OMB No. 0925-0001 and 0925-0002 (Rev. 10/15 Approved Through 10/31/2018)

BIOGRAPHICAL SKETCH

NAME: Barry Smith

eRA COMMONS USER NAME (credential, e.g., agency login): barrysmith

POSITION TITLE: Distinguished Professor of Philosophy; Professor of Biomedical Informatics, Computer Science, and Neurology

EDUCATION/TRAINING

| INSTITUTION AND LOCATION | DEGREE  (if applicable) | Completion Date | FIELD OF STUDY |
| --- | --- | --- | --- |
| Oxford University (UK) | BA, MA | 08/1973, 08/1977 | Mathematics and Philosophy |
| Manchester University (UK) | PhD | 08/1976 | Philosophy |

# A. Personal Statement

I have a long track record in development and application of ontology resources in clinical and translational science, including applications in the fields of electronic health record technology and clinical trial informatics. I I have played a leadership role in a series of major ontology initiatives, beginning with the Open Biomedical Ontologies (OBO) Foundry, now widely recognized as a successful model for coordinated ontology development based on a tested set of best practice principles for the development of interoperable ontology modules. These principles have been adopted by some 300 ontology initiatives throughout the world. From 2005 to 2015 I served as co-PI responsible for dissemination and ontology best practices on the National Center for Biomedical Ontology (NCBO) initiative. From 2014-2017 I served as ontology lead on the NIAID Bioinformatics Integration Support Contract (BISC), where I worked to develop ontologies to support annotation of the huge collection of immunology clinical trial data being assembled in the ImmPort Immunology Database and Analysis Portal. In addition, I have worked on developing ontology resources for disease and disease sub-groups, quantitative histological imaging, tissue biobanking, protein complexes and protein sites, cell types and cell states, patient demographics, biomarkers, as well as carrying out extensive research on ontology-based quality control, harmonization and wrangling of data. Most recently, I have worked on use of ontologies to support machine learning, including application of ontologies in support of AI-driven data analysis.

1. Smith B, Ashburner M, Rosse C, et al. The OBO Foundry: Coordinated evolution of ontologies to support biomedical data integration, Nature Biotechnology 2007; 25 (11): 1251-1255. [PMC2814061](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2814061/)
2. Musen MA, Noy NF, Shah NH, Whetzel PL, Chute CG, Story MA, Smith B; NCBO team. [The National Center for Biomedical Ontology.](http://www.ncbi.nlm.nih.gov/pubmed/22081220) J Am Med Inform Assoc. 2012 Mar-Apr;19(2):190-5. [PMC22081220](http://www.ncbi.nlm.nih.gov/pubmed/22081220)
3. Scheuermann RH, Ceusters W, Smith B. Toward an ontological treatment of disease and diagnosis. Summit on Translat Bioinforma. 2009; 116-120. PMC3041577
4. S Bhattacharya, P Dunn, C Thomas, B Smith, et al. ImmPort: toward repurposing of open access immunological assay data for translational and clinical research. Scientific Data 2018;5:180015

# B. Positions and Honors

## Positions and Employment

1976-79 Postdoctoral Research Fellow, University of Sheffield, England

1979-89 University Lecturer, Department of Philosophy, University of Manchester, England

1989-93 Professor of Philosophy, International Academy of Philosophy, Schaan, Liechtenstein

1994- Professor of Philosophy and Member of the Center for Cognitive Science, University at Buffalo

2002-06 Director, Institute for Formal Ontology and Medical Information Science, Faculty of Medicine, University of Leipzig and Saarland University, Germany

2004- SUNY Distinguished Professor of Philosophy and Julian Park Chair, University at Buffalo, NY

2005- Director, National Center for Ontological Research

2006- Research Scientist, Center of Excellence in Bioinformatics and Life Sciences, Buffalo, NY

2008- Affiliate Professor of Neurology, University at Buffalo, NY

2009- Affiliate Professor of Computer Science and Engineering, University at Buffalo, NY

2009-12 Director, Center for Brain and Behavior Informatics, University at Buffalo, NY

2013- Affiliate Professor of Biomedical Informatics, University at Buffalo, NY

Other Experience and Professional Memberships

2006 NIH Study Section, Biodata Management and Analysis (BDMA)

2006- Coordinating Editor, Open Biomedical Ontologies (OBO) Foundry

2006-10 Scientific Advisory Board, Gene Ontology Consortium

2006- Scientific Advisory Board, Ontology for Biomedical Investigations (OBI) Consortium

2007-10 Scientific Advisory Board, The Cleveland Clinic Semantic Database in Cardiothoracic Surgery

2008-14 Editorial Board, Journal of Biomedical Informatics

2008-11 Scientific Advisory Board, Human Disease Ontology

2009-11 NIAID Major Histocompatilibity Complex (MHC) Ontology Working Group

2010-12 Advisory Board, Ontology for Clinical Research (OCRe) (University of California at San Francisco)

2010- Advisory Board, International Association for Ontology and its Applications (IAOA)

2012- Director (with W. Hogan) of the Clinical and Translational Science Ontology Group (CTSOG)

2015- Senior Expert, Ontology Development Group, United Nations Environment Programme (UNEP)

2017- Editor, International Standards Organization, ISO/IEC 21838-1 (Top-Level Ontology) and 21838-2 (Basic Formal Ontology)

Honors

2001 Wolfgang Paul Prize, Alexander von Humboldt Foundation, Germany

2002 SUNY Chancellor’s Award for Excellence in Scholarship

2004 Honorary Professor, Saarland University, Saarbrücken, Germany

2005 Carl Linnaeus Lecturer, Mälardalen University, Sweden

2010 Paolo Bozzi Ontology Prize, University of Turin, Italy

2014 Fellow, American College of Medical Informatics (FACMI)

# C. Contribution to Science

# 1. In 2002, with funding from the German Ministry of Science and Research, I established IFOMIS (the Institute for Formal Ontology and Medical Information Science), the world’s first research institute devoted to biomedical ontology. The work of IFOMIS is now continued by the National Center for Ontological Research, which I founded in Buffalo in 2005. IFOMIS was established to test the hypothesis that a top-level ontology architecture constructed on the basis of sound logical principles will be of value in the creation of domain ontologies in the different fields of biomedicine that will in turn prove themselves to have useful applications in information-driven science. Basic Formal Ontology (BFO) is now used in this way as common architecture for over 170 biomedical ontologies. It thereby promotes interoperability of these ontologies in ways that enhance integration of data across disciplines and research communities. It is currently under development as ISO/IED standard 21838-2.

1. Smith B, Rosse C. The role of foundational relations in the alignment of biomedical ontologies. Medinfo 2004;11(1):444-8 PMID 15360852
2. Spear AD, Ceusters W, Smith B. Functions in Basic Formal Ontology. Applied Ontology 2016:11 (2), 103-128
3. Bandrowski A, Brinkman R, Brochhausen M, et al. The Ontology for Biomedical Investigations, PLoS ONE 2016;11(4). PMC4851331
4. Arp R, Smith B, Spear A. Building ontologies with Basic Formal Ontology, Cambridge. MA: MIT Press, August 2015

2. Much of the initial work of IFOMS was devoted to the development of a principled approach to ontology evaluation, resting on the assumption that if we identify the features which contribute to the success of an ontology in real-world applications then we can define associated metrics that can be used as the basis for an ontology evaluation process. In collaboration with my IFOMIS (now Buffalo) colleague Werner Ceusters, this process has now been applied to a range of existing ontologies, terminologies, and coding systems. Our published results of these applications have since led to major changes in established resources, and also to the gradual adoption of new standards of logical consistency and coherence, described under 3., below.

1. Ceusters W, Smith B, Goldberg L. A terminological and ontological analysis of the NCI Thesaurus, Methods Inf Med, 2005;44:498-507. PMID 16342916
2. Bodenreider O, Smith B, Kumar A, Burgun A. Investigating subsumption in DL-based terminologies: A case study in SNOMED-CT, Artif Intell Med. 2007;39(3):183-195. PMID: 17241777
3. Ceusters W, Spackman KA, Smith B. Would SNOMED CT benefit from Realism-Based Ontology Evolution? AMIA 2007 Annual Symposium Proc. 2007; 105-109. PMC2655780
4. Ceusters W. Applying evolutionary terminology auditing to the Gene Ontology. J Biomed Inform. 2009;42(3): 518-529. PMC3041454

