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Understanding life together: A brief history of collaboration in biology

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Abstract

The history of science shows a shift from single-investigator 'little science' to increasingly large, expensive, multinational, interdisciplinary and interdependent 'big science'. In physics and allied fields this shift has been well documented, but the rise of collaboration in the life sciences and its effect on scientific work and knowledge has received little attention. Research in biology exhibits different historical trajectories and organisation of collaboration in field and laboratory – differences still visible in contemporary collaborations such as the Census of Marine Life and the Human Genome Project. We employ these case studies as strategic exemplars, supplemented with existing research on collaboration in biology, to expose the different motives, organisational forms and social dynamics underpinning contemporary large-scale collaborations in biology and their relations to historical patterns of collaboration in the life sciences. We find the interaction between research subject, research approach as well as research organisation influencing collaboration patterns and the work of scientists.

Introduction

In science, a single lifetime is often enough to witness major transformations.[1] Though the 20th century witnessed major developments in physics research, its second half was marked by transformations in molecular biology. Nobel Prize winners James Watson and John Sulston both witnessed, contributed to, and chronicled these changes.[2] Watson's 'Double Helix' recounts the reconstruction of the structure of Deoxyribose Nucleic Acid (DNA) in 1953, as published in a seminal *Nature* paper. He developed the model of DNA, together with Francis Crick, within the Cavendish Laboratory in the traditional English university town Cambridge. They worked relatively independently and the number of other scientists that figure in 'The Double Helix' is limited.[3] Watson describes the scientific quest of a small group of scientists pursuing research in a small-scale academic environment. Sulston's story relays a completely different world. Though Sultson's career began in the worm research community in much the same small-scale academic environment as Watson – the Laboratory of Molecular Biology in Cambridge – his description of his later years deciphering the human genome illustrates a radically different world, involving the planning and adaptive management of a large, dynamic project with a clear mission, huge budget and expensive instruments involving hundreds of scientists in laboratories spanning the globe. Moreover, the exclusively academic environment is supplanted by an international and political setting, including academia, governments, funding bodies, business, media and the public.

As in molecular biology, so too has research in ecology undergone major transformations, transitioning rapidly from single-investigator studies conducted within a few square metres over a single study season to large, highly interdependent, transdisciplinary, cross-sectoral collaborations blending basic and applied science.[4] Fred

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[2] Watson, J. D. (1968). *The double helix: a personal account of the discovery of the structure of DNA*. New York: Atheneum; Sulston, J. and Ferry, G. (2002). *The Common Thread: A Story of Science, Politics, Ethics and the Human Genome*. London: Bantam Press.

[3] Jim and Francis are accompanied by Maurice Wilkins and Rosalind Franklin, with occasional interactions with Max Perutz, John Kendraw, and Sir Lawrence Bragg. Those beyond this small group are of secondary influence. To many, it is a recognisable narrative of 'little science': the story of bold scientific heroes gaining ground on the unknown. This caricature of science is annually reinforced through the well-known Nobel Prize and its laureates. The individual character has led to the 'HGP Nobel Prize problem' – a concrete problem highlighting the mismatch between the collectivity of scientific practice and the individualisation of its assessment. See Zwart, H.A.E. (2010). The Nobel Prize as a Reward Mechanism in the Genomics Era: Anonymous Researchers, Visible Managers and the Ethics of Excellence. Bioethical Inquiry 7: 299–312.

[4] We base the arguments in this paper largely on our earlier work on collaboration in biology in which we also refer substantially to literature on collaboration and related issues that has informed our work. When we do not give specific references to other sources here, the relevant references can be found in earlier papers: Parker, J. (2006). *Organisational Collaborations and Scientific Integration: The Case of Ecology and the Social Sciences*. PhD Thesis, Arizona State University; Parker, J.N, Vermeulen, N. & B. Penders. (2010). *Collaboration in the New Life Sciences*. Farnham: Ashgate; