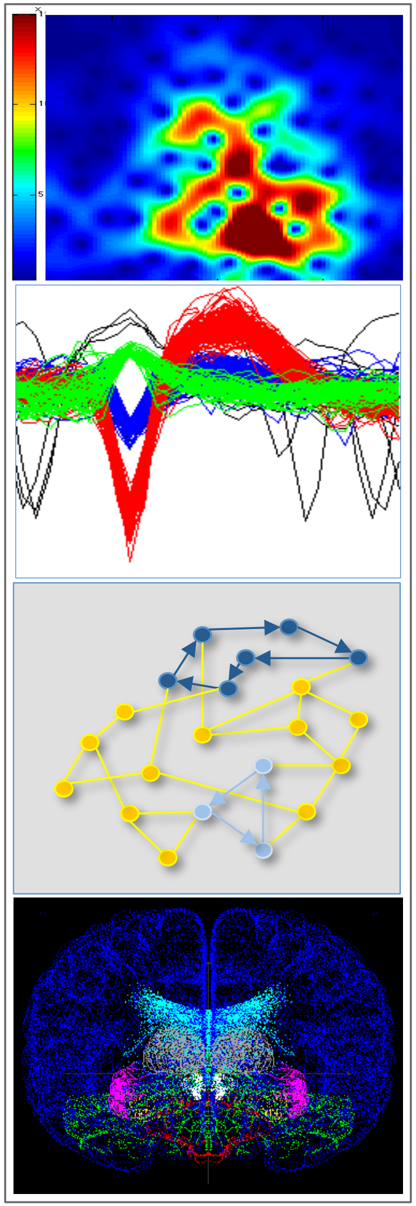


Neuroinformatics

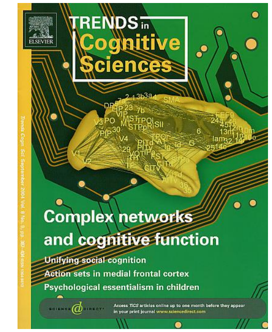
Marcus Kaiser

Week 1: Course Overview

www.dynamic-connectome.org

neuroinformatics.ncl.ac.uk

Brief introduction (Dr Marcus Kaiser)



2002 MSc Biology, Computer Science
Bochum University, Germany

2005 PhD Computational Neuroscience
Jacobs University Bremen, Germany

2005 RCUK Academic fellowship (~Assistant Professor)
Newcastle-upon-Tyne, UK

2007 Initiator and Co-Director of Wellcome Trust 4-year PhD Programme:
‘Systems Neuroscience: From Networks to Behaviour’

2008 Editorial board PLoS ONE and Frontiers in Neuroinformatics

2009 Visiting Associate Professor, Seoul National University, South Korea

2010 Associate Professor (Reader), Newcastle Univ. Neuroinformatics2011
Leader of UK INCF SIG Image-based Neuroinformatics

2011 Leader of UK INCF SIG Image-based Neuroinformatics

2015 Professor in Neuroinformatics

Organisation of this course

Contact details: Prof. Marcus Kaiser (m.kaiser@n-science.com),
Course web http://www.dynamic-connectome.org/t/cneurosci/

Course components

Practicals: Introduction to Matlab, Analyzing brain connectivity, Modelling Neural networks; Instructors: Dr Marcus Kaiser, Dr Roman Bauer, Dr Sol Lim, Mr Chris Thornton, Mr Chris Papasavvas, Ms Frances Hutchings.

Seminars (after the reading week): oral presentation of research articles (20 minutes plus 10 minutes discussion) worth 10% of the mark; list of articles will be provided within the next two weeks.

Small research project: worth 10% of the mark; list of projects will be available at the start of week 3 (choose before the end of week 4); submission of project: mid December.

Exam: January, worth 80% of the mark

Course Overview

Week 1: Introduction (Chapter 1)

Week 2-4: Single neurons, populations, and plasticity (Chapters 2-4)

Week 5: Cortical organisation (Chapter 5) (plus Neuroinformatics Methods lecture)

Week 6: Brain network analysis I (additional material)

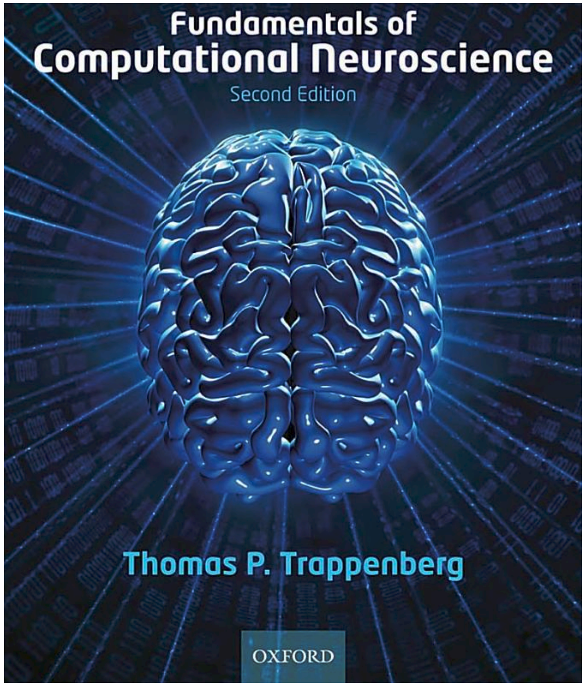
Week 7: midterm

Week 8: Network analysis II (additional material)

Week 9-11: Maps and Memory (Chapters 6-8)

Week 12-13: Motor control, reinforcement and cognition (Chapters 9-10)

