Institution: University of Dundee

Unit of Assessment: 5: Biological Sciences

Title of case study: The creation of the Open Microscopy Environment (OME) and impact of life sciences companies worldwide.

1. Summary of the impact (indicative maximum 100 words)

Led from Dundee by Prof Jason Swedlow FRSE, The Open Microscopy Environment (OME) is an international consortium building tools to enable the storage and analysis of biological image data. OME releases Bio-Formats, an image format translation library, and OMERO, software for the visualisation, management and analysis of image data recorded by microscopes and high-content screening systems. OME software is open-source and transforms the way researchers manage the vast amount of image data routinely produced in research laboratories. Glencoe Software is the commercial arm of OME and provides commercial licenses, support, and customisation for OME's software tools to major industrial customers.

2. Underpinning research (indicative maximum 500 words)

Prof. Jason Swedlow FRSE (Professor of Quantitative Cell Biology at the College of Life Sciences) is a world expert in the development of pioneering new technology for viewing and analysing living cells using digital microscopy. He has been in the vanguard of biologists adopting a more quantitative and systematic approach to microscopy to extract meaningful and reproducible results from image data (1,2,3). The successful application of the green fluorescent protein (GFP) from the jellyfish *Aequorea victoria* in 1994 as a genetically encoded marker, with concomitant development of new live cell imaging systems has also resulted in a massive increase in studies of the dynamics of macromolecules and structures of living cells. However, the advent of this new era in microscopy created a major problem in the management and analysis of the substantial amounts of data collected as a result of this innovation. Moreover, the bioinformatics tools required for hypothesis-driven analysis of digital images were very immature in the field.

Starting in 2000, Prof Swedlow's group at the University of Dundee embarked on a research programme to create a pioneering image-management system geared to the needs of quantitative microscopy that could be used for probing cellular structure and dynamics and for performing cell based screens. The major focus of the Open Microscopy Environment (OME) created by Swedlow and his team was to develop software and protocols that would allow image data from any microscope to be stored, shared and transformed without loss of image data or information about the experimental setting, the imaging system or the processing software. The concepts and first implementation of OME were published in 2003 (3) and subsequent publications from the University of Dundee have reported the development of solutions for conventional digital microscopy and high-content screening (4,5). Starting in 2005, Dundee's OME team started developing OMERO, a modern open source data management system that used advanced software engineering techniques to enable access, sharing, analysis, and publication of complex, multi-dimensional image data. First released in 2007, OMERO has become the world-leading data management application for light microscopy, and is now installed and in use at >3,500 sites worldwide (6). OMERO does not replace or compete with commercial software for controlling microscopes, acquiring images or performing image analysis but instead serves as a neutral broker between otherwise incompatible software. Dundee's OME team also contributes to Bio-Formats, a Java library installed and in use at >50,000 sites worldwide that converts >120 proprietary file formats to a common model, accessible by anyone.

In 2011, Jason Swedlow was awarded a £4.2 million Wellcome Trust Strategic Award to continue support for the OME, as well as funding development positions in nine satellite laboratories. In the same year, Jason Swedlow was named BBSRC "Innovator of the Year" for the impact of OME.

3. References to the research (indicative maximum of six references)

Publications:

1. Andrews PD, Ovechkina Y, Morrice N, Wagenbach M, Duncan K, Wordeman L, **Swedlow JR**. (2004) Aurora B regulates MCAK at the mitotic centromere. Dev Cell. *6*, 253-268.

(doi:10.1016/S1534-5807(04)00025-5) (Citations 271, Scopus Nov 2013)

2. **Swedlow, J.R**., Hu, K., Andrews, P.D., Roos, D.S., and Murray, J.M. (2002) Measuring tubulin content in Toxoplasma gondii: a comparison of laser-scanning confocal and wide-field fluorescence microscopy. Proc Natl Acad Sci USA. *99*, 2014-2019. (doi:10.1073/pnas.022554999) (Citations 76, Scopus Nov 2013)

3. **Swedlow, J.R**., Goldberg, I., Brauner, E., and Sorger, P.K. Informatics and quantitative analysis in biological imaging. (2003) Science *300*, 100-102 (doi:10.1126/science.1082602) (Citations 133, Scopus Nov 2013)

