungarian example was copied by the Soviet Union in the 1930s and by the whole of Eastern Europe after the Second World War. Each country then developed a system with its own local character.

The *IMO* started in 1959 as an event for countries in the Soviet bloc and helped to stimulate the development of national events, journals, local weekly mathematics circles, summer camps, etc. involving large numbers of students. The achievements of many of the smaller countries were truly remarkable, but Hungary stands out: each year from 1959 (when there were 7 countries) to 1975 (when there were 17 - including the UK) they finished first, second or third! In 1965 Finland was invited as the first non-communist participant, and in 1967 the UK, France, Sweden and Italy were invited. Since then numbers have grown steadily (with 23 countries in 1979 when the *IMO* was held in London, 38 countries in Finland in 1985, and 73 countries this year).

Since 1988 the UK has seen the growth of a sequence of Mathematical Challenges for all secondary ages, now involving some 250 000 pupils each year. On each level there is a large (and growing) multiple choice paper for "the masses":

the **UK JMC** (Years 7-8);	the **UK IMC** (Years 9-11);	the **NMC** (Years 12-13).
(105 000 entries)	(115 000 entries)	(30 000 entries)

These events provide an unusual and enjoyable challenge for large numbers of students; and modest rewards encourage them to aim that little bit higher. As part of this strategy of seeking to encourage able youngsters, 1000 or more participants on each level are invited to take a subsequent written paper

the **UK JMO** (Years 7-8);	the **IIIMC** (Years 9-11);	the **BMO** (Years 12-13).

These written papers are quite different from the multiple choice papers, both in style and in purpose. Most of those who take part at this level are used to getting all their schoolwork right without too much difficulty. This can mislead students into thinking that Mathematics is easy. It is not! The problems on these written papers are meant to be accessible, but they require candidates to think, to piece together a complete solution to a small number of problems (the first time you take such a paper you should aim to complete just one or two problems), and then to present their solutions clearly.

In Mathematics it helps to be clever, but it is more important to develop tenacity - the determination to work away at a problem until you see how to solve it completely. As in the fable of *'The Tortoise and the Hare'*, the student who is not satisfied with just giving an 'answer' which seems to work, who never gives up, and who is determined to find a complete solution can often outrun others who think they are 'quicker'.

[Since it is not easy for Year 9 students to qualify for the Year 10 IIIMC, we invite the top 5 000 Year 9 participants in the UK IMC to take the *European Kangaroo* - a multiple choice paper shared with 10 or so other countries, and taken by large numbers of students across Europe on the same day in March.]

In addition to the above events, we now have two residential meetings:

- the three day *Olympiad Training Weekend* - mainly for those in Years 12-13, held in Trinity College, Cambridge in April, and
- the *National Mathematics Summer School* for those in Years 10-11 (plus a few from years 12-13), held in The Queen's College, Oxford in early July.

The *Olympiad Training Weekend* has been going for 10 years or more, but is restricted to just twenty students, and is strongly focussed on preparation and selection for the IMO. The *National Mathematics Summer School* started only in 1994, is larger (with 60 or so students), involves mainly younger students (Years 10-11), and is more relaxed (though just as hard work). This year's second *Summer School* followed the same lines as last year, and was a great success. Next year we plan to try out a number of variations.

In the long run, success in Mathematics depends on students being willing to work on their own. This is one reason why we try to arrange for those who do well at the highest levels to have the chance of some correspondence work. However, what we really need is somehow to ensure that solving hard problems becomes a natural and accepted part of adolescent mathematical life in the UK! It is good to see that we now have a number of journals with problem corners: e.g. *Plus* for younger students, *Mathematical Spectrum* and the Student Problem Corner of the *Mathematical Gazette* for older students. But we do not yet have anything to match the journals available in Eastern Europe. **Any teachers who would be interested in helping to create such a journal should contact Tony Gardiner, School of Mathematics, University of Birmingham, Birmingham B15 2TT.**

Preparing for the 1995 IMO

How is the UK IMO team chosen? As a result of the *British Mathematical Olympiad Round 1* in January (which attracted a record entry this year of 850+), 105 students were invited to take *Round 2* in February. We then chose 20 students (including 10 or so younger students) to attend the three day *Olympiad Training Weekend* in Trinity College, Cambridge in April. The weekend ends with a 4 1/2 hour Olympiad-type paper, after which the UK *IMO* team of six-plus-reserve is chosen. This year's Magnificent Seven were:

Ed Crane	(Colchester RGS;	contact teacher Dr G Davey)
Matthew Fayers	(Wilson's S;	contact teacher D K Pearson)
Ben Green	(Fairfield GS;	contact teacher F Burke)
Peter Keevash	(Leeds GS;	contact teacher Dr RJ Jones)
Joseph Myers	(Rutlish S;	contact teacher I Makinson)
Louisa Orton	(Northgate HS;	contact teacher Y Gostling)
Hugh Robinson	(King Henry VIII S;	contact teacher JG Cooper)

Hugh was subsequently nominated as reserve. The Leader this year (his last) was Tony Gardiner (University of Birmingham), and the Deputy Leader (also in his last year) was Christopher Bradley (Clifton College).

How does the team prepare for the IMO? Most of the countries that land up in the top 15 or so at the IMO have residential 'training' camps - for one or two months (or more). Fortunately we in the UK cannot do likewise, since public examinations dominate the period from early May right up to the very end of June. Nevertheless it is important that those who go to the *IMO* should do themselves justice. Thus, in addition to the work students do in the process of being selected, some fairly serious preparation has to be done between April and July. Those selected somehow have to fit in a tough schedule of *IMO* correspondence problems, in addition to their ordinary school and exam work. The team then meets for a few days (this year at the *Mathematics Summer School* in Oxford) just before leaving for the *IMO*. This is the first time the students have met *as a team*, but they have already been suffering together (ringing each other up when necessary) for two months! Success at the *IMO* depends on how the team knits together, not just on how individuals perform.

Who else is involved? Hundreds of people! As indicated above, no school could take part if some teacher in that school was not willing to do the work of entering students and helping them to prepare. The papers would never be set if there were not teachers and mathematicians willing to give up their time to devise and to select the questions. The results would never appear if bunches of individuals did not abandon family and friends to mark the scripts and produce results lists. Prizes sometimes arrive late, but they would *never* arrive at all if the necessary work was not done. Residential meetings depend on tutors, and on support from places - like Trinity College (Cambridge) and The Queen's College (Oxford) - where we can meet. And though all the work is voluntary, everything costs money, so we could not continue without sponsors. But the most important part of any event are the participants. So we hope the hundreds of thousands of students who have taken part at various levels of the 'pyramid' this year feel that they too have 'been involved'.

The 36th IMO

How did we get on? The answer will depend on what one expects! My own priority is that students who represent the UK should find the experience not only challenging (i.e. hard), but also rewarding: that is, they should feel afterwards that they have achieved something. In an Olympiad problem-solving competition that means that every student should aim to solve at least one problem completely (out of three) on each day (easy to say, but much more difficult to achieve!). A secondary (but important) goal in boosting the team total is for each team member to try to avoid scoring zero on any problem. Faced with problems of a kind one has never seen before, with the clock ticking away, it is only too easy to get stuck, or to spend a long time on an approach which turns out not to work, and then to be left with nothing.

Each problem is marked out of 7 - and there are no sympathy marks. A perfect solution will score 7 marks, even if it includes the odd slip of the pen. The marking this year was exceedingly tough: the markers started from the assumption that solutions would fit into one of the categories

perfect solution	7
almost perfect	5
partial solution	2
nothing relevant	0

Thus it was almost impossible to score the "middle marks" of 3 or 4 on a question, and almost as hard to score 6. Judges were especially strict in deciding whether an interesting attempt was "relevant" or "irrelevant" to a possible solution of the given problem. Hence there were far more 0s than usual. The judges are looking for *solutions*; they are not there to reward bright ideas which *don't work*. The one exception is that a bright idea *which could have worked* does get rewarded: a partial solution which was simply not completed may score 3 marks, depending on how much is missing. [Thus, for example, Ben's scores of 3 and 4 on Q2 and Q6 show just how unlucky he was.]

In the event the UK team did (almost) everything I asked of them. Everyone scored at least one 7 on each day, and we almost avoided 0s (only two teams scored fewer 0s than we did!). Here are their scores, question by question.

	Q1	Q2	Q3	Q4	Q5	Q6	Total	Medal
Ed Crane	7	7	7	7	5	4	37	Gold
Matthew Fayers	7	7	5	6	7	0	26	Bronze
Ben Green	7	3	7	7	7	4	35	Silver
Peter Keevash	7	0	2	3	7	1	20	Bronze
Joseph Myers	7	7	7	7	2	7	37	Gold
Louisa Orton	7	7	2	1	7	1	25	Bronze

The cut-off scores for medals were set as follows:
Gold ≥37 (30 students); Silver ≥29 (71 students); Bronze ≥19 (100 students)

Like the Olympics the IMO is supposed to be a purely individual event, but there is strong interest in team rankings. Last year the USA finished way ahead, when all six of their students achieved perfect scores. This year they finished 11th, one place behind the UK. The standard this year was impressive with only two of the seventeen west European teams finishing in the top 25! The top twenty three teams were as follows:

China 236 (2), Romania 230 (9), Russia 227 (3), Vietnam 220 (6),
Hungary 210 (5), Bulgaria 207 (4), S Korea 203 (13=), Iran 202 (8),
Japan 183 (10), United Kingdom 180 (7), USA 178 (1), Taiwan 176 (13=),
Israel 171 (≥21), India 165 (16), Germany 162 (11), Poland 161 (13=),
Czech Rep 154 (≥21) & Yugoslavia (Serbia-Montenegro) 154(-), Canada 153 (≥21),
Hong Kong 151 (18), Australia 145 (12) & Slovakia 145 (≥21), Ukraine 140 (17).

Here are this year's questions: remember 4½ hours are allowed each day.

FIRST DAY

1. Let A, B, C, D be four distinct points on a line, in that order. The circles with diameters AC and BD intersect at the points X and Y. The line XY meets BC at the point Z. Let P be a point on the line XY different from Z. The line CP intersects the circle with diameter AC at the points C and M, and the line BP intersects the circle with diameter BD at the points B and N. Prove that the lines AM, DN and XY are concurrent. (Bulgaria)

2. Let a, b and c be positive real numbers such that $abc = 1$. Prove that
$$\frac{1}{a^3(b+c)} + \frac{1}{b^3(c+a)} + \frac{1}{c^3(a+b)} \geq \frac{3}{2}.$$ (Russia)

3. Determine all integers $n>3$ for which there exist n points $A_1, A_2, \ldots, A_n$ in the plane, and real numbers $r_1, r_2, \ldots, r_n$ satisfying the following two conditions:
   (i) no three of the points $A_1, A_2, \ldots, A_n$ lie on a line;
   (ii) for each triple i, j, k $(1 \leq i < j < k \leq n)$ the triangle $A_iA_jA_k$ has area equal to $r_i+r_j+r_k$. (Czech Republic)

SECOND DAY

4. Find the maximum value of x_0 for which there exists a sequence of positive real numbers $x_0, x_1, \ldots, x_{1995}$ satisfying the two conditions:
   (i) $x_0 = x_{1995}$;
   (ii) $x_{i-1} + \frac{2}{x_{i-1}} = 2x_i + \frac{1}{x_i}$ for each $i = 1, 2, \ldots, 1995$. (Poland)

5. Let ABCDEF be a convex hexagon with AB=BC=CD, DE=EF=FA, and $\angle BCD = \angle EFA = 60^\circ$. Let G and H be two points in the interior of the hexagon such that $\angle AGB = \angle DHE = 120^\circ$. Prove that AG+GB+GH+DH+HE ≥ CF. (New Zealand)

6. Let p be an odd prime number. Find the number of subsets A of the set $\{1,2,\ldots,2p\}$ such that
   (i) A has exactly p elements, and
   (ii) the sum of all the elements in A is divisible by p. (Poland)

You are invited to send in solutions - enclosing an SAE to: Tony Gardiner, School of Mathematics, University of Birmingham, Birmingham B15 2TT.

How is the IMO organised? This year's host, Canada, offered to host the 1995 IMO way back around 1990 - before the break up of the Soviet Union and of Yugoslavia - expecting to cater for up to 60 countries. In the event they landed up having to invite some 78 countries. This makes planning rather hard The host country is committed to invite all countries who took part in one of the three previous years - including parts of previously participating countries (together with any new countries it chooses). They cover all costs "from touchdown to take off". Thus other participating countries only need to cover the cost of preparation and travel. This system works remarkably well: the list of willing hosts stretches to 2003! The 1996 IMO is in India.

Each team has a *Leader* and a *Deputy Leader*. The *Deputy Leaders* travel with their teams. The *academic organisation* is the responsibility of the *IMO Jury*, on which each *Leader* has one vote. The Jury meets three days before the teams arrive - selects the problems, agrees on exact wording, and approves the translations (into nearly 50 languages)! The variety of educational systems, and of populations (from China with 1.5 billion to Trinidad and Tobago with around 150 000), make it a miracle that the system works at all. Yet despite its flaws, it does work - up to a point. Great care is taken to keep the *Leaders* (who know the six problems) separate from the teams (who don't).