Textbook

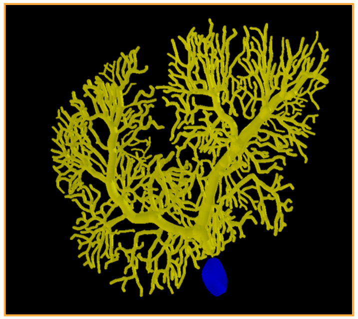


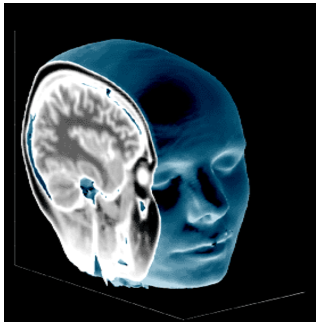
Thomas P. Trappenberg: Fundamentals of Computational Neuroscience, Oxford University Press, **Second Edition**, 2010, ISBN 0199568413.

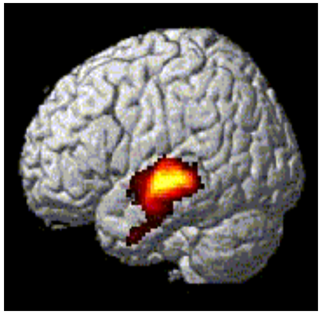
Available in Robinson Library 4th floor, 612.82 TRA

Neuroinformatics

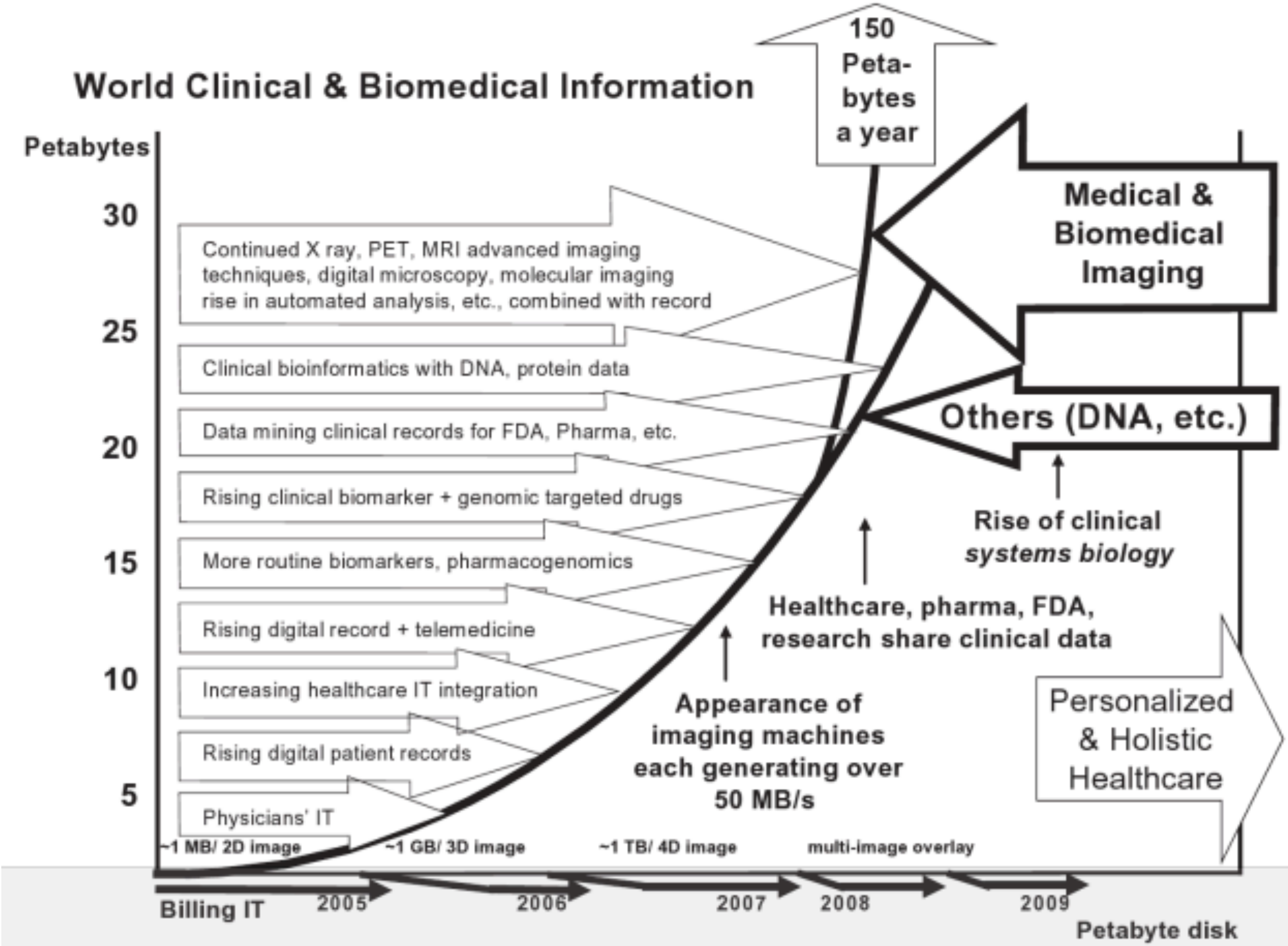
- The challenges
- The methods
- The solutions
- Neuroinformatics in Newcastle







A brief history



Barry Robson, O. K. Baek (2009) The engines of Hippocrates: from the dawn of medicine to medical and pharmaceutical informatics.

Information overload I

<u>Example: Neuroimaging</u>

2011 20,000 MRI scanners

-> 120,000,000 scans per year

(say 1 GB per scan)

-> 120 PB = 120 * 10^{15} Bytes = 120 million GB

(more than data storage at Google!)

Additional data from MEG, CT, EEG

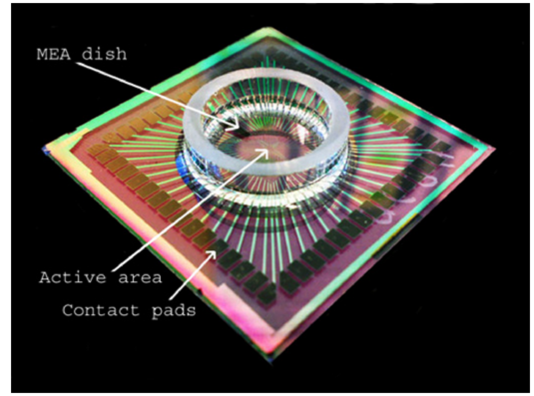
-> Data volume (SPACE): How to store and organize the data?

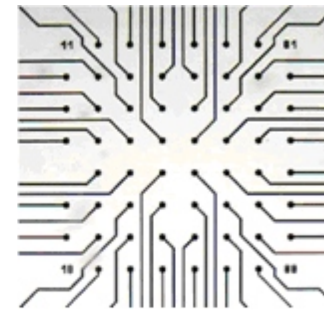
-> Long-term storage (DATA CURATION): neural diseases can last for a long time (e.g. epilepsy, schizophrenia, autism), patient data must be accessible for several decades!

Information overload II

<u>Example: electrophysiology</u>

1980	1 electrode
1990	10 electrodes
2000	100 electrodes
2010	10,000 electrodes





-> Data volume (SPACE): up to 100x as much as a decade ago
Problem: How do you share 5 TB of data with a colleague?

-> Calculations (TIME): up to 10,000 times as many as a decade ago (e.g. correlations between all pairs of k electrodes, $O(k^2)$)
Problem: Computer speed *only* increases by a factor of 32 in a decade (Moore's law)!

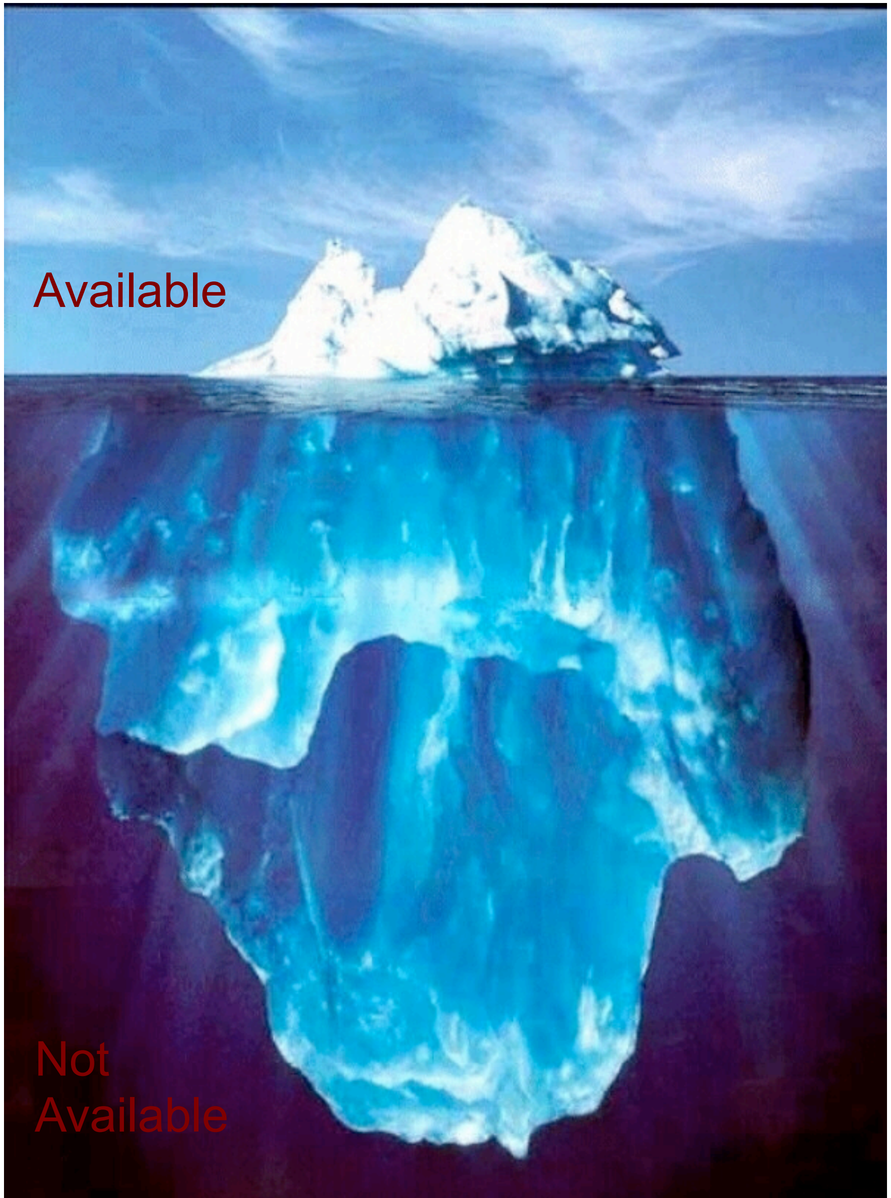
Data comparison

<u>Combining and comparing experimental results:</u>

More than 20 data formats for electrophysiology alone:
often each manufacturer of recording equipment has its own data format!
-> how to convert to a common format?

Experiments in different labs use different procedures: How much metadata must be provided to define an experiment (make it reproducible)?
-> annotate experimental data with metadata about the experiment (e.g. sampling rate, species, recording equipment).

The neuroscience data treasure



<u>Taxpayer value for money:</u>

1) Getting data is expensive

2) Data from one lab might be useful for another lab (no need to re-do experiments)

3) Data should not be lost over the years (data/storage formats)

-> Databases are needed!

Neuroinformatics around the world

- In 2002 OECD Neuroinformatics Working Group identified the need to work cooperatively in order to achieve major advances -> formation of the International Neuroinformatics Coordinating Facility (www.INCF.org) is a consortium of 17 countries (Australia; Belgium; Czech Republic; Finland; France; Germany; India; Italy; Japan; Netherlands; Norway; Poland; South Korea; Sweden; Switzerland; United Kingdom; USA) established in 2005.
- Executive Office is based at the Karolinska Institute, Stockholm
- 5 UK Special Interest Groups (SIGs), one led by Newcastle: SIG Image-based Neuroinformatics (led by Marcus Kaiser, CS)

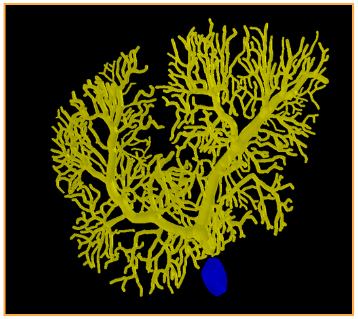
Neuroinformatics

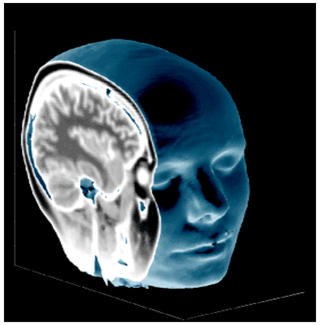
The challenges

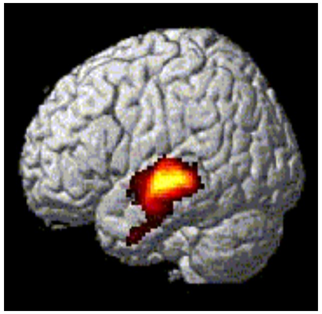
The methods

The solutions

Neuroinformatics in Newcastle







Analysts provide the tools to statistically and mathematically describe the data

Theoreticians and modellers need data and can provide predictions to experimentalists

Experimentalists obtain original data to test hypotheses and derive new knowledge

Metadata

- Metadata: means to describe data files providing information about a certain item's content (e.g., means of creation, purpose of the data, time and date of creation, creator or author of data)
- Often stored in XML (Extensible Markup Language) format. Do you know other markup languages?
- Minimum information: How much information is necessary to analyze a data set?

Nature Precedings : hdl:10101/npre.2008.1720.1 : Posted 25 Mar 2008

Minimum Information about a Neuroscience Investigation (MINI): Electrophysiology

Frank Gibson*[1], Paul G Overton[2], Tom V Smulders[3], Simon R Schultz[4], Stephen J Eglen[5], Colin D Ingram[6], Stefano Panzeri[7], Phil Bream[4], Evelyne Sernagor[6], Mark Cunningham[6], Christopher Adams[6], Christoph Echtermeyer[8], Jennifer Simonotto[1], Marcus Kaiser[1], Daniel C Swan[9], Martyn Fletcher[10], Phillip Lord[1]

Data curation

Digital curation involves organising and preserving digital information so that it may be available for future use. Effectively curated research data can be better shared among the wider research community, enhancing the long-term value of your work.

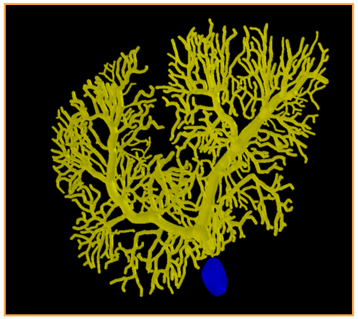
-> make sure people can still use your data in 10-50 years

Can you open a 1983 Word 1.0 file for MS-DOS?
How about a document file on a 5 ¼" floppy disk?

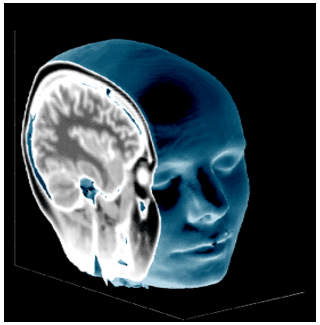
http://www.dcc.ac.uk/

Neuroinformatics

The challenges

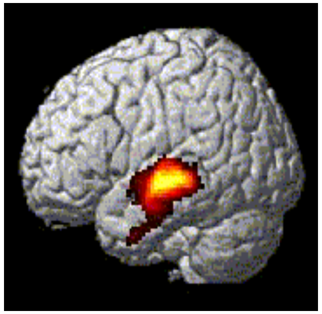


The methods



The solutions

The future



Neuroimaging Databases

Store data from several hospitals in one database.
Benefits:

- Consistency: Use the same scanning protocol for data comparison.
- Critical mass: easier to get enough patients for a clinical study (one hospital might not have enough patients).
- Time: the necessary number of patients can be reached earlier -> faster publication!

Human Connectome Project

HUMAN Connectome PROJECT

Mapping structural and functional connections in the human brain

Washington University in Saint Louis - University of Minnesota - Oxford University

Saint Louis University - Indiana University - University d'Annunzio - Ernst Strungmann Institute

Warwick University - Radboud University Nijmegen - Duke University

- Running 2010-2015
- $30m NIH project

http://humanconnectome.org/

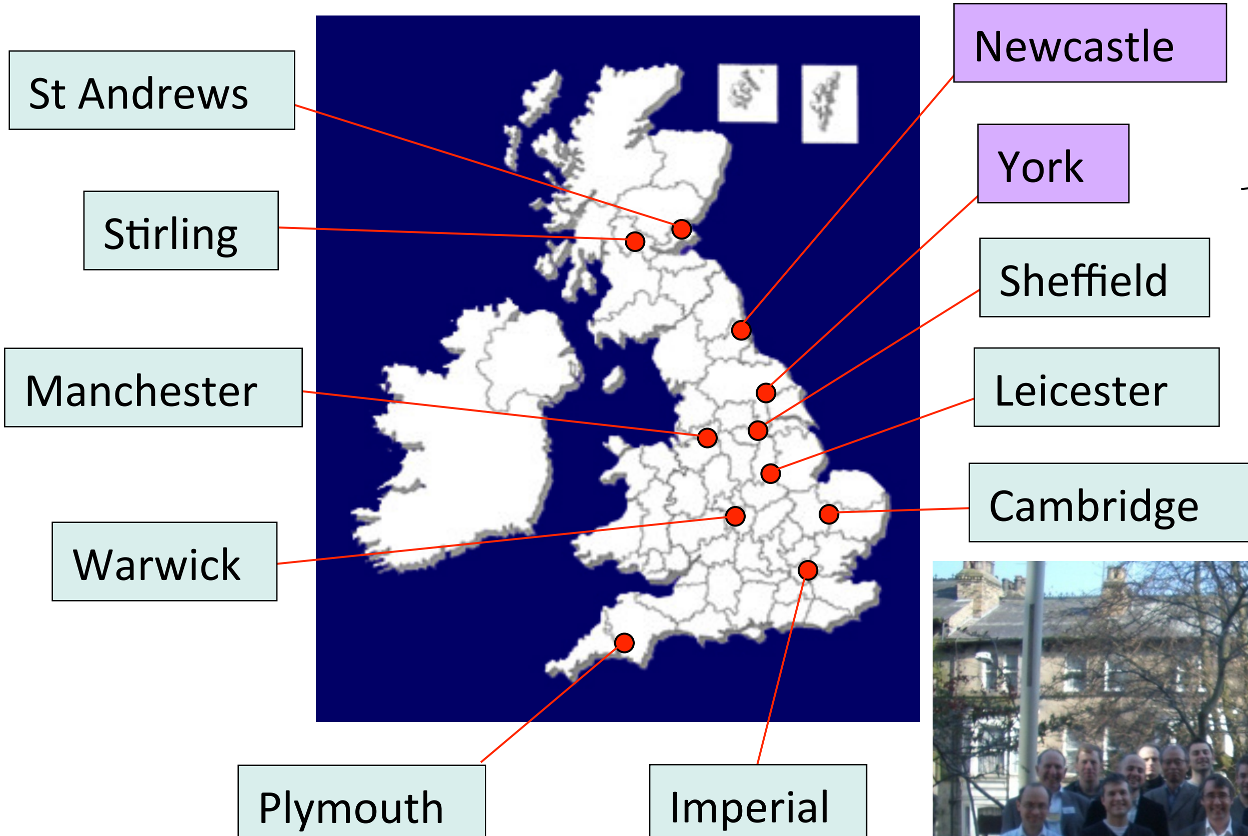
Electrophysiological Databases

Current databases which support electrophysiological data are mainly limited to:

- Sources of analysis software
- Simulators of neural function and networks
- Repositories for original data

Few attempts have been made to produce platforms that allow for data integration, manipulation and analysis within one grid (web) environment