4. Goldberg, I.G., Allan, C., Burel, J.M., Creager, D., Falconi, A., Hochheiser, H., Johnston, J., Mellen, J., Sorger, P.K. and **Swedlow, J.R**. (2005) The Open Microscopy Environment (OME) Data Model and XML file: open tools for informatics and quantitative analysis in biological imaging. Genome Biol. *6*, R47. (doi: 10.1186/gb-2005-6-5-r47) (Citations 92, Scopus Nov 2013)

5. Moore, J., Allan, C., Burel, J.M., Loranger, B., MacDonald, D., Monk, J., and **Swedlow, J.R.** (2008) Open tools for storage and management of quantitative image data. Methods Cell Biol. *85*, 555-570. (doi: 10.1016/S0091-679X(08)85024-8) (Citations 16, Scopus Nov 2013)

6. Allan, C., Burel, J.M., Moore, J., Blackburn, C., Linkert, M., Loynton, S., Macdonald D., Moore, W.J., Neves, C., Patterson, A., Porter, M., Tarkowska, A., Loranger, B., Avondo, J., Lagerstedt, I., Lianas, L., Leo, S., Hands, K., Hay, R.T., Patwardhan, A., Best, C., Kleywegt, G.J., Zanetti, G., and **Swedlow, J.R**. (2012) OMERO: flexible, model-driven data management for experimental biology. Nat Methods *9***,** 245-253. (doi: 10.1038/nmeth.1896) (Citations 14, Scopus Nov 2013)

Key research grants relevant to this case study:

1. **Wellcome Trust Technology Development Award** (2002) Open image informatics software and database for biological microscopy. Value: £988,172. Grant Ref. 068046/Z/02/Z. Principal Grant Holder: J.R. Swedlow
2. **Wellcome Trust Technology Development Award** (2006) Open image informatics software and database for biological microscopy. Value: £612,849. Grant Ref. 080087/Z/06/Z. Principal Grant Holder: J.R. Swedlow
3. **Wellcome Trust Technology Development Award** (2008): The Open Microscopy Environment: towards the development of a scientific data management system. Value: £1,305,516. Grant Ref. 085982/Z/08/Z. Principal Grant Holder: J.R. Swedlow
4. **BBSRC Research Grant** (2006): Open image informatics software for biological microscopy. Value: £398,637. Grant Ref. BB/D00151X/1. Principal Grant Holder: J.R. Swedlow;
5. **BBSRC Research Grant** (2010) Intuitive large-scale image processing for biologists. Value: £350,064 Grant Ref. BB/I000755/1. Principal Grant Holder: J.R. Swedlow
6. **Wellcome Trust Strategic Award** (2011): The open microscopy environment – image informatics for biological sciences. Value: £4,230,140 Grant Ref. 095931/Z/11/Z. Principal Grant Holder: J.R. Swedlow.

4. Details of the impact (indicative maximum 750 words)

Beneficiaries (and nature of the benefits/impacts):

(a) UK Biotech (through the creation of Glencoe Software and their support for Aridhia Informatics Ltd)
(b) Major biotechnology companies (by licensing software to PerkinElmer (PE) and Applied Precision Inc for their commercial imaging platforms).
(c) All Pharma and Biotech companies using PE high-content screening technology
(d) All academic translational programs using PE high-content screening technology and/or OMERO (see (b))
(e) International publishing (by providing Rockefeller University Press with Data Viewer solutions)

(f) The international biological and clinical research communities handling image BigData (by providing data format, image storage and analysis solutions)

The OME Data Model (first released in 2002), Bio-Formats (first released in 2003) and OMERO (first released in 2007) have enabled the sharing and analysis of image data as readily as genomic data. Some examples of how OME is used, for example by BioBus, which provides hands-on science education for Schools in the USA, are available on the OME web site (1). A major impact is the uptake of OME image software and management tools by multinational companies, which is provided to them through the Glencoe Software spin-out, founded in late 2005 by Swedlow.

