

**REVIEW OF MATHEMATICAL BIOLOGY**

**AT BBSRC-SPONSORED INSTITUTES**

A report to BBSRC Council by the  
Review Panel commissioned by Council

November 2006

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## REVIEW OF MATHEMATICAL BIOLOGY IN BBSRC-SPONSORED INSTITUTES

### INTRODUCTION

1. In order to pursue modern biology it is necessary to have access to expertise in mathematical biology (defined in this context as embracing bioinformatics, modelling and statistics). Every four years, the BBSRC-sponsored institutes are subject to the Institute Assessment Exercise (IAE), which includes a Visiting Group (VG), of scientists and users of research who assess the totality of the institute's activities and outputs, including the intrinsic quality and strategic relevance of its research and where appropriate, the provision of mathematical biology.
2. The IAE 2001 exercise identified a number of issues in the provision of mathematical biology in BBSRC institutes and in response BBSRC provided extra resource (a £250K BBSRC grant for Bioinformatics and E-science) to the institutes\*. However, the recent IAE 2005 exercise has identified continued issues of provision and hence BBSRC Council commissioned this review.

*\*Not yet awarded to IAH*

### MEMBERSHIP

3. An independent panel of experts was set up to review of mathematical biology (MB) in BBSRC-sponsored institutes:

Professor Malcolm Weir (chair; BBSRC Council)	(ex-Inpharmatica, now MRC Technology)
Professor Andy Brass	University of Manchester
Professor John Crawford	University of Abertay
Professor Peter Donnelly	University of Oxford
Professor Mike Kearsey	University of Birmingham
Professor Christine Orengo	University College London

4. In addition the following members joined the panel for discussions at its last meeting with institute directors:

Professor Steve Buckland	University of St Andrews
Professor David Westhead	University of Leeds

### TERMS OF REFERENCE

5. The agreed Terms of Reference (TOR) for this review are to:
  - review current facilities and expertise in mathematical biology across the BBSRC-sponsored institutes;
  - identify gaps in provision, both currently, and arising from possible departures of key staff;
  - consider the appropriate balance between service provision, fundamental research, and technology development for the institute base;

- advise BBSRC Council on how to develop and maintain a suitable set of skills, expertise and infrastructure for the provision of mathematical biology within the BBSRC-sponsored institutes.
6. The panel divided mathematical biology into the three principal areas:
- Bioinformatics and quantitative biology (including QTL analysis, systems biology, the –omics and molecular analysis).
  - Statistical analysis and experimental design.
  - Theoretical biology and mathematical modelling
7. Furthermore the review was undertaken within the context of the three major strategic research areas crossing BBSRC-institutes:

Animal Health and Welfare

Roslin Institute (RI)  
Institute for Animal Health (IAH)

Biomedical and Food Sciences

Babraham Institute (BI)  
Institute of Food Research (IFR)

Sustainable Agriculture and Land use

Rothamsted Research (RRes)  
Institute of Grassland and Environmental Research (IGER)  
John Innes Centre (JIC)

**INFORMATION REVIEWED BY THE PANEL**

8. In April 2006 the panel considered:
- short reports from each institute on how they had used the £250K BBSRC Bioinformatics and E-Science (BES) grant (not yet awarded to IAH);
  - information from the 2005 Institute Assessment Exercise, particularly from the reports from Visiting Groups (VGs) independent peer review panel which visited the institutes over a 4 day period . Copies of the VG reports can be found at [http://www.bbsrc.ac.uk/about/pub/reports/06\\_feb\\_visitinggroups.html](http://www.bbsrc.ac.uk/about/pub/reports/06_feb_visitinggroups.html).
9. The panel also commissioned information in a standard format in response to a written questionnaire (**Annex 1**).

**“LIGHT TOUCH” VISITS TO INSTITUTES**

10. The panel agreed that panel members should visit each institute, between July and September 2006. Where possible, the same panel members visited all the institutes within each key strategic research area. The lead panel members for each strategic area were:

<u>Strategic Area</u>	<u>Lead Panel member</u>
Animal Health and Welfare (IAH, RI)	Mike Kearsley
Biomedical and Food Science (IFR, BI)	Christine Orengo
Sustainable Agriculture and Land Use (IGER, RRes, JIC)	John Crawford

11. The panel agreed that the visits should be built around informal discussions with institute staff. In particular it was felt important that a large proportion of the visit should be spent talking to staff without institute senior management.

