1st INCF Workshop

on

Needs for Training in Neuroinformatics

July 23-25, 2008 - Edinburgh, United Kingdom

incf

1st INCF Workshop on Needs for Training in Neuroinformatics

July 23-25, 2008

School of Informatics, University of Edinburgh

Scotland, United Kingdom

Author

David Willshaw

Scientific Organiser

David Willshaw, University of Edinburgh, Edinburgh, United Kingdom

Workshop Participants

Ad Aertsen	Bernstein Center for Computational Neuroscience (BCCN), Freiburg, Germany
Dagmar Bergmann-Erb	BCCN, Munich, Germany
Simone Cardoso de Oliveira	BCCN coordination, Freiburg, Germany
Peter Dayan	Gatsby Computational Neuroscience Unit, UCL, UK
Kenji Doya	Okinawa, Japan
Piotr Durka	Warsaw, Poland
Gary Egan	Melbourne, Australia
Gaute Einevoll	Aas, Norway
Jeff Grethe	Biomedical Informatics Research Network (BIRN), UCSD, USA
Rolf Kötter	Radboud University, Nijmegen,Netherlands
Kit Longden	Imperial College London, UK
Risto Näätanen	Århus, Denmark & Helsinki, Finland
Barry Richmond	NIH, Bethesda, USA
Raphael Ritz	INCF Secretariat, Stockholm, Sweden
Arjen van Ooyen	Amsterdam, Netherlands
Mark van Rossum	Edinburgh, UK
Jonathan Victor	Weill Cornell, USA
Hui Wang	INCF Secretariat, Stockholm, Sweden
David Willshaw	Edinburgh, UK

Kevan Martin (Zurich, Switzerland) was unable to attend the workshop but has been involved in drafting the report.

Scribes at discussion sessions: Catherine Ojo, Ian Saunders, Nicolas Heess, Edinburgh, UK

The following also contributed to the report:
Hirsch Cohen	Sloan-Swartz Foundation, USA
Erik De Schutter	Okinawa, Japan
Jim Bednar	Edinburgh, UK

Contents

1 Executive Summary

At this workshop the needs for training in neuroinformatics in the context of the current opportunities and challenges were discussed.

The delivery of two types of training was of particular interest. (i), Given that neuroinformatics requires the acquisition of knowledge from different disciplines, generally it is best for students to acquire the necessary background at the Masters level. Neuroinformatics Masters courses are an appropriate training medium for PhD students before embarking on their research; an ideal PhD course in neuroinformatics is described. (ii), PhD students who cannot profit from substantial Masters level training, researchers entering at the postdoctoral level and, in principle, academic staff, will all benefit from suitable short courses, which can range from a fraction of a day to a few weeks in duration.

Seven recommendations for the INCF were made, aimed at improving the provision of the appropriate training at national and international levels. These include: the inclusion in the INCF Portal information about current training material and information about training material of all kinds: the development of new short training courses and the support of existing ones, the development of a specific programme in neuroinformatics training, as well as future workshops on training. A list of the current training provision known to participants is contained in Appendix A and Appendix B gives a set of Web links relevant to neuroinformatics training issues.
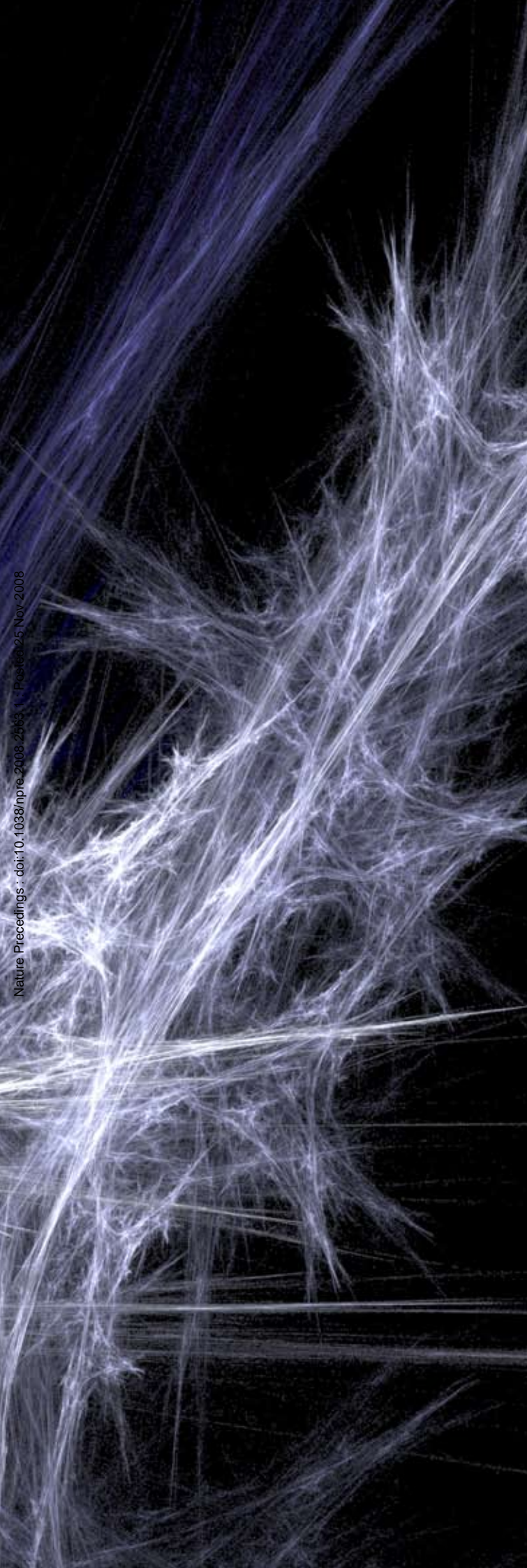
2 Introduction

Neuroinformatics, the new research field situated at the intersection of neuroscience and the physical sciences, is by its nature interdisciplinary.