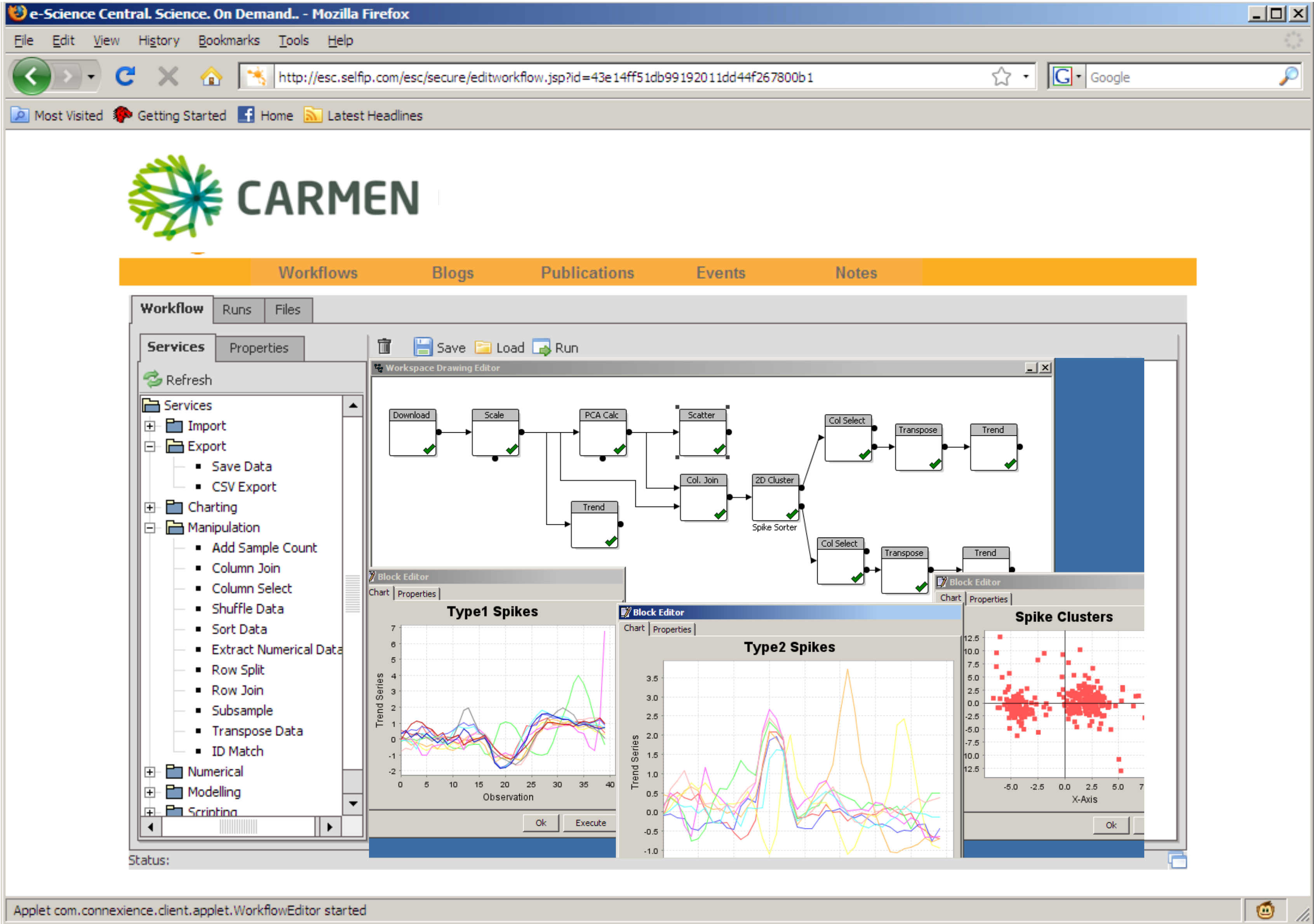
CARMEN Consortium



First two compute nodes

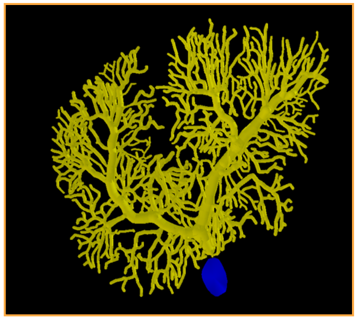
CARMEN

Workflow Software – e-Science Central

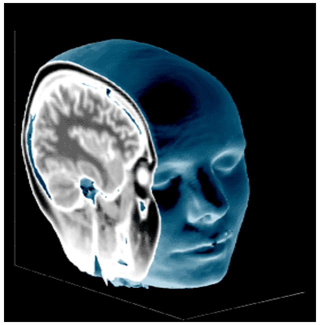


Neuroinformatics

The challenges

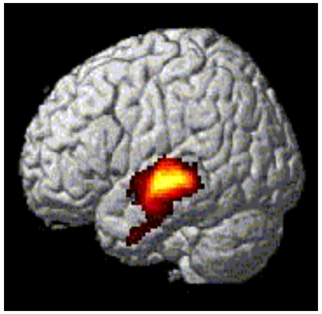


The methods



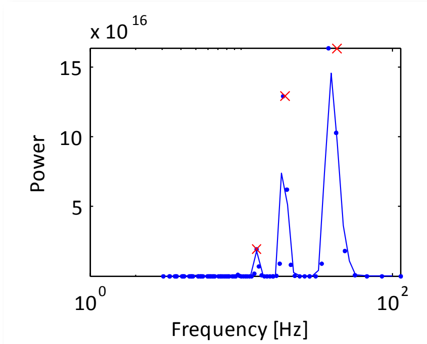
The solutions

Neuroinformatics in Newcastle

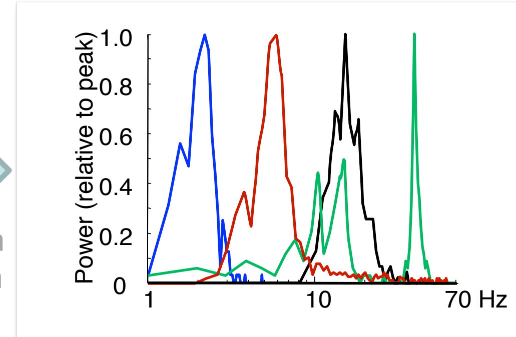


Topological correlates of epilepsy

Simulation of network dynamics and network development



comparison
explanation



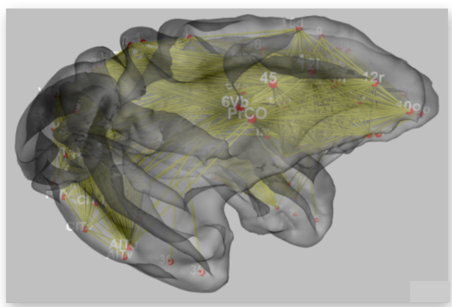
Time series and network analysis

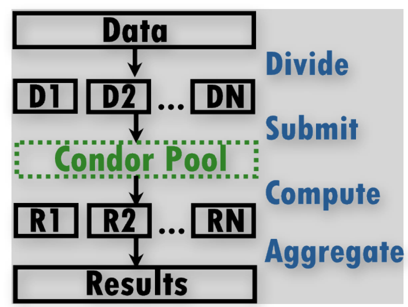
Lim et al. Cereb Cortex, 2014
Varier & Kaiser PLoS CB, 2011