12. The visits comprised:

- Brief introduction from senior management
- Overview of MB from leading staff
- Informal meeting with cross-section of staff/students including those delivering MB and those using it (no senior management present)
- Brief site tour

Individual reports, informed by the visit and the other information supplied to the panel (paragraphs 8-9), are at **Annex 2**.

### **MEETING WITH DIRECTORS**

13. The final element of the review was a meeting with each of the institute directors, who each made a short presentation to the panel. Directors were supplied with copies of the draft final report which informed their subsequent discussions with the panel. The panel agreed final changes to the draft final report at this meeting, including the development of an action plan (see Implementation).

### **KEY EMERGING ISSUES**

14. The main points are drawn from the generic issues emerging from the review (see **Annex 2** for individual institute reports); individual institutes are cited where the panel wishes to highlight examples of best practice.

### **General**

15. For the purposes of the review and this report mathematical biology is defined as: bioinformatics, statistics and modelling (see also paragraph 6). It was clear from the written submissions and from the site visits that there was a wide variation between institutes in the balance between these three components as well as in the resources allocated to them. Organisation of mathematical biology provision including the balance between service provision and basic research and/or technology development also varied significantly.
16. Many of these differences clearly resulted from the different requirements of each institute. However the panel also felt that this situation reflected differences of

vision and commitment to mathematical biology and how it could be applied to the institutes' science missions. While there were excellent examples of how innovative mathematical biology approaches were being applied to core science activities, it was not clear that all institutes fully recognised the potential applications and so were potentially under-exploiting their existing research outputs. Fundamental to achieving sufficient integration was the need to have mathematical biology at the heart of research activities, integrating experimental and theoretical biological approaches. Such a change will often represent a strategic realignment which is necessary if the potential of increasingly data-rich experimental biology is to be realised.

17. The remainder of this report sets out how the institutes might best achieve greater integration between 'wet' and 'dry' science, exploring the factors that are likely to affect it:
- the vision and leadership for mathematical biology;
  - the awareness, skills level and training of experimental biologists in mathematical biology;
  - the status of mathematical biology within institutes;
  - the structural organisation including the balance between wet and dry science;
  - the balance between mathematical biology service provision and basic research and technology development; the amount and sustainability of funding; and
  - the on-going professional development, recruitment and retention, of those delivering mathematical biology.

The report also explores the potential for closer working and sharing of best practice with other organisations including between BBSRC institutes.

### **Vision and leadership**

19. In the panel's view it was essential that the integration of mathematical biology and institute core experimental science should be at the heart of the institute's long-term strategy, fully to exploit all the scientific opportunities and to maintain international competitiveness. There was a wide recognition amongst institute staff that mathematical biology played a central role in the full exploitation of experimental research and that this was likely to increase greatly in the near future with the move towards more quantitative and systems biology approaches. However, this was not being fully realised in most institutes.
20. There were a number of excellent individual examples of the effective integration of experimental or 'wet' science with theoretical or 'dry' science from across most of the different institutes, with mathematical biology staff 'embedded' in research groups. However in most cases such integration did not cross the full spectrum of institute science. Most institutes lacked the appropriate level of mathematical biology input, particularly the application of advanced and novel mathematical biology approaches.