3. In 2004, at a meeting organized at IFOMIS, the BFO-based strategy for coordinated ontology development was adopted by the OBO (Open Biological Ontologies) community, most prominently by the Gene Ontology (GO). The strategy enabled a new kind of mediation between working biologist users of ontologies and those researchers interested in their logical and computational foundations, exemplified in a series of conferences, workshops and training events which I organized under the auspices of the NIH Roadmap National Center for Biomedical Ontology (NCBO). Most notable outcome of these activities was the establishment in 2005 to the OBO Foundry initiative, membership in which requires developers of biomedical ontologies to work in tandem in order to ensure interoperability, consistency and non-redundancy across disciplinary boundaries. Since then the OBO Foundry has spawned a series of interrelated endeavors, including the MIBBI (Minimum Information for Biological and Biomedical Investigations) suite of checklists, the Planteome initiative, to develop common reference ontologies for plant science, the IDO suite of infectious disease ontologies, and the NIST Industrial Ontologies Foundry. The strategy has also helped to shape new terminology standards, for example in the area of pain research.

1. Taylor CF, Field D, Sansone SA, et al. Promoting coherent minimum reporting requirements for biological and biomedical investigations: The MIBBI Project, Nature Biotechnol. 2008; 26: 889-896. [PMC2771753](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2771753).
2. Jensen M, Cox AP, Chaudhry N, et al. The Neurological Disease Ontology. J Biomed Semantics. 2013;4:42. PMC4028878
3. Schiffman E, Ohrbach R, Truelove E, et al. [Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for Clinical and Research Applications: recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group.](http://www.ncbi.nlm.nih.gov/pubmed/24482784) J Oral Facial Pain Headache. 2014 Winter;28(1):6-27. PMC4478082
4. Cooper L, Meier A, Laporte, M-A et al. The Planteome database: an integrated resource for reference ontologies, plant genomics and phenomics, Nucleic Acids Res. 2018;46(D1):D1168–D1180. PMC5753347

4. Working within the OBO Foundry framework, I have been involved in the initiation and management of a series of ontology development efforts. I have played a guiding role in the development of the Foundational Model of Anatomy, the Cell Ontology, the Protein Ontology, the Infectious Disease Ontology, the Ontology for Biomedical Investigations, the Ontology for General Medical Science, the Environment Ontology, the Vaccine Ontology, the Plant Ontology, the Quantitative Histopathology Image Ontology, and the MicroRNA Ontology.

1. Buttigieg PL, Morrison N, Smith B, Mungall CJ, Lewis SE; ENVO Consortium. The Environment Ontology: contextualising biological and biomedical entities. J Biomed Semantics. 2013 Dec 11;4(1):43. doi: 10.1186/2041-1480-4-43. PMC3904460
2. Smith B, Arabandi S. Brochhausen M, et al. Biomedical imaging ontologies: A survey and proposal for future work. J Pathol Inform. 2015:6;37. PMC4485195
3. Gurcan MN, Tomaszewski JE, Overton JA, et al. Developing the Quantitative Histopathology Image Ontology (QHIO): A case study using the hot spot detection problem”, J Biomed Inform, 2017;66:129-135. PMC5316345
4. [Natale DA, Arighi CN, Blake JA, et al. Protein Ontology (PRO): Enhancing and scaling up the representation of protein entities](javascript:void(0)). Nucleic Acids Res. 2017;45(D1):D339-D346. PMC5210558
5. Through all of the above I have worked to codify and to refine the methodology for successful ontology-based research in order to establish a set of best practices for ontology development, coordination, application and evaluation, and also to explore how these best practices can be applied in areas such as electronic health records.
6. Ceusters W, Smith B. Tracking referents in Electronic Health Records, Stud Health Technol Inform. 2005;116:71-76. PMID: 16160238
7. Masci AM, Arighi CN, Diehl AD, et al. An improved ontological representation of dendritic cells as a paradigm for all cell types, BMC Bioinform. 2009;10:70. PMC2662812
8. Zheng, J, Harris MR, Masci AM, et al. The Ontology of Biological and Clinical Statistics (OBCS) for standardized and reproducible statistical analysis, Journal of Biomedical Semantics, 2016:7 (53). PMC5024438
9. Prodromos K, Kalousis A, Smith B, Kiritsis D. Biomedical ontology alignment: an approach based on representation learning. J Biomed Semantics. 2018:9;21