Neuroinformatics requires the integration of knowledge from mathematics, physics, computer science and engineering together with detailed knowledge of the nervous system. It is essential that neuroinformaticians should be able to communicate with researchers across the spectrum of all relevant disciplines.

Neuroinformatics poses a specific challenge for training, as this variety of knowledge and research cultures is only rarely combined in one single place and often falls at the boundaries of traditional academic departments.

Given the broad scope of neuroinformatics, only few countries will be able to provide a wide range of neuroinformatics training; this will require international cooperation. It is therefore essential to establish best practice in neuroinformatics training at the international level.

2.1 Workshop

These considerations make a discussion of neuroinformatics training a highly relevant subject for discussion by the INCF. In cooperation with the UK Neuroinformatics Node, a 3-day INCF workshop was held in Edinburgh, UK, from 23rd to 25th July 2008. The intention was to discuss the best training for preparing neuroinformatics students for successful work in the academic, clinical or industrial/technological context. The four key aims of the workshop were to:

1. Establish the different target groups requiring training.

2. Establish a profile of the current provision for training.

3. Discuss needs for training and how this training should best be delivered.

4. Develop a set of recommendations for the INCF Board and thereby for national agencies and funding bodies.

The workshop was structured around a number of discussion sessions preceded by scene-setting talks by participants. This report is based on the summary reports of these discussion sessions.

The report is written for the Governing Board of the INCF. We hope that it may also be useful to the neuroinformatics scientific communities and national decision-making and funding bodies.

2.2 The scope of neuroinformatics & training

Neuroinformatics is concerned primarily with the application of methods from the physical sciences, such as mathematics, physics, computer science and engineering, to studying the nervous system.

The participants defined the following set of core competencies of which at least basic knowledge is expected of neuroinformatics researchers:

(a) Knowledge of the physiology, anatomy and biochemistry of the nervous system

(b) Knowledge of the brain at the systems/cognitive/ psychological level

(c) Experience in working in a "wet" neuroscience lab

(d) Mathematics at an advanced level including linear algebra, dynamical systems analysis

(e) Knowledge of stochastic modelling, time series analysis, exploratory data analysis and applied statistics

(f) Ability to programme in high level languages

(g) Knowledge of imaging techniques and image analysis

(h) Familiarity with widely used neuron and network models

(i) Knowledge of basic modelling techniques together with relevant simulators

There is a large range of additional specialised topics including, for example:

(a) Bioinformatics/systems biology

(b) Development of the nervous system

(c) Theoretical biology

(d) Brain/machine interface

(e) Hardware applications

(f) Clinical applications

(g) Computational neuroanatomy

(h) Large scale, reusable software development and parallel implementation

(i) Machine learning techniques

2.3 Target groups

Five different target groups for neuroinformatics training were identified, each with different training needs:

Group 1: Undergraduates
Group 2: Graduate students following a Masters course
Group 3: PhD students
Group 4: Postdoctoral researchers
Group 5: Academic staff

The concept of defining separate undergraduate, Masters and PhD programmes is essential to the European Bologna process, which aims to develop standards for training in European higher education by 2010, and corresponds approximately to the prevalent training structure in the USA.

3 Current Provision

All workshop participants contributed information about the training programmes known to them. From the discussions the following picture emerged, shaped by the fact that neuroinformatics depends on training in different disciplines, the combination of which is not encountered in conventional courses.

At the undergraduate and Masters levels, most neuroinformatics training is delivered as part of another degree programme. At the undergraduate level, there are no degree courses at present; at Masters level there are a few.

Some PhD programmes offer a period of training before students embark on their research, either in a neuroinformatics programme or in one in a related subject. Otherwise, PhD students acquire their training by attending the short courses available, which are of many different types and duration.

Most postdoctoral researchers and academic staff who receive training in neuroinformatics do so by attending short courses. Others receive informal "training on the job" or acquire their knowledge through reading text books or by browsing the web. While many of the longer (more than a week) short courses are configured for PhD students and postdoctoral researchers, there are no short courses designed for academic staff. However, there are funding schemes available for academics who wish to shift disciplines, corresponding to the more specific neuroinformatics-oriented fellowships available at the postdoctoral level.

The full list of current neuroinformatics training opportunities known to the participants is given in Appendix A.

4 Needs for Neuroinformatics Training

To carry out research requires the integration of different kinds of knowledge. It is difficult to train students so that by the end of their first degree they are equipped to do neuroinformatics research, having acquired sufficient knowledge of neurobiology coupled with the requisite mathematical and computational skills. To attain this solely through an undergraduate degree programme requires several structural and social barriers to be overcome. As described in Section A.1 of Appendix A, undergraduate programmes are emerging, which may help to make undergraduate teaching of neuroinformatics a firm possibility.

- The best opportunity for training students for neuroinformatics research is through Masters level training following a first degree in the biological or the physical sciences.

- Similarly, researchers who switch into neuroinformatics at the postdoctoral level are most likely to have acquired training in either the life sciences or the physical sciences and therefore need training in areas of research that are completely new to them.

In the discussion at the workshop it was decided to concentrate on the needs for two types of training: the training required to carry out a PhD (Group 3), which may also be relevant to Masters students (Group 2); and the training delivered in short courses, which is relevant to all groups at postgraduate level and beyond.

4.1 Training for a PhD

The overwhelming consensus was that to carry out neuroinformatics research, an extensive period of training is required.

4.1.1 Components of the ideal PhD course

The ideal PhD course has the following components:

1. This is made up of an extended period of training (typically 1 or 2 years) followed by 3 years of research. This will serve the needs of Group 3. Students obtain a Masters degree after the training period. The taught component could also be used as a stand alone Masters degree (Group 2).

2. Formal recognition of the course by the training institution is essential, as it increases the chances of attracting funding and other benefits enjoyed by properly constituted courses.

3. The training should be flexible and cater to different student backgrounds. In particular, there should be basic training in mathematical and computational techniques for life sciences students and training in basic biology for physical sciences students.

4. There should be a core set of taught courses together with a larger set of more advanced courses from which the students choose.

5. There should be lab rotations. This is a way of making students aware of the research being carried out in the local environment and of potential supervisors.

6. During the training, the students should have hands-on experience in at least one experimental lab.

7. There should be a range of additional activities, such as the students being given introductory texts to prepare them for the course, journal clubs, and seminars on success stories in neuroinformatics.

8. Students should be encouraged to spend time in another lab, preferably in another country.

9. Students' PhD topics should be decided at the end of the period of training, once the students have acquired knowledge of the subject and what is feasible within the specific environment.

10. The thesis committee should contain at least one experimentalist and one theoretical/computational person.

4.1.2 Contents of the taught component

The taught courses relate closely to the basic competencies that a neuroinformatics researcher should have, as discussed in Section 1.4.

Preparatory courses, to be studied by students to fill in gaps in their undergraduate education, are followed by core courses and then a set of electives, the contents of which depends on the local environment.

Preparatory courses: The precise training will have to be tailored to each student's background. In broad terms,

life sciences students will need mathematics at an advanced level and the ability to programme in at least one higher level programming language such as MATLAB or Python. Students from the physical sciences require a basic knowledge of biology and neurobiology.

Core courses:

(a) The physiology, anatomy and biochemistry of the nervous system

(b) How neurons interact, specifically their role in development, sensory processing, learning & memory and motor systems

(c) Neural processes at the cognitive/psychological level

(d) Imaging techniques and image analysis

(e) Time series analysis and signal processing

(f) Data acquisition, storage and analysis techniques

(g) Common neuronal and network models, such as Hodgkin-Huxley, integrate-and-fire neurons and mean field models and their best known applications, such as in associative memory and sensory processing

(h) Basic modelling techniques together with relevant simulators such as NEURON and GENESIS

(i) Experimental design and model evaluation

Optional courses:

There is a large range of additional, specialised topics from which specialised options can be chosen, including:

(a) Bioinformatics

(b) Systems biology

(c) Theoretical biology

(d) Developmental neurobiology

(e) Functional neuroimaging and high density EEG/MEG

(f) Computational neuroanatomy

(g) Software development for neuroscience

(h) Neuroscience databases

(i) Information theory and neural coding

(j) Machine learning techniques, including Bayesian approaches

(k) Brain/machine interface

(l) Neuroprosthetics

(m) Hardware applications

In addition, it is important to have courses available on transferable/soft skills, such as time management, paper writing, giving presentations, preparing posters, etc.

4.1.3 Practical issues of implementation

At any particular university or research institute that offers neuroinformatics training, local structural constraints will shape the actual course that can be constructed.

In some universities it may be difficult to organise a degree course across different departments or faculties, or it may be easier to cater to students exclusively from the life sciences or the physical sciences, rather than from both.

Local research directions will define the content of the optional courses to be offered to students and so it is to be expected that different courses will acquire their own flavour.

Given the specific national and local constraints, some of the essential components of this ideal course will be missing in any particular programme. Cooperation between different institutes is therefore desirable; for example, by allowing students from other institutes to attend courses or to host student visits.

4.2 Short courses

The workshop participants felt that short courses play an extremely valuable role in the education of PhD students and postdoctoral researchers. For both target groups they provide essential training that otherwise would be unavailable to the student or researcher. Short courses should be continued and expanded in type and number. Academics especially would profit from shorter tutorials for interested non-experts; particularly to introduce experimentalists to novel ways of using their data. In our recommendation R3, we propose that the INCF takes part in this process. In addition, Recommendation R2 is that the INCF facilitates other methods of delivering training, particularly using the Internet.

We found a number of shortfalls in the courses currently available, which need to be addressed:

- Many courses are chronically oversubscribed. This could be seen as a positive feature which allows organisers to select the optimal mix among motivated students. However, this also means that many students do not obtain the much-needed training,

- Most of the courses are expensive, which is another barrier to student attendance, especially in labs that are new to neuroinformatics and so do not have the funding available.

- There is an uneven coverage of topics. For example, there are few experimental neuroscience courses which are accessible to non-biologists because of competition for places with life scientists. There are no courses teaching neuroinformatics tools for data base applications.

- There is no course designed specifically for academics who wish to learn about neuroinformatics; neither for physical scientists to learn about neuroscience nor for biologists to learn about the mathematical basis of computational methods. Academics do attend very short courses; organisers of courses stretching over weeks tend not to select academics because of their effect on community building amongst the much younger participants.

- While some of the annual courses have a secure financial basis, many do not. For example, the European advanced course on computational neuroscience has trained around 500 students over 13 years, yet it has been a struggle to obtain reliable funding from year to year.

5 Recommendations

Workshop participants made seven recommendations. R1 is a general recommendation about neuroinformatics; R2 is about using the INCF portal. R3, R4 are about supporting training, R5 is about funding schemes, and R6, R7 are about future activities looking at neuroinformatics training issues. Any measures that are adopted should encourage the increased involvement of women, who are insufficiently represented in the field.

5.1 Outreach and publicity actions

A prime factor for the success of the INCF in developing and facilitating neuroinformatics worldwide is that neuroinformatics becomes known beyond the confines of the neuroinformatics community.

There are at least six important groups who need to be informed as to what neuroinformatics is, why it is important and, in the present context, why it is important to develop neuroinformatics training. These are:

- Students at the Masters and undergraduate levels and pupils in high school
- The basic and clinical neuroscience communities who are not involved in neuroinformatics
- Other related scientific communities such as those working in systems biology, computer science, physics, etc.
- Commercial sectors such as pharmacology and computing where neuroinformatics may find application
- The general public
- Politicians and decision makers of funding agencies

Recommendation R1: that a professional science writer be employed to develop one section of the INCF portal to contain a layperson's guide to neuroinformatics topics, including academic success stories, interesting CVs of leading neuroinformatics figures, and sets of FAQs.

5.2 Web-based training portal

There is great scope for using the INCF portal to aid neuroinformatics training.

It could provide details of all current undergraduate, Masters, PhD courses, short courses and training seminars available and as much of their contents as is possible.

This will help students make their choices and also make teachers aware of other courses.

Given the current shortage of training opportunities, other ways of providing training material are also needed. The portal could contain relevant materials of many different types (including those mentioned under 4.1), such as:

- Recorded talks in different formats, particularly those suitable for the general public or high school students
- Interviews with eminent people in the field
- Information about relevant text books
- Other self-study materials, such as sets of benchmark data suitable for testing competence in a particular technique
- Materials that could be used for training that relate to the areas in which the INCF has established working groups.

The portal could also be used to record information about the destinations of students after training, valuable for both course evaluation and for applications for funding. This could be a resource for people wishing to organise follow-up networking.

Inspiration for using the INCF portal for training purposes can be gained from the Society for Neuroscience web-based neuroscience teaching portal at http://www.ndgo.net/sfn/nerve/.

Recommendation R2: that a section of the INCF portal be used for making material relating to neuroinformatics teaching universally available.

5.3 Support of short courses

It is crucial that the current short courses be maintained and expanded, in terms of the number of places available and the coverage of themes and target groups (such as academic staff, for which no course exists). The INCF should undertake an initiative to ascertain where the need is most prominent and should facilitate and support courses, financially where possible. In addition, the INCF could develop or support existing or new annual courses in areas of need. It is strongly recommended that such a course be organised immediately before or after the annual Neuroinformatics Congress.

Recommendation R3: that the INCF identifies short courses that are needed, coordinates funding initiatives, develops new courses, and supports existing courses financially.

5.4 Training visits

In the discussions at the workshop, the importance of students having experience of different research environments was emphasised. This would be one way for theoreticians to experience experimental neuroscience. We recommend that the INCF encourages institutions to initiate schemes for training visits, advertises such opportunities (see R2) and makes funds available for such visits.

Recommendation R4: that the INCF develops a scheme of visits for training purposes and sets up a site on which requests and offers can be posted.

5.5 Novel funding schemes

There are national funding schemes that support neuroinformatics training which could well be adopted by other countries.

Examples of suitable schemes are:

- Many, but not all, national bodies provide explicit funding for PhD programmes
- Some countries run fellowship schemes that enable researchers to enter neuroinformatics at the post-doctoral level
- Discipline hopping schemes enable academic staff and postdoctoral researchers to change fields

Recommendation R5: that the INCF collects and evaluates information about novel funding schemes that potentially are applicable to neuroinformatics; and that the INCF encourages funding agencies to adopt or maintain those schemes that have been proven successful.

5.6 Future workshops about training

As representatives of the academic basic science community, workshop participants felt that there were other topics that have an impact on neuroinformatics training that could be discussed at a separate workshop. Of particular interest was the possible application to clinical neuroscience and to commerce and industry, particularly the pharmacological sector. One subject to discuss

would be the organisation of placements in industry.

Recommendation R6: that future workshops on training issues be organised, particularly one to discuss training issues relating to clinical and industrial applications and in which clinical and industrial representatives take part.

5.7 Coordination of training issues at INCF level

We recommend that the INCF establish an INCF activity in the area of training. This would involve the formation of the respective committees and planning a set of activities. There is a need for a person at the INCF Secretariat to be directly responsible for training matters.

Recommendation R7: that an INCF Programme be set up and a designated person at INCF Secretariat be responsible for the coordination of matters concerning neuroinformatics training.

Appendix A: Current Teaching Provision

The current teaching provision is described by giving examples of what are known to the participants as highly respected programmes. It was not the intention, nor was it possible, to give an exhaustive list.

A1 Group 1 (undergraduates)

A1.1 Degree programmes in neuroinformatics

Currently there is no undergraduate programme in neuroinformatics. There is a BSc course under development and due to be launched at Warsaw in Autumn 2009. Half of the curriculum is made up of courses in physics and applied mathematics. In the other half there are (i) courses in cell biology, neurobiology and psychology together with (ii) a variety of elective courses including neural networks, statistical inference and programming. In addition, there is (iii) significant practical training in EEG acquisition and analysis.

A1.2 Neuroinformatics as a significant part of a degree programme

The Center for Neural Science at New York University, USA, offers a major in Neural Systems. In one half of the course, students study physics, chemistry, psychology and mathematics. In the other half, there are mandatory courses on cellular & molecular neuroscience and on behavioral & integrative neuroscience. The several elective courses include computational neuroscience. There are two lab rotations.