21. Levels of service provision in applied statistics and bioinformatics were more consistent, being applied primarily through a central facility accessible to all staff. However, in many cases, it was clear to the panel that staff were spread too thinly without clear prioritisation mechanisms being in place. This often resulted in these staff having little or no time to carry out any basic research or technology development.
22. Institute staff and senior management recognised that more resources were needed. However, the panel was concerned that, in most cases, there did not appear to be a coordinated strategy to achieve this. In some cases, the panel felt that institutes were reactive rather than proactive in supporting mathematical biology. In particular, there was a reluctance to accept the necessity to alter the balance between CSG-funded staff involved in wet and dry science. In many cases expansion of effort was too heavily reliant on opportunistic, short-term grant support, indicative, in the panel's view, of a lack of long-term commitment and vision by senior management at some institutes.
23. The panel felt that to develop a coordinated and strategic vision for mathematical biology, strong and focussed leadership in the area, from within the institute, was essential. To achieve this it was important that mathematical biology interests should be represented and championed by senior staff, including within the institute executive management structures. Leadership might come from a senior mathematical biologist heading a multidisciplinary team, or in the more classical form of the head of a core group of experts; it is likely that at least one such figurehead would be instantly recognisable within a given institute.
24. In the view of the panel, greater integration of wet and dry science across the whole range of institute research was necessary. Raised awareness and deeper engagement between experimental and theoretical scientists within the institute was required. This would be facilitated by adopting strategic approaches to training and recruitment.
25. The panel felt that the mathematical biology provision within an institute setting should be exemplified by meeting the following conditions: a long history of quantitative approaches to research, with a high skills level and awareness of mathematical biology across all sections of the research programme and at all levels of seniority within an institute, resulting in effective integration of wet and dry science. This would provide a critical mass of mathematical biology skills, essential to provide an attractive environment in which to recruit and retain key skills. In addition there would need to be a long-term commitment to, and development of, a clear vision for mathematical biology within an institute context. Importantly this must be backed up by commitment of significant core institute resources in a sustainable financial model of support.

### ***Recommendation 1***

*The development of a coordinated, long-term, strategic vision for mathematical biology was essential for the full exploitation of institute experimental science. This required:*

- *Visionary leadership and commitment from within the institute senior management*
- *Increased interaction between wet and dry scientists in a balanced model of service and research provision*

- *A proactive rather than reactive development of mathematical biology provision including a strategic approach to building capacity through training and recruitment*
- *A sustainable model of financial support*

### **Awareness and status of mathematical biology**

26. The panel identified the way in which mathematical biology was viewed by institute senior management and institute experimental scientists as a key issue. In some institutes mathematical biology was represented on senior management structures and had a clear 'voice' when competing for resources. This was particularly evident at one institute where many of the staff (at all levels of seniority) had a strong background in mathematical biology. At other institutes mathematical biology was regarded primarily as having a service or support function, and had to compete with other institute priorities (e.g. new investment in equipment) for allocation of funding from the Core Strategic Grant (CSG). Although there were mechanisms for indirect representation to senior management, the success or otherwise in obtaining funding was likely to be affected by the amount and level of direct representation within institute management structures. This also impacted on the status or at least the perception of status of mathematical biology, by other staff at the institute.
27. Where mathematical biologists had been 'embedded' into research groups the wider benefits of more complex quantitative approaches were increasingly seen as valuable and integral to the core research itself. However, with finite resources available, priority was often given to addressing basic service provision requirements (e.g. in statistics and bioinformatics) as this was often seen as the most immediate need by many institute staff and senior management. In such cases this was likely to have the effect of reinforcing the view of mathematical biology as equivalent to other service providers within the institute (e.g. computer services; administration).
28. The panel believed that more formal mechanisms, including participation of mathematical biology staff in seminars and research group meetings, would encourage greater engagement and there were some good examples of these approaches from some institutes. Moreover, a mathematical biology user group would be a useful mechanism for promoting increased feedback and dialogue. Greater participation and involvement of mathematical biologists in experimental research was essential for the successful and competent design, execution and exploitation of institute science.

### **Recommendation 2**

*Institutes should seek to raise the awareness, profile and status of mathematical biology and deepen the engagement between wet and dry science, reviewing and if necessary establishing formal mechanisms for encouraging and instigating outreach and integration. Staff should be encouraged to re-examine their work from mathematical perspectives, maximising exploitation and utilisation of existing work, so maintaining long-term competitiveness of institute research.*

29. The panel was concerned, that as a result of a lack of provision of mathematical biology input into institute research, there was likely to be a lack of awareness of

how mathematical biology approaches could be used to maximise the potential across the full range of institute science. Although the panel recognised that there were good examples of the effective exploitation of mathematical biology approaches, almost without exception this was only applicable for parts of the research programme within institutes. Without such awareness institutes may be missing out on key research opportunities and risk becoming non-competitive.