This year things went remarklably smoothly, thanks to a superbly flexible-but-firm Chair - Professor Pat Stewart. (The Chair is always provided by the host country.) The 73 members of the Jury, together with 20 or so "Observers", met in the University of Waterloo - a university with six or seven different Mathematics Departments and around 3 500 undergraduates "math majors" and 350 postgraduate mathematics students! However, we saw little of the campus, and less of the town, being confined (very comfortably) in a student residence, 15 minutes walk from the central campus, with the temperature outside over 90°F, and breaks between our working sessions lasting only half and hour!

How are the problems chosen? Each participating country is asked to submit up to five problems. These form a pool of 120-150 questions. A local *Problems Committee* selects a shortlist of around 30 of the best problems submitted, and the *Jury* uses this as the basis from which the six *IMO* problems are selected. In principle the Jury could ask for additional (non-shortlisted) problems. For the last three years one of the questions submitted by the UK survived the selection process and has appeared on the final paper. This year we thought we had submitted some good problems, but not one of them survived to appear on the shortlist! The origin of each of this year's problems is given on page 5.

On arrival we were given the 30 or so shortlisted problems, and spent most of the next 24 hours trying to solve them, and to assess their merits without the benefit of solutions. The problems were better than in some recent IMOs - but that does not mean that it was easy to achieve a consensus as to which to choose. Assessing the difficulty of a problem is never easy - especially when solutions are to hand. In the event, the problems we chose were slightly harder than last year -though few members of the Jury knew that at the time.

Despite the fact that this year's problems turned out to be harder than most people expected, we would have liked them to be even harder! Ideally the six problems should include one or two of medium difficulty, and two or three real stinkers. This year's problems not hard enough for our liking: only when the going gets really tough does originality have chance to outperform mere training. Hard problems come as a surprise to everyone and allow bright but untrained students to compete with those who have been well-drilled. Problems of medium+ difficulty can trip up many students, yet be solved in a routine way by those who have been well trained. This year's Problem 2 was a good example: many middling countries scored six straight 0s on this question; but China, Russia, S Korea, and Vietnam scored six 7s, Bulgaria and Romania scored five 7s, Iran and Taiwan scored four 7s and a 2, Armenia four 7s. In contrast to these well trained teams, many countries came away with scarcely any marks on this problem: the UK score of three 7s, a 3, a 1 and a 0 reflected well on their originality - though we could have done better.

Jury members may have worked with their teams for several months, and take their job seriously. Indeed, there is a danger that things can be taken a little too seriously at times. Typical of the light touch of the organisers in Waterloo was the introduction of a "pool" in which Jury members could guess which six problems would appear on the final papers! Once the problems were known, we all guessed again how many "perfect scores" there would be, and what the "Gold", "Silver", and "Bronze" cut-offs would be. It is all to easy for "amateurs" to be intimidated by others with so much more experience. It was thus refreshing to discover how inaccurate many of these guesses proved to be.

Snapshots of the 35th IMO

Tuesday 18th July: It is 4pm and the Leaders have been ushered into the three front rows of the gallery in the *Ford Centre for the Performing Arts* in York, a suburb north west of Toronto, prior to the IMO 1995 Opening Ceremony. That morning we approved the last of the 47 language versions of the final problems and have just been on a pointless, three hour bus-tour-to-nowhere to keep us out of the way! We are being carefully kept away from the students. Slowly the teams trickle in and take their seats in the stalls below. Leaders and teams wave to greet each other. The UK team arrives and Ben throws me my team T-shirt. I put it on over my shirt-and-tie - the only gesture of solidarity available. It's a strange feeling: I have great faith in them all, yet cannot show it, or know how they will respond to the challenge we have set them.

After the speeches, the parade of flags, and a short but impressive laser show, the Leaders are ushered out to their buses to drive the 120km back to Waterloo before the teams are allowed to leave the hall. Tomorrow is D-day.

Wednesday 19th July: The first paper starts at 9am. For the first half hour of the exam, students are free to pose written questions to the Jury about the wording and meaning of the questions. With so many different school systems and so many different languages, it is better to know about (and resolve) any unintentional confusion before it blows up into an international incident! In the event, the number of queries is an all time low - just ten on each day. Most queries on Day 1 concern the meaning of the word "concurrent". The Jury's stock answers to most questions are "No comment", or "Read the question again". But in this case there is nothing to stop a definition being given (as was also the case on Day 2 when one student asked "What do you mean by 'an odd prime'? Surely *all* primes are odd." The reply: "$p \neq 2$"!).
The rest of the morning is devoted to long-term issues affecting the IMO, followed by a (purely scientific) visit to the local brewery.

This year, for the first time, all the scripts are photocopied before they are returned to us for marking. (In the past we were told a "sample" of scripts has been copied, but one suspects that this sample was rather small.) The task is daunting: if each student writes five pages on each problem, there will be more than 12 000 pages to copy in a few hours! Not surprisingly there is a slight delay before the scripts arrive that evening for marking.