The Radboud University Nijmegen, Netherlands, offers undergraduate students in biomedical sciences a Master in Clinical Human Movement Sciences with an optional Minor in Neuroscience. The latter comprises several systems neuroscience courses with a strong computational component and an elective of at least 4 months, which may be done in a relevant "wet" or computational lab.

The Centre for Neurogenomics and Cognitive Research (CNCR) at the VU University Amsterdam, Netherlands, offers undergraduate neuroscience courses including courses on computational neuroscience, neuroscience-oriented bioinformatics and systems neuroscience.

The Faculty of Information Technology at the Peter Pazmany Catholic University at Budapest teaches a 3-year undergraduate degree in Information Engineering with a minor in neuroscience and genetics.

The Division of Biophysical Engineering, Department of Systems Science, Osaka University, Japan offers an undergraduate course combining biological and physical sciences teaching, including neurophysiology, cell biology, signal processing and computer programming.

A1.3 Neuroinformatics courses as a small part of a degree programme

Despite this lack of formal courses, many students gain a valuable introduction to neuroinformatics by studying for a degree in a related subject in which courses in neuroinformatics form a small component of the degree. To give one example, a survey of neuroinformatics teaching in the UK in 2006 revealed that 23 universities offered such courses, mainly in the final year of study. These were in degree programmes in mathematics, physics, computer science, informatics, electronics, engineering, bioengineering, biosciences, physiology, neuroscience, psychology or cognitive sciences.

A2 Group 2 (Masters students)

The definition of a Masters courses used here is that it is a separate degree course taken after the Bachelor's and has as prerequisite the Bachelor's degree. PhD courses that contain a large amount of course work where Masters degrees can be awarded to students who finish prematurely are included in Section A3 (Group 3, PhD students).

A2.1 Dedicated Masters degrees in neuroinformatics

There are Masters degree programmes devoted specifically to neuroinformatics, or to one strand of neuroinformatics. Most of these courses are a combination of taught modules and a research project.

The goals of the 18-month Master in Neural Systems and Computation at the University of Zurich and the Swiss Federal Institute of Technology is to supply training in experimental, theoretical and computational neurosciences and neuromorphic engineering. The programme is open to students with a Bachelor's degree in biology, chemistry, mathematics, physics, computer science, information technology or engineering.

The University of Manchester, UK, offers a 1-year MSc in Computational Neuroscience and Neuroinformatics to

both biology graduates and those from the numerate sciences. The first of three semesters has courses on computational neuroscience and methods in neuroinformatics, together with a course in mathematics for the biologists and one in neuroscience for those from the numerate sciences. In each of semesters 2 and 3, the students carry out a research project, on two different topics. Funded places are available.

The University of Plymouth, UK, offers a 1-year MSc in Theoretical and Computational Neuroscience. Two teaching streams are recognised, according to whether students are from the life sciences or the physical sciences. Students are taught a wide range of theoretical techniques, including mathematical and computational modelling, probabilistic methods for analysing data and topics from neuromorphic engineering and brain inspired computing. There are two semesters of taught courses and in the third semester a research project is undertaken.

The University of Edinburgh, UK, runs a large 1-year MSc degree programme in Informatics, comprising taught courses and a summer project. Students choose a particular combination of courses. One of these is neuroinformatics, with courses on neural computing, neural information processing, computational neuroscience of vision, cognitive modelling, probabilistic modelling and machine learning.

In Berlin, Germany, a 2 year Masters in Computational Neuroscience started in September 2006. "It uses theoretical approaches from a variety of disciplines including mathematics, physics, computer science and engineering to understand the brain". The first year is devoted to taught courses, the second year to lab rotations and a research project. The course is taught by the Berlin BCCN, with representation from the three major universities in Berlin.

A2.2 Courses as part of a Masters degree in another subject

As for Group 1, a variety of courses with neuroinformatics content can be taken as part of a Masters degree course in another subject. These subjects may be either one of the physical or the life sciences.

Courses taught in a life sciences department

Many of the seven two-year Masters courses in Neuroscience in the Netherlands include courses on neuroinfor-

matics related topics, such as computational neuroscience, neural development, systems biology, cognitive modelling, data analysis and image analysis. The universities offering these courses are Amsterdam, Groningen, Maastricht, Nijmegen, Rotterdam, Utrecht, and the VU University of Amsterdam.

In Germany, the Universities of Bremen, Göttingen, Heidelberg, Magdeburg, Munich, Rostock and Tübingen all now offer Masters courses in Neuroscience with a neuroinformatics component. Typically the courses are 18 months long, combining taught courses, lab rotations, and a research project.

In addition, Germany still maintains, at a few places, the traditional Diploma degree education in which students acquire a Diploma degree in Biology with a possible specialisation in neuroinformatics according to the courses they choose and the specialization in their research towards the Diploma thesis. In Freiburg the Diploma course is soon to be replaced by BSc and MSc programmes.

The neuroinformatics-related specializations at Freiburg, Göttingen and Munich are in association with the Bernstein Centers for Computational Neuroscience (BCCN; see Section A3.1).

The University of Sheffield, UK, offers a 1-year MSc in Cognitive and Computational Neuroscience.

The Norwegian University of Science and Technology at Trondheim offers a 2-year Masters programme in Neuroscience, which has some neuroinformatics content (http://www.ntnu.no/studier/helsefag/mnevro).

The University of Helsinki, Finland is offering a 2-year Masters course in Neuroscience from September 2008. This comprises taught courses and a research project (consisting of one third of the total time). The focus is on experimental neuroscience although a few of the courses are devoted to topics in neuroinformatics.

Courses taught in a physical sciences department

In the UK, both the 1-year Advanced Computing MSc at Bristol and the 1-year Bioengineering MSc at Imperial College London have a neuroinformatics component.