30. The panel felt that all institutes, in developing and sustaining a strategic vision for mathematical biology, would benefit from independent external advice including that drawn from national and international communities. This should be in addition to advice already provided through existing scientific advisory panels. Institute senior management should seek to obtain exemplars of best practice in mathematical biology provision from other organisations, including those analogous to research institutes from both the UK and overseas (see also Recommendation 9)

### **Recommendation 3**

*In developing and sustaining a strategic vision for mathematical biology, the panel strongly recommended that institutes should seek independent external advice, including that drawn from overseas organisations that exemplified best practice in mathematical biology.*

### **Capacity and balance**

31. It was sometimes difficult for the panel accurately to assess the proportion of institute resources directed to mathematical biology. Staff in support roles were clearly separated and identifiable, whilst in other cases mathematical biology effort had been fully embedded into science programmes for many years. Individual experimental scientists may have a particular skill in mathematical biology but this was not always recorded.
32. All institutes reported that they wanted to increase the resources allocated to mathematical biology, with some suggesting that 15-25% of total staff resources should be allocated to dry science. Most institutes, by their own estimation, had a much lower ratio of dry to wet scientists, in most cases by an order of magnitude or greater (in some cases well below 3% of staff were contributing to mathematical biology).
33. In most cases recognition of the need to increase resources for mathematical biology appeared to be aspirational, responding to a general awareness of the need to increase effort in this area. Most institutes had not developed a clear road-map in the context of a strategic vision and with a sustainable financial strategy. Although effective use had been made of funding from the Bioinformatics and E-science initiative, there was, in the view of the panel an over-reliance on opportunistic funding and a general reluctance to redirect significant additional resources from CSG. The panel was also concerned by reports from some institutes that, in seeking responsive mode funding to support projects with a significant mathematical biology component, BBSRC Research Committees would not fully support these costs.

**Recommendation 4 (BBSRC)**

*The panel recommended that BBSRC ensure that Research Committees review procedures for support of mathematical biology on grant funding, ensuring that Research Committees are themselves fully aware of the potential and opportunities offered by novel quantitative approaches.*

34. The balance between the different components of mathematical biology (i.e. bioinformatics, statistics and modelling) varied between institutes, reflecting both specific institute requirements and past investment. In some cases the panel was not satisfied that this balance was suitable for the future needs of institutes (see individual reports).
35. At some institutes mathematical biology was primarily seen as fulfilling a service or support role. At others mathematical biology staff were embedded to varying degrees within research programmes. In the view of the panel an appropriate balance between service provision and basic research and technology development was essential for mathematical biology to thrive within institutes. Without applying adequate and appropriate quantitative approaches there was a risk of under-exploiting the potential of institute experimental science, including post-genomic analyses and novel theoretical approaches. This would have long-term effects on national and international competitiveness.
36. At some institutes some of the gaps in basic research provision in mathematical biology had been very successfully addressed through productive strategic collaborations. The panel fully supported such approaches, but felt that this was not likely to address the needs across much of the institute programme where the potential for novel mathematical approaches may not always be recognised by institute staff. Integration of wet and dry science within the institute setting would enable, for example, a fresh look at existing work and perhaps lead to pilot studies which might uncover potential areas for exploitation, with or without external collaborators. Some institutes proposed coping with the lack of mathematical biology skills by internal training of wet lab staff but this indicated a failure to appreciate the depth of skills necessary to exploit the new quantitative, -omics based science now pervading international science, and the panel felt that more radical approaches to recruitment were required (see also Vision and Leadership, Recommendation 1, and Recruitment and Retention, paragraph 54).
37. It was the panel's view that in most cases there was neither the correct level of total resource nor the appropriate balance between different components of mathematical biology and/or between service and research provision (see institute reports). In the view of the panel only two institutes approached the optimal level of total resource allocation to mathematical biology, with only one of these approaching the correct balance between service and research. Expressed as the percentage of total institute staff involved in mathematical biology provision the panel strongly felt that this should be around 15%, but not less than 10%. Indeed this reflected the aspirations of most institutes. However the panel was concerned that five of the seven institutes were below 10%, and with three of these, less than 3% of staff were involved in mathematical biology (these figures based on estimates provided by institutes as part of this review). At such low levels of provision there was little opportunity for research and technological development, with even basic service provision being over-stretched.