**NCBI Bibliography:** https://www.ncbi.nlm.nih.gov/myncbi/barry.smith.1/bibliography/public/

# D. Research Support

Ongoing Research Support

NIH / NIGMS R01GM080646-09 Wu (PI) 09/21/2015 – 08/31/2020

PRO: A Protein Ontology in Open Biomedical Ontologies

The major goal of this project is to create a formal ontology for proteins within the framework of the OBO Foundry and to apply this ontology to the annotation of proteomics and other clinically relevant data.

Role: PI of Buffalo sub-contract

NIH / NCATS 1UL1TR001412-01 Murphy (PI) 07/15/2015 – 04/30/2020

Buffalo Clinical and Translational Research Center

To contribute to the national CTSA consortium by developing novel health informatics tools; leveraging our strength as a leading center on research in standards and ontologies; and testing and disseminating ontology-based methods to share translational image data.

Role: Key personnel

NIH / NCI 1U24CA199374-01 Madabhushi (PI) 09/17/2015 – 08/31/2020

Pathology Image Informatics Platform for Visualization, Analysis and Management

To allow end users with different needs and technical backgrounds to seamlessly (a) archive and manage, (b) share, and (c) visualize Digital Pathology Image data acquired from different sites, formats, and platforms.

Role: Key personnel

NLM 1T15LM012495 Elkin (PI) 07/01/2017 – 06/30/2022

BRIGHT Education: Buffalo Research Innovation in Genomic and Healthcare Technology Education

The goal of the project is to train 5 post-docs and 2 5-yr PhDs plus 3 short term trainees in research on biomedical informatics. The training focus is on health and healthcare/clinical informatics, translational bioinformatics and clinical research informatics.

Role: Co-PI

Air Force Office of Scientific Research (AFOSR) Crassidis (PI) 9/01/2018 – 8/30/2022

Event Characterization Fusing Hard and Soft Data via Semantic Models

Project to create a space event ontology to enable space event characterization on the basis of both human derived information and information from physics-based sensing mechanisms.

Role: Co-PI

Intelligence Community Postdoctoral Research Fellowship Program

Referent Tracking for Intelligence Analysis Smith (PI) 10/01/2018 – 9/30/2020

This project aims to identify the lessons learned from the most advanced Referent Tracking (RT) work in medicine and to explore how these lessons might be translated to the domain of intelligence analysis.

Role: PI/Mentor

C5ISR Center, US Army Combat Capabilities Development Command

Cognition Data Framework Phase II Rudnicki (PI) 05/09/2019 – 02/15/2020

To automate a significant portion of the intelligence analysis process by employing two foundational concepts: (1) an open data store that is accessible by all cognition forming processes, and (2) ontological rigor in the development of classes needed for the correlation of evolving intelligence.

**Completed Research Support**

Naval Postgraduate School N00244-18-1-0003 Llinas (PI) 04/01/2018 – 03/31/2019

Data Science Approaches to Automation of Analytic Work​flow

The goal of the project is to define a system engineering approach to the functional design of a closed-loop adaptive information collection system supportive of both intelligence analysis and tactical mission operations. This will include: careful assessments of ontological elements supporting current analytic frameworks and research on the ontological elements supporting an optimal cognitively-based information collection system.

Role: Co-PI​

NIH / NIAID HHSN272201200028C Butte (PI) 04/01/15-9/29/2017

Bioinformatics Integration Support Contract (BISC)

To provide ontology services to the IMMPORT Database and Analysis Portal which provides advanced information technology and bioinformatics support in the collection, analysis and exchange of scientific data for NIAID-funded science researchers investigating immunology and immune-mediated diseases.

Role: Co-PI (Ontology lead)

DMDII 15-11-03 Smith (PI) 01/01/2017 – 05/31/2018

Coordinated Holistic Alignment of Manufacturing Processes

A combined government, academia and industry initiative to advance interoperability of manufacturing industry information systems through incorporation of ontology technology.

Role: PI