One variant of this theme is used at the University of Waterloo, Canada. The Centre for Theoretical Neuroscience (http://ctn.uwaterloo.ca) offers a diploma to students al-

ready registered for a Masters (or PhD) in a related discipline. Students attend a course on simulating biological systems, two courses chosen from a list of options and a seminar in theoretical neuroscience.

The International Masters Programme in Computational and Systems Biology in Stockholm, Sweden has a module on mathematical modelling that focusses on neural modelling. http://www.csc.kth.se/utbildning/program/compsysbio/.

The Master of Science programme in Computational Biology at the Norwegian University of Life Sciences, Aas, Norway also has a neuroinformatics component. http://www.umb.no/21220

A3 Group 3 (PhD students)

Most students in neuroinformatics have to acquire several different types of knowledge and skills which should necessitate their attending formal training courses. In some cases this training is integrated in the PhD course; in some cases students receive their training while being enrolled in a programme in one of the related larger disciplines (e.g., physics, biology, computer science); in other cases, they attend short courses; in some cases, the training that they receive is acquired implicitly while carrying out their research project, without participation in formal courses.

A3.1 Neuroinformatics PhD courses

The basic structure for training doctoral students in the USA would seem ideal for interdisciplinary education as they study for over 5 years, with taught coursework in the first two years (roughly equivalent to a Masters programme), followed by a research project (similar to a European PhD).

PhD programmes specialising in computational neuroscience exist at the Universities of Chicago, Princeton, Pennsylvania and Carnegie Mellon.

The Interdisciplinary Center for Neural Computation (ICNC; http://icnc.huji.ac.il) at the Hebrew University, Jerusalem, Israel, is the largest and oldest dedicated neuroinformatics PhD programme worldwide and has been in existence since 1992. It takes in around 12 funded students per year for a 5-year course in computational neuroscience. Student backgrounds include biology, physics, chemistry, psychology, computer science, engineering

and mathematics. Students acquire theoretical and experimental expertise in neurobiology and psychology (including information processing in nerve cells), physics (including neural networks and statistical mechanics) and computer science (including computation theory and optimization).

The Gatsby Computational Neuroscience Unit at University College, London, UK has run, since 1998, a 4-year PhD programme in theoretical and computational neuroscience and machine learning. In the first year, there is intensive instruction in techniques and research in theoretical neuroscience and machine learning. This is made up of core courses followed by specialist courses in theoretical neuroscience and in machine learning and then a research project. Students have to undergo assessment before admission to the 3-year research for their PhDs.

The Doctoral Training Centre in Neuroinformatics and Computational Neuroscience at Edinburgh, UK, opened in 2002 and admits around 10 funded students per year on a 4-year programme. This is intended for students from the physical sciences and so a criterion for admission is a good level of mathematical and computational knowledge. The first year is effectively a Masters course involving a combination of coursework and research project. The first semester is shared with students studying for the MSc in Neuroscience. In the second semester, students study neuroinformatics courses including a course based on the local neuroinformatics research. Over the summer, students carry out a research project in an experimental lab. During this first year, the students decide on their PhD project, which they carry out in years 2 to 4.

In Germany, all four Bernstein Centres, at Berlin, Freiburg, Göttingen and Munich offer training for PhD students in computational neuroscience. The courses offered by BCCN Berlin are formalised into a 3-year programme, in which, in addition to carrying out research, each PhD student takes one full-time semester of course work.

A3.2 PhD courses with a major neuroinformatics component

The Computation and Neural Systems programme at Caltech, USA, combines the study of computation with that of neural systems. The curriculum is designed to promote a broad knowledge of relevant aspects of experimental and theoretical molecular, cellular, neural, and systems biology; computational devices; information

theory; emergent or collective systems; modelling; and complex systems.

At Weill Cornell, USA, neuroinformatics graduate training is part of a larger programme in computational biology. The course is made up of one summer of lab rotations, one year of coursework in mathematics, applied mathematics, and computer science, a year of lab rotations and biology coursework at the medical school campus, and then thesis work (2-3 years). About one third of the students are interested in neuroscience, and the students with little biology background seem to benefit a lot from this training.

The German Research School for Simulation Sciences has initiated a joint training activity involving RWTH Aachen and the Jülich Research Centre (http://www.grs-sim.de/), hosting the largest civil computing resource in the world. Masters and PhD degrees are awarded by the RWTH Aachen after 2 and 3 years, respectively.

In the Netherlands, CNCR at the VU University Amsterdam offers PhD research projects on neuroinformatics topics. Students can attend courses in neuroscience as well as from other disciplines such as mathematics and theoretical biology.

In Japan, the Department of Bioinformatics and Genomics, Nara Institute of Science and Technology, the Department of Complexity Science and Engineering, University of Tokyo and the Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology all offer teaching and research programmes in computational neuroscience.

A3.3 PhD training delivered through short courses

There is a wealth of courses which PhD students can attend, ranging from one-off single day (or even shorter) courses to week-long or month-long courses. Many run on an annual basis. These courses are attended by PhD students, postdoctoral researchers and, exceptionally, academic staff. Therefore, the comments made in this section about these courses may also apply to groups 4 (Postdocs) and 5 (Academics), as well as to group 3. It is convenient to distinguish short courses which are for one week or more from those which are for less than one week.

A3.3.1 Short courses with a duration of one week or more

These courses combine seminars with hands-on, practical work and are restricted to a small number of students, typically between 12 and 30. Course fees are charged but most courses award stipends to students.