### **Recommendation 5**

*The panel supported the aspiration that institutes should increase the ratio of dry to wet science. However it would be essential for this to be backed up by a clear strategic vision, and a sustainable financial strategy. In some cases there was an urgent need to radically increase the allocation of core resources to maintain (and in some cases achieve) a balanced, sustainable set of mathematical biology skills. The panel recognised that this process would require institutes to make radical decisions about overall priorities if they are to achieve the necessary increases in staff numbers and improved leadership in mathematical biology. The Panel recommended that institutes develop clear plans of how they intend to move forward to address this issue over the period 2007-2010.*

### **Management and organisation of mathematical biology**

38. Most institutes had developed a combination of clearly identified support roles and staff who were embedded into research programmes. This 'hub and spokes' model was endorsed by the panel. Critical to its success however was obtaining the correct balance between the different components. There was an on-going need for in-house provision of core support services (e.g. in applied statistics and bioinformatics), but this needed to be combined with greater integration between research groups and theoretical scientists.
39. A common observation was that mathematical biology effort was not distributed evenly across the range of research at institutes. At some institutes effort was, in the panel's view, too service-focussed with little or no integration with wet science. This often reflected the pattern of past investment history at institutes, but underlined the need to develop a more coordinated, strategic long-term vision with strong and focussed leadership.
40. In maintaining a mix of support and embedded roles, the panel felt it was important that the mathematical biology staff within an institute maintained a common vision, which ensured collective views were fed back to senior management. Embedded scientists should not be 'lost' permanently to a particular research group; they should continue to contribute to the expertise available to the institute. Similarly those primarily in service or support roles should be encouraged to develop closer links with research scientists as part of their ongoing continued personal professional development.
41. With clear pressure on resources the panel was concerned that in some institutes mathematical biology support services appeared to be provided to research staff on an *ad hoc* basis. The panel felt that without a formal and transparent mechanism for reviewing and prioritising tasks it would be difficult for senior management accurately to assess both the level of demand and the appropriate level and type of resource required.
42. The panel felt that institutes would benefit from sharing best practice and would encourage increased dialogue between institutes (see also Collaboration Between Institutes and Recommendation 9).

### **Recommendation 6**

*The panel supported the principle of a genuine ‘hub and spokes’ model for mathematical biology provision within institutes. This must correctly balance essential service provision roles in statistics and bioinformatics with the need to increase integration of dry science into research programmes fully to exploit mathematical biological approaches to core institute science. Institutes should review their existing arrangements to ensure key mathematical biology skills were more effectively utilised across all research programmes. Furthermore the panel recommended that institutes should have formal mechanisms to review and prioritise tasks and so more accurately determine level and type of demand for mathematical biology.*

### **Physical space and infrastructure**

43. The panel noted that where dry scientists (including those embedded within research groups) were physically located in the same unit this promoted a collective vision for mathematical biology and a greater awareness of the needs from across the range of institute science. Clearly it was critical for embedded scientists to balance their time within research groups and within a mathematical biology unit carefully.
44. The panel also emphasised the advantages of locating mathematical biologists within a central, easily accessible location, such as close to a central meeting/refreshment point, so promoting further, informal interactions with experimental scientists. The panel saw a number of good examples of this practice during its site visits.

### **Recommendation 7**

*The panel recommended that institutes consider the physical location of mathematical biologists as part of a process to deepen integration between wet and dry scientists whilst not undermining the collective identity and vision of mathematical biology staff.*

45. Most institutes reported that large –omics datasets had accumulated and that these were likely to increase further in size and complexity. The panel was concerned that resources established for database analysis, data entry, quality assurance and maintenance sometimes appeared vulnerable. It was not clear that there was a BBSRC institute-specific policy on the use and exploitation, including publicity and public access, of these potentially valuable resources and their associated intellectual inputs. The panel felt that where institute remits overlapped, that BBSRC ensure that a clear policy on data sharing was developed which needs to take account of BBSRC’s recently published data sharing policy ([http://www.bbsrc.ac.uk/society/dialogue/consultations/data\\_sharing\\_policy/Welcome.html](http://www.bbsrc.ac.uk/society/dialogue/consultations/data_sharing_policy/Welcome.html)).