Thursday 20 July: After the morning "Queries" session, we collect our things and board buses to transfer to the main site in York. We arrive at 1pm. It is a vast campus - "Beautiful", said one colleague, "but not for people!". My room is on the top floor of a 14 storey block. Fortunately most things are no more than half a mile apart. I find the exam room in time to greet the team as they emerge from the second paper: any flaws in their solutions have yet to dawn on them - not a good time for too many questions! We make our way to our 14th floor to be greeted by "box lunches". The food is clearly not the high point of this IMO: I am given free access to a box full of various "muffins" (muffins - giant cup cakes that have overflowed their paper cases - are to Canada what rice is to China). The team will be leaving shortly to watch the local baseball team - the *Toronto Blue Jays* - at the famous "SkyDome" (a huge baseball stadium with a roof), while Christopher and I try to make sense of

their scripts. At 7pm I walk the half mile to the IMO Office, collect the second day's scripts and return to a long night of marking. Around 1am I fall asleep while trying to make sense of Ben's Q2. The team are not yet back.

Friday 21 July: Judging begins at 9am on Friday: we have six sessions, each of up to 1½ hours, before bedtime - with endless "waiting in line". (We could come back on Saturday morning, but would miss the trip to *Canada's Wonderland* - an amusement park with huge rides.) The markers are well prepared and are going to be tough. Their job is to be firm and consistent; ours to present students' work as best we can. There are disagreements, but things work out as long as everyone feels that mathematics and consistency are being respected

We finish just before midnight. During the day students' scores are entered on a large scoreboard in one of the dining rooms. We now know our students' scores, but what about others? We go to peruse the giant scoreboard, but it is too tantalisingly full of "gaps" for us to be able to tell where the cut-offs will be, or how the team has performed. Eventually I decide on a working visit to the *Cock and Bull* pub to see what I can discover from other Leaders!

Saturday 22 July: Feeding 1200 people (contestants plus Leaders and Deputies plus Observers plus hundreds of helpers) is never easy. This means Breakfast is in two shifts and starts appallingly early. We arrive at *Wonderland* as it opens at 10am. It is another blistering hot day, and I have a foul headache (cause unknown!). Ideal conditions for boneshaking rides! As I queue for my second ride, I see Joseph looking slightly puzzled in a carriages of one of the more fearsome rides - *The Bat*. Seven hours later we meet again after much queueing, rattling of bones and aggravating of headaches. One of the Croatian students has won a giant gorilla - soon christened "*Miro*".

In the evening, the teams are taken out to meet the people of Toronto. Most teams were hosted by members of their own national community in Toronto ("the world's most international community"); for some reason the UK team are hosted by the Italian community. Meantime the Jury has its final meeting to confirm the scores and medals and to attend to other business. Ed and Joseph just make the Gold cut-off; Ben will be kicking himself for just missing (knowing he could have made it, and was certainly worth it). One has to be careful with "if onlys": my own view of the team is that they were certainly worth three Golds, two Silvers and a Bronze. But even if we had collected all the points we might reasonably have expected, we would still have done no better than 9th overall. There are some mighty good teams out there!

Sunday 23 July: Up even more horribly early for breakfast: 6.30 departure for *Niagara*. When shifting 6-700 people on buses things always go wrong. Relax! The power and beauty of the *Niagara Falls* are incredible - especially viewed from underneath in a boat! On the way home we stop outside *Fort George*, a nicely restored early nineteenth century stockade used by the British to defend this border country against the Americans. We arrive home weary, but ready (after a shower and change) for a long night. I manage to dance (as instructed by Matt) until the music is turned up for the third time.

Monday 24 July: I wake early from habit. The others are still sleeping! Breakfast has almost no takers. Brunch begins at 10. We try to sort out our rooms and pack our cases (since we leave for home very early next morning and may not have much time that evening!) before the buses depart at 11.30 for the *Closing Ceremony* (at the home of the *Toronto Symphony Orchestra*). The Closing Ceremony is very well staged. There are some nice touches - especially when Miro (of Croatia) brings his huge gorilla (also called Miro) onto the stage to collect his medal and insists that he too should have a handshake. The final banquet lasts almost four hours - including a marvellous video coverage of the whole IMO, starring many participants (including Ben and Louisa); most of the time is spent taking photos, exchanging addresses, and saying goodbye to those with whom one had shared a memorable ten days. Next morning the team woke me at six to catch our flight. Most had not been to bed!