The courses are very competitive and are designed for early career researchers and most attendees are doctoral students. The courses fulfill the need for students in neuroinformatics who wish for training in another technique or wish to increase their knowledge of a particular topic. However, they cannot serve to give a basic grounding in a subject (such as teaching neuroscience to a physicist). Here are some examples of short courses:

The Marine Biology Laboratory, Woods Hole, USA (http://www.mbl.edu/) and Cold Spring Harbor, USA (http://www.cshl.edu/), each runs an annual programme of courses. The 3-week course Methods in Computational Neuroscience, the 2-week course Neuroinformatics (focusing on methods for acquisition, storage and analysis of time series neuroscience data and, more recently, computational neuroanatomy), both offered by Woods Hole, and the 3-week course Computational Neuroscience: Vision offered by CSHL all emphasise the multidisciplinary approach. Many other courses would be of interest to students studying neuroinformatics, but generally are less accessible owing to the severe competition for places with neuroscientists. About half the participants on the Woods Hole courses are graduate students.

The Computational Neuroscience Course at Okinawa, Japan has run annually since 2004. Currently it is three weeks long. Its aim is "to provide opportunities for young researchers with theoretical backgrounds to learn the latest advances in neuroscience, and for those with experimental backgrounds to have hands-on experience in computational modelling."

The 4-week European Advanced Course in Computational Neuroscience This course has run every year since 1996, offering 30 places per year. The course is intended for "advanced graduate students and postdoctoral fellows who are interested in learning the essentials of the field." The course offers a combination of lectures and tutorials with small projects conceived by the students are performed by them under the guidance of course tutors and faculty.

The one-week school in April/May 2008 in St Petersburg, Russia, Models in Neuroscience: Turning Experiments into Knowledge (http://www.neuroscience.spb.ru/school) focused on training students to transform experimental data into plausible theoretical models. The goal of the school was to bridge the gap between future cellular and cognitive neuroscientists and to engage the students majoring in physics and mathematics into the field of computational neuroscience. The course was designed for graduate students and young post-doctoral researchers with interest in cellular and cognitive neuroscience as well as the students with physics/math majors.

The week-long course on Computational Neuroscience run by the BCCN, Göttingen, Germany, has been presented annually since September 2003. It combines 3-hour tutorials by visiting speakers with the study of selected research papers. The course is intended as a tutorial for BCCN students as well as an open course for external students. It attracts around 25 participants.

A3.3.2 Short courses with a duration of up to one week

There is a variety of training events of this length, ranging from a few hours to a day or two. Some of these occur regularly, being attached to regular scientific meetings; some are organised on a one-off basis. Some are free and some charge a fee. Here are some examples:

Since 2002 the functional neuroimaging community involved in Statistical Parameter Mapping has held a variety of training events lasting 2-3 days typically, initially in London and now spreading to other locations. The courses are very popular. They are attended mainly by people working in the field already and fees are charged.

The Japanese Neural Network Society has organised a Neuroinformatics Summer/Autumn School from 1999 to 2003 and from 2006.

A 1-day techniques course precedes the annual Human Brain Mapping conference.

The Society for Neuroscience holds short courses at the SfN annual meeting, such as the annual one-day course on the widely used neural simulator, NEURON (http://www.neuron.yale.edu/dc2008.html).

NIPS, the annual Neural Information Processing Systems Conference (http://nips.cc), which attracts predominantly mathematicians and computational people, runs 2-hour tutorials in which neuroscience topics figure strongly. These are attended by pre- and postdoctoral workers and by academics.

Various organisations, such as learned societies or local networks, run one-off courses teaching a technique. For example, the UK Spike Train Analysis Network (http://www.spiketrain.org/) ran a one-day workshop for mathematicians on spike train analysis methods.

Immediately following the 1st Neuroinformatics Congress, the INCF held a two-day autumn school for PhD students on methods for imaging cortical activity.

The German Neuroscience Society supports a number of annual short neuroscience courses, amongst those being a 1-week course in Freiburg, on Analysis and Models in Neurophysiology.

A4 Group 4 (postdoctoral researchers)

Many neuroinformatics practitioners enter at the postdoctoral stage. These are mainly people who are educated in one branch of science and who require training in another branch.

A4.1 Fellowships

In 1994, the Sloan Foundation recognised that many neuroinformaticians enter from the physical sciences. The Foundation established the Sloan Centers for Theoretical Neurobiology at five USA research institutions, Brandeis, Caltech, NYU, Salk Institute, and UCSF. The initial emphasis was on pre- and postdoctoral training. When the Swartz Foundation took over the funding in 2003, having been co-sponsor from 2000 to 2003, this became principally a postdoctoral programme.

The current Sloan-Swartz programme offers 2-year fellowships for both experimentally and theoretically trained scientists from the physical sciences to work in experimental brain research laboratories. In this environment, they become conversant with neuroscience questions and experimental approaches in neurobiology, enabling them to apply skills learned from studying the physical sciences to problems in neuroscience. There are now 11 centres, Harvard, Princeton, Columbia, Yale, UCSD and Cold Spring Harbor having joined the original five. These centres vary in their requirement for Sloan-Swartz postdoctoral fellows to undergo formal training. The pro-

gramme at Caltech is closely associated with the post-graduate Computation and Neural Systems Programme (Section A3.1).

Several funding bodies offer fellowships for which aspiring researchers at the postdoctoral level could apply. In the UK, the Medical Research Council offers Training Fellowships in the areas of Computational Biology, Bioinformatics and Neuroinformatics.

Several of the UK Research Councils offer discipline hopping grants to "enable established researchers in the engineering or physical sciences to apply for funding to investigate and develop ideas, skills and collaborations in biological, clinical and population health research. Alternatively, established life science researchers can apply for funding to develop ideas, skills and collaborations with physical scientists or engineers."