### **Recommendation 8**

*The panel recommended that BBSRC should consider how to ensure the development of a compliant policy on the sustainable curation, management, and use of –omics datasets and associated intellectual inputs, from institutes and other BBSRC-sponsored research. In the view of the panel, these publicly-funded databases represented a valuable but potentially underutilised resource which could lead to productive*

*collaborations between institutes and with external partners, particularly in applying novel mathematical approaches and treatments.*

### **Recruitment and retention**

46. In the view of the panel, recruitment of mathematical biology staff was potentially adversely affected by a number of factors. A lack of critical mass and potential intellectual isolation within the institute was considered to be a particularly significant issue. It was essential that new senior mathematical biology staff were integrated into existing science programmes and not seen as another 'pair of hands' in a support role. At the same time institutes needed to encourage a separate mathematical biology identity. Managed correctly this would create an intellectually challenging, stimulating and attractive environment for recruitment purposes.
47. Some institutes benefited from the critical mass created by closer working with mathematical biologists at neighbouring universities, including the running of joint Masters courses. This also had the effect of acting as a pipeline for recruitment for students and postdocs.
48. The panel felt that there were opportunities to increase mathematical expertise in the institute as part of the normal process of recruitment to experimental research posts, provided this was also compatible with the needs of the core science programme (see also Vision and Leadership and Recommendation 1).
49. For staff embedded within research groups, career opportunities were the same as for experimental scientists. However for staff in primarily demand-led and, often stretched, support roles fewer career development opportunities were available. This was attributed primarily to the multidisciplinary nature of their work sometimes combined with a lack of leadership roles.
50. Formal recognition of mathematical biology input to publications was sometimes not recorded. Where it was, this was typically as an acknowledgment or as a junior author. The panel recognised the real difficulty for such staff in obtaining first or last authorships on publications. One institute reported that staff could build accreditation through the development of clear authorship agreements with colleagues leading the research programmes. The panel endorsed this approach and also encouraged mathematical biology staff to consider how to get additional value from the experimental research in which they were involved, for example, by publishing as lead authors where novel mathematical approaches had been developed.
51. The panel felt that institutes should seek to avoid labelling staff as either fulfilling "research" or "service" roles. A more flexible approach to career development, particularly at the interface between these roles should be managed to the benefit of individuals, who can broaden their experience, and to institutes, in being able to respond more effectively to changing demands. The panel also felt that the BBSRC should consider how the procedures and criteria governing promotion affected staff working in multi-disciplinary teams, particularly where this required a high-level but often transitory input to a number of different research programmes at an institute.

52. Some institutes reported that BBSRC pay levels were not always competitive, particularly where they were competing with industry (e.g. in applied statistics), and that recruitment was difficult. Where pay premiums had been applied including through the use of BBSRC Recruitment and Retention Allowances [RRA], these were reported as being at least partly successful, but the need to reapply on an annual basis to maintain the pay level created uncertainty.

**Recommendation 9**

*Institutes need to ensure that mathematical biology staff are able to interact with other dry and with wet scientists. There must be a critical mass of theoretical scientists to develop an attractive and intellectually stimulating environment to increase recruitment and retention. This was particularly important where institutes could not compete with other employers on the basis of salary alone. Institutes should ensure that, where appropriate, mathematical biology staff are formally recognised on publications, and should encourage such staff to publish independently in specialist journals.*

**Recommendation 10 (BBSRC)**

*The panel recommended that BBSRC review how the current procedures and criteria governing promotion affect staff whose job necessitates working in multiple teams. As appropriate, institutes should apply the existing flexibility within the pay system. BBSRC should seek to clarify and if appropriate simplify the relevant rules.*

53. The panel wished to highlight the particular difficulty in recruitment and retention of staff in applied statistics. Recruitment and retention in this area of mathematical biology was affecting all research organisations and not just institutes and was a potentially significant barrier to progress of BBSRC-sponsored science. The panel felt that institutes did not provide a sufficiently attractive environment in which to recruit. None could offer the financial rewards offered by commercial employers. Although tackling interesting and exciting biological questions may provide some incentive to recruitment, in most cases, the lack of critical mass did not appear to provide a sufficiently attractive intellectual environment to recruit into. The panel felt that this issue should be considered separately by BBSRC as it was a major capacity issue that could affect all research sponsored by the Council.

**Recommendation 11 (BBSRC)**

*The panel was concerned that recruitment and retention of expertise in applied statistics was a major capacity issue that potentially affected all research sponsored by BBSRC, not only institutes. The panel recommended that BBSRC consider its strategy in relation to the provision of statistics in biological sciences research.*

**Training**

54. Where mathematical biology skills were maintained at a high level across research staff and students, this had the effect of reducing pressure on mathematical biology staff, particularly in support or service roles. Such staff were then able to direct more time to research and technology development.
55. All institutes had in place a good basic training programme provided through a combination of in-house and external provision. The panel highlighted the good

- practice at a number of institutes of reviewing training needs and obtaining feedback on training provided. The panel felt there were opportunities for institutes to work together in meeting basic training needs. Where extensive in-house provision had been developed the institute should consider if this could be offered to staff at other institutes.
56. The panel identified a number of ways in which training opportunities could be increased cost-effectively. This included increased access to web-based modular courses. The panel also suggested that BBSRC should explore ways of cooperating with other Research Councils that provided appropriate training. Where BBSRC supports relevant university courses, arrangements should be made with the university to allow BBSRC staff to participate (subject to logistical and cost considerations).
  57. Although supportive of increased training in mathematical biology, the panel felt that this approach alone, would not address some of the key skills gaps that existed at some institutes (see also Vision and Leadership, Recommendation 1, and Capacity and Balance, paragraph 34).

**Recommendation 12**

*Institutes should review their training provision and consider mechanisms to increase training opportunities and deliver these more cost-effectively. Cross-institute cooperation may prove particularly beneficial since much of the basic training requirements were generic.*

**Recommendation 13 (BBSRC)**

*BBSRC should explore ways of ensuring maximum access to cost-effective training resources for institute staff. This should include working closely with other Research Councils that provide similar training. Where BBSRC supports relevant university courses, it should seek to negotiate arrangements that allow BBSRC staff to participate.*

**Collaboration between institutes**

58. There were some good examples of collaboration between institutes in the provision of mathematical biology and/or supporting technologies, often associated with a particular project or person. However, overall there was little evidence of a coordinated or strategic approach between institutes to the provision of mathematical biology support and training. The panel felt there were considerable opportunities for much closer working that were not being taken in: underpinning bioinformatics technologies; data management (see Physical Space and Infrastructure and Recommendation 6); the provision of basic support and training (see also Training and Recommendation 8).
59. There was significant opportunity to share best practice between institutes. The panel was surprised that there had been little formal or informal communication between those leading on mathematical biology at the different institutes. Time would be well spent in visiting other institutes to review how others approached management and organisation of mathematical biology. As a matter of urgency the panel felt that the relevant staff should meet to discuss opportunities for closer working and cooperation. BBSRC should also explore appropriate

mechanisms to facilitate closer working, including existing structures such as the Institute Research Computing Committee.

**Recommendation 14**

*The panel recommended that staff leading in mathematical biology at each institute should, as a matter of urgency, meet, and spend time at other institutes, to explore the potential for sharing best practice and closer working.*

**Recommendation 15**

*The panel recommended that BBSRC explore mechanisms for promoting the sharing of best practice and closer working between institutes.*

**IMPLEMENTATION**

The panel stressed the importance of monitoring the progress of implementation of the recommendations in this report and agreed the following action plan:

**ACTION PLAN**

Institutes will be asked to respond to the recommendations set out in this report with an action plan comprising specific milestones and timelines. It was felt that institutes could make significant progress within existing total resource, so in responding to these recommendations institutes should put forward cost-neutral proposals.

The panel wished to further emphasise to institutes the importance of seeking independent, external advice (international where appropriate) in developing their strategies to address the key recommendations in this report (see also Recommendation 3).

Institutes should prepare an interim action plan for the panel, within three months, and a final response at six months. The panel will as necessary provide advice and feedback on the interim action plan.

BBSRC should respond to the relevant recommendations within this report within 3 months. These responses will inform institute responses to this report.

## **SUMMARY OF RECOMMENDATIONS**

### *Recommendation 1*

*The development of a coordinated, long-term, strategic vision for mathematical biology was essential for the full exploitation of institute experimental science. This required:*

- *Visionary leadership and commitment from within the institute senior management*
- *Increased interaction between wet and dry scientists in a balanced model of service and research provision*
- *A proactive rather than reactive development of mathematical biology provision including a strategic approach to building capacity through training and recruitment*
- *A sustainable model of financial support*

### *Recommendation 2*

*Institutes should seek to raise the awareness, profile and status of mathematical biology and deepen the engagement between wet and dry science, reviewing and if necessary establishing formal mechanisms for encouraging and instigating outreach and integration. Staff should be encouraged to re-examine their work from mathematical perspectives, maximising exploitation and utilisation of existing work, so maintaining long-term competitiveness of institute research.*

### *Recommendation 3*

*In developing and sustaining a strategic vision for mathematical biology, the panel strongly recommended that institutes should seek independent external advice, including that drawn from overseas organisations that exemplified best practice in mathematical biology.*

### *Recommendation 4 (BBSRC)*

*The panel recommended that BBSRC ensure that Research Committees review procedures for support of mathematical biology on grant funding, ensuring that Research Committees are themselves fully aware of the potential and opportunities offered by novel quantitative approaches.*

### *Recommendation 5*

*The panel supported the aspiration that institutes should increase the ratio of dry to wet science. However it would be essential for this to be backed up by a clear strategic vision, and a sustainable financial strategy. In some cases there was an urgent need to radically increase the allocation of core resources to maintain (and in some cases achieve) a balanced, sustainable set of mathematical biology skills. The panel recognised that this process would require institutes to make radical decisions about overall priorities if they are to achieve the necessary increases in staff numbers and improved leadership in mathematical biology. The Panel recommended that institutes develop clear plans of how they intend to move forward to address this issue over the period 2007-2010.*

### *Recommendation 6*

*The panel supported the principle of a genuine 'hub and spokes' model for mathematical biology provision within institutes. This must correctly balance essential service provision roles in statistics and bioinformatics with the need to increase integration of dry science*

*into research programmes fully to exploit mathematical biological approaches to core institute science. Institutes should review their existing arrangements to ensure key mathematical biology skills were more effectively utilised across all research programmes. Furthermore the panel recommended that institutes should have formal mechanisms to review and prioritise tasks and so more accurately determine level and type of demand for mathematical biology.*

*Recommendation 7*

*The panel recommended that institutes consider the physical location of mathematical biologists as part of a process to deepen integration between wet and dry scientists whilst not undermining the collective identity and vision of mathematical biology staff.*

*Recommendation 8*

*The panel recommended that BBSRC should consider how to ensure the development of a compliant policy on the sustainable curation, management, and use of –omics datasets and associated intellectual inputs, from institutes and other BBSRC-sponsored research. In the view of the panel, these publicly-funded databases represented a valuable but potentially underutilised resource which could lead to productive collaborations between institutes and with external partners, particularly in applying novel mathematical approaches and treatments.*

*Recommendation 9*

*Institutes need to ensure that mathematical biology staff are able to interact with other dry and with wet scientists. There must be a critical mass of theoretical scientists to develop an attractive and intellectually stimulating environment to increase recruitment and retention. This was particularly important where institutes could not compete with other employers on the basis of salary alone. Institutes should ensure that, where appropriate, mathematical biology staff are formally recognised on publications, and should encourage such staff to publish independently in specialist journals.*

*Recommendation 10 (BBSRC)*

*The panel recommended that BBSRC review how the current procedures and criteria governing promotion affect staff whose job necessitates working in multiple teams. As appropriate, institutes should apply the existing flexibility within the pay system. BBSRC should seek to clarify and if appropriate simplify the relevant rules.*

*Recommendation 11 (BBSRC)*

*The panel was concerned that recruitment and retention of expertise in applied statistics was a major capacity issue that potentially affected all research sponsored by BBSRC, not only institutes. The panel recommended that BBSRC consider its strategy in relation to the provision of statistics in biological sciences research.*

*Recommendation 12*

*Institutes should review their training provision and consider mechanisms to increase training opportunities and deliver these more cost-effectively. Cross-institute cooperation may prove particularly beneficial since much of the basic training requirements were generic.*

*Recommendation 13 (BBSRC)*

*BBSRC should explore ways of ensuring maximum access to cost-effective training resources for institute staff. This should include working closely with other Research*

*Councils that provide similar training. Where BBSRC supports relevant university courses, it should seek to negotiate arrangements that allow BBSRC staff to participate.*

*Recommendation 14*

*The panel recommended that staff leading in mathematical biology at each institute should, as a matter of urgency, meet, and spend time at other institutes, to explore the potential for sharing best practice and closer working.*

*Recommendation 15*

*The panel recommended that BBSRC explore mechanisms for promoting the sharing of best practice and closer working between institutes.*

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