Impacts:

Glencoe Software (2) has tripled in size since its launch and by 2013 employed 13 people, with a revenue growth of 20-40% during the assessment period. It has recently entered a partnership with **Aridhia Informatics Ltd**, a Scottish-based company that specialises in accessing, storing and analysing health-care information to create innovative products for personalised therapies and improved patient outcomes (3).

Glencoe Software provides commercial licenses, extensive data management support, and customisation for OME's software tools to companies delivering imaging solutions to their customers. OME's Bio-Formats file translation library is the most comprehensive image file format translator available and has been incorporated into several commercial products. Moreover, as the data management solutions are continually developed and supported, companies benefit by not only acquiring the right to use them in their closed-source software but take advantage of the open-source foundation of knowledge, specifications, and new software produced by the OME Consortium. Examples of companies currently distributing software platforms developed by OME and provided by Glencoe Software through commercial licence include:

Applied Precision Inc
The first customer of Glencoe Software was Applied Precision Inc (http://www.api.com/), which integrated the data management solutions provided by Glencoe with its Deltavision imaging system. Glencoe Software collaborated with Applied Precision to develop a customised version of OMERO called softWoRx DMS™, which was installed on every DeltaVision image acquisition system sold during the assessment period (4).

PerkinElmer
PerkinElmer, Inc. is a multinational technology corporation that operates in 150 countries and produces instruments, diagnostics, and (bio)medical imaging solutions. In 2008 PerkinElmer licensed OMERO from Glencoe Software and has used it as the foundation for its successful Columbus™ platform for high-content screening and microscopy image storage, management and analysis*. Columbus™ now dominates the market for data management in high-content screening in Pharma and academia, and thus makes major contributions to drug discovery and basic research (5). The system is a commercial product, but supports the open source OME applications. This adaptable feature enables images to be imported from any other imaging system and is a major reason for the dominance of Columbus™ in these markets (5,6).
*Note: PerkinElmer systems that incorporate the Columbus™ platform are built in Cardiff.

Rockefeller University Press (RUP)
In 2008, Rockefeller University Press launched ***the JCB DataViewer, the world's first on-line publication system for multi-dimensional life sciences image data*** (http://jcb-dataviewer.rupress.org). The JCB Data Viewer is a customised version of Bio-Formats and OMERO built by Glencoe Software, in partnership with RUP. The DataViewer web browser permits scientists to view, and share multi-dimensional image data associated with articles published in The Journal of Cell Biology. Currently, >280 articles and >980 figures are linked to >99,000 image datasets in the JCB DataViewer (7).

Harvard Medical School
Glencoe Software has licensed Bio-Formats and OMERO to Harvard Medical School as the foundation for publishing data from its NIH-funded LINCS project, which provides a resource for thousands of image-based assays of well-known drug molecules (8) that is accessed by industry and academia.

Other measures of impact:
In 2011, the BBSRC announced Prof Swedlow as 'Innovator of the Year' in recognition OME as "a revolutionary venture into open source software" (9). He received the prize from David Willetts MP, Minister for Universities and Science, who spoke at the BBSRC Bioscience for Growth business networking event in London on March 2011.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Information about BioBus can be found on the Open Microscopy website http://www.openmicroscopy.org/site/community/ome-stories

2. Further information about Glencoe Software can be found at http://www.glencoesoftware.com

3. Information about Aridhia Informatics Ltd and partnership with Glencoe Software can be found at http://aridhia.com/about-us/our-partners

4. Information regarding softWoRx DMS™ by Applied Precision Inc can be found at http://www.api.com/news/2008/12-13-2008.asp

5. Information regarding the Columbus™ platform can be found at http://www.perkinelmer.com/pages/020/cellularimaging/products/columbus.xhtml

6. Press release by Perkin Elmer about the Columbus™ platform http://www.perkinelmer.com/AboutUs/PressRoom/PressReleaseDetails/ArticleId/1621

7. Information regarding the JCB Data Viewer provided by Rockefeller University Press can be found at http://jcb.rupress.org/content/191/2/231.full

8. Information regarding the HMS-LINCS software can be found at http://lincs.hms.harvard.edu/resources/software/

9. BBSRC Innovator of the Year announcement http://www.bbsrc.ac.uk/news/people-skills-training/2011/110325-pr-innovator-of-the-year.aspx