US National Research Council (NRC) will pay a bonus in salary (currently $10,000) for people with degrees in physical sciences (physics, chemistry, mathematics, statistics) or engineering who wish to do postdoctoral research into biomedical sciences. This is to encourage people to come into the field. This applies to neuroinformatics or neuroscience. The NIH will also pay this bonus to people with these Ph.Ds to enter NIH Intramural programmes.

Researchers holding postdoctoral fellowships who want to develop skills in other disciplines can attend MSc courses (usually at their own cost).

A4.2 Short courses

While the many of the attendees at the short courses mentioned under in Section A3.1 are PhD students, a significant proportion (up to 50% in some cases) are post-doctoral researchers.

In addition, postdoctoral researchers acquire training in specific techniques through attending at courses of a few days or less. These short courses have been described under the provision for PhD students in Section A3.2 above.

A5 Group 5 (Academic staff)

There are no courses designed specifically for this group. It is very rare for them to attend the longest running short courses (never in the case of the annual European course on computational neuroscience; occasionally for Woods Hole courses). Such courses tend to be designed with the early career researcher in mind. Additionally, spending several weeks studying at a course may not be feasible for academics. However, most of the teachers at the short courses are academic staff who benefit through interacting across the disciplines. Academics do attend short courses of a few days, particularly those attached to a larger event such as a conference. The number of academics who attend varies from course to course.

From 2000 to 2003, Edinburgh University, UK, ran a one-week summer school on training in the use of neural simulators, for around 30 students. Occasionally, academic staff attended as students and integrated well.

There are other types of extended events attended by academics which can have a training element. One example of this is the 3-week neuromorphic engineering workshop held annually at Telluride, USA. Similar shorter workshops have been initiated in Europe, made possible by several EU-funded projects pooling their resources.

The Brain Connectivity Workshop (www.hirnforschung. net/bcw) has established itself as a successful venue for high-level discussions of all aspects of the structural, dynamical and functional organisation of the brain. It runs for 2-3 days in spring every year in a different location. In some years it is preceded by a short course bringing newcomers up to speed with relevant concepts.

Many academics attend the tutorials held in association with larger events, such as conferences.

Members of academic staff are able to obtain financial support occasionally from national or international funding organizations for learning techniques in a different lab. Such fellowships are offered, for example, by DFG (Heisenberg; Germany), Humboldt Foundation (Germany), Wellcome Trust, Royal Society (UK), NZ MRC, EU (Marie-Curie).

Appendix B: Links to Relevant Web Sites

The information about training provision here described in Appendix A is a sample of what is available. More information is available on the Internet. Some relevant websites have been mentioned in the text and some other are given below. Most of these carry information about courses in a particular country or for particular types of students. There is no one web site with universal coverage. At the workshop, it was agreed that such a resource would be very useful and one of the recommendations from the workshop was that the INCF facilitate the production of a training portal (Recommendation R2).

Web sites about neuroinformatics training:

(a) Masters programmes in the Netherlands:
http://www.neurofederatie.nl/masters/

(b) PhD programmes in computational neuroscience in the USA:
http://neuroscienceblueprint.nih.gov/neuroscience_resources/training_comp_neurosci.htm

(c) Masters and PhD neurosciences courses in Europe:
http://fens.mdc-berlin.de/nens/

(d) Masters and PhD courses in the Bernstein Network for Computational Neuroscience, Germany
http://www.nncn.de/

(e) Summer schools in neuroscience:
http://www.bccn-berlin.de/graduate_programs/important-web-links

(f) Courses at Woods Hole, USA:
http://www.mbl.edu/

(g) Courses at Cold Spring Harbor, USA:
http://www.cshl.edu/

(h) The Okinawa Computational Neuroscience Course, Japan:
http://www/irp.oist.jp/ocnc/

(i) Two web sites giving a variety of information about neuroinformatics:
http://neurobot.bio.auth.gr
http://www.hirnforschung.net/cneuro/

(j) Other relevant web sites:
The Society for Neuroscience's neuroscience teaching portal
http://www.ndgo.net/sfn/nerve/

The journal PLoS Computational Biology, prominent in publishing in neuroinformatics, maintains an extensive section with tutorials, perspectives and informative series such as "Ten simple rules for...", "Getting started in...", "What has computational biology done for...".
http://www.ploscompbiol.org/

Site about the EC's Bologna process:
http://ec.europa.eu/education/policies/educ/bologna/bologna_en.html

Appendix C: Workshop Programme

July 23:

14:00 - 14:15	Welcome and orientation (David Willshaw)
14:15 - 16:00	Session I: "Training in neuroinformatics" -scientific presentations
16:00 - 17:30	Session II: "Current provision of training in neuroinformatics" -discussion in small groups
19:00	Dinner
Gary Egan	Educational programmes and professional development challenges in neuroinformatics with case studies in neuroimaging
Mark Van Rossum	Neuroinformatics and Computational Neuroscience
Barry Richmond	Neuroinformatics and training from an experimentalist's perspective

July 24:

09:00 - 13:00	Session III: "Future provision of training in neuroinformatics" -scientific presentation and discussion in small groups
13:00 - 14:00	Lunch
14:00 - 17:00	Session IV: "Mapping out the future" -work on draft report in small groups and discussion
18:00	Reception hosted by the Edinburgh Doctoral Training Centre in Neuroinformatics and Computational Neuroscience
Rolf Kötter	Neuroinformatics training for the future - a personal view

July 25:

09:00 - 12:00	Session V: "Formulating recommendations" -discussion in small groups
12:00 - 13:00	Discussion and conclusions

International Neuroinformatics
Coordinating Facility

incf