Roopun et al. PNAS, 2010
Roopun et al. Front Neurosci, 2008

Model of neural connectivity

Sporns et al. TiCS, 2004
Kaiser, Neuroimage, 2011



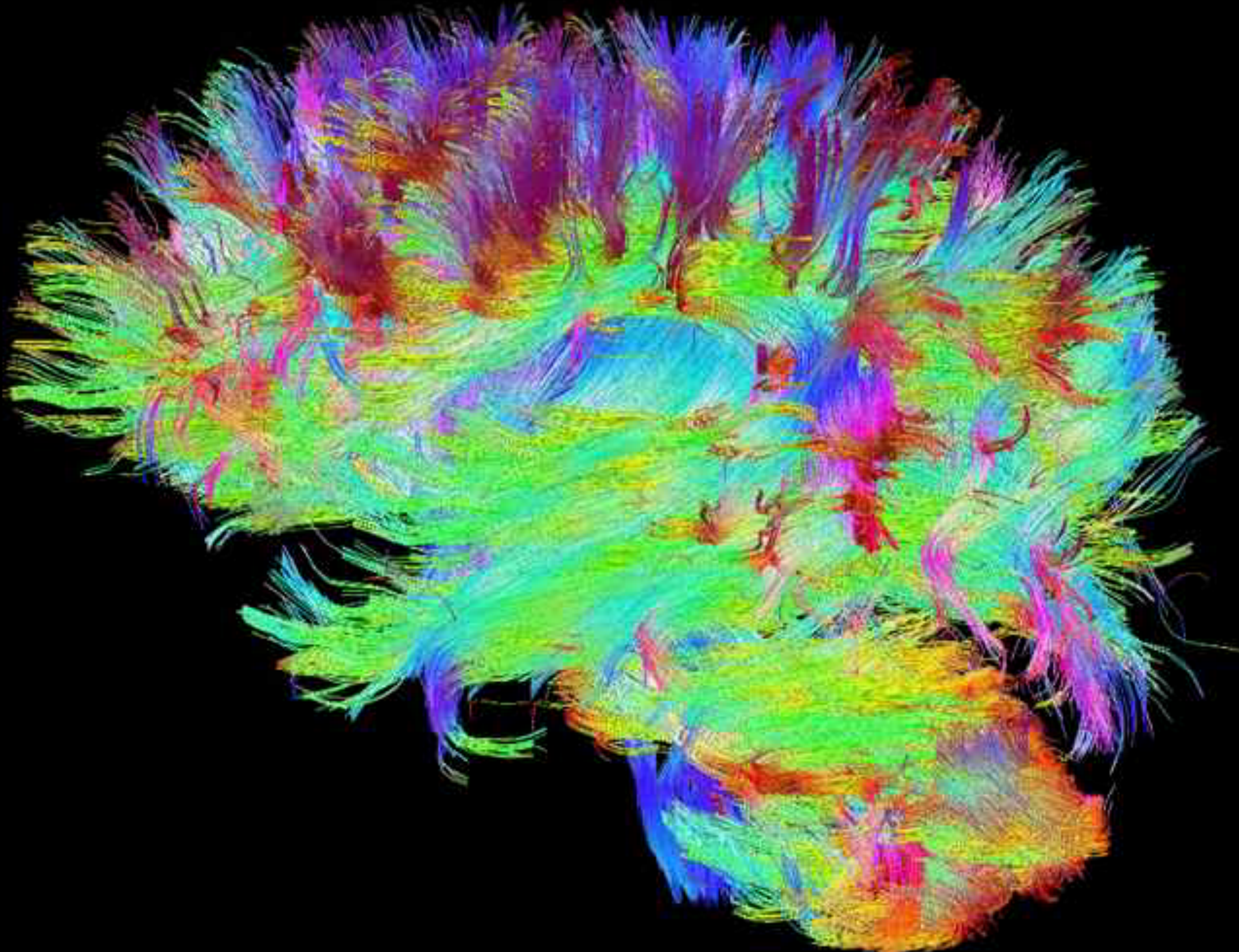


e-science and grid computing

Ribeiro et al. J Neurosci Meth, 2009
Echtermeyer et al. PLoS ONE, 2011

Neuroimaging: Diffusion tensor imaging, Resting state network, Tract tracing

Electrophysiology: EEG, ECoG, Multi-electrode array recordings

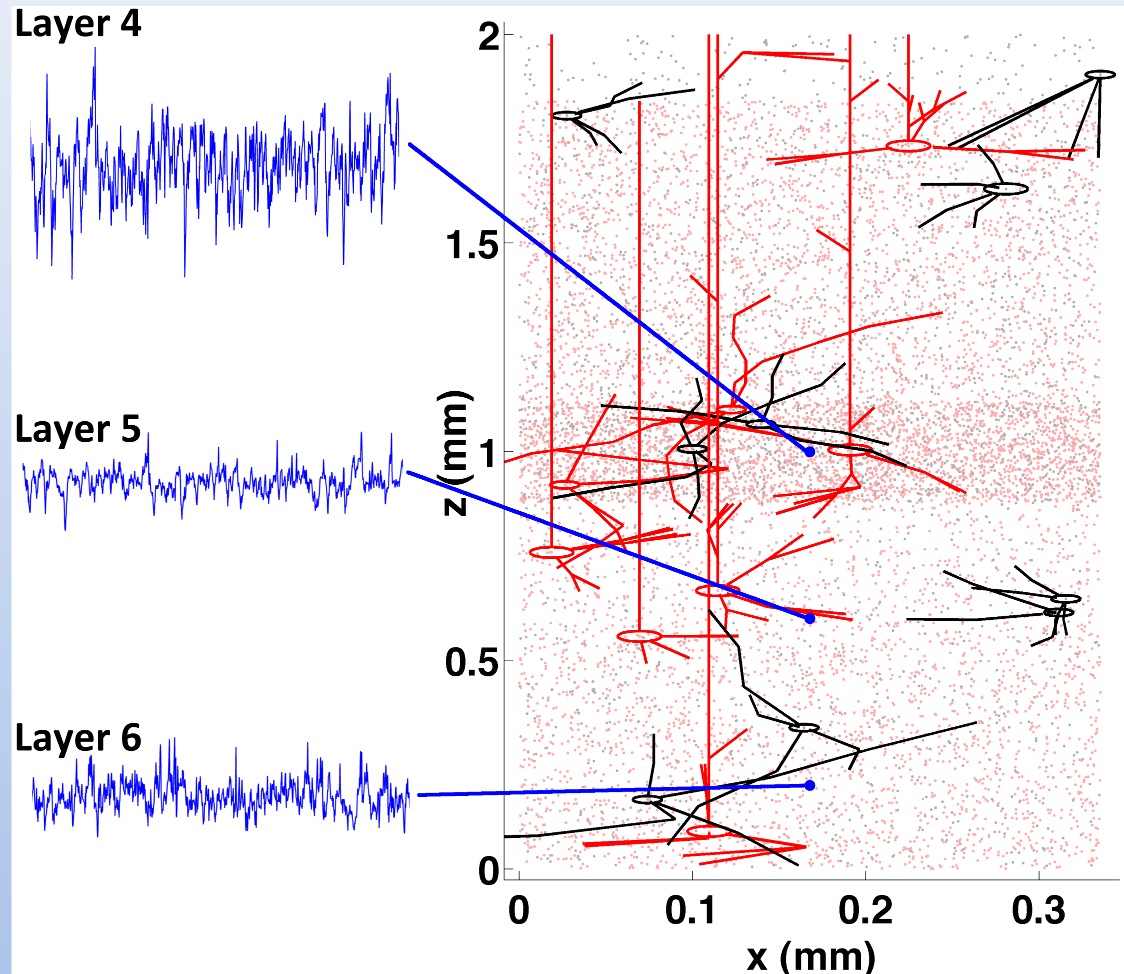


Virtual electrode recordings: the rise of seizures

Model of cortical slice preparation, with realistic neuronal populations, 3D laminar structure and connectivity.

Simulation of LFPs using multi-compartment simple spiking neurons showing similar frequency scaling as the experimental recordings.

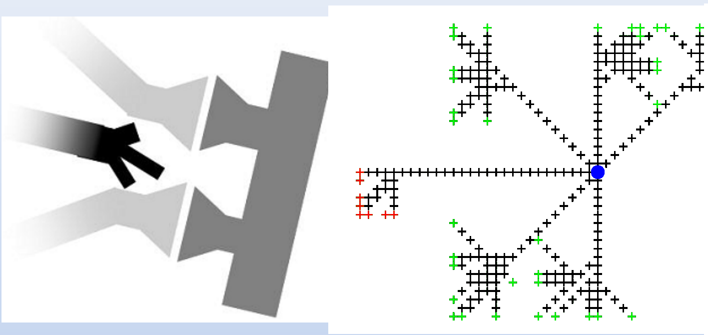
www.vertexsimulator.org



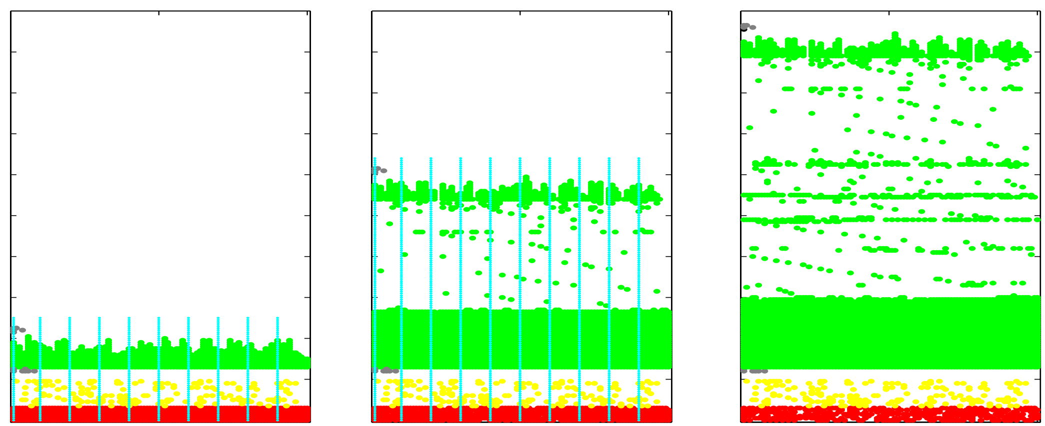
Tomsett et al. Brain Structure and Function, 2015.

Engineering and Physical Sciences Research Council

Understanding brain development in health and disease



- **Axon growth** in 3D
- **Network** organization
- Starting point for **simulations**



Lim et al. *Cerebral Cortex*, 2015.
Kaiser et al. *Cerebral Cortex*, 2009
Varier & Kaiser, *PLoS Computational Biology*, 2011
Varier et al., *Journal of the International Neuropsychological Society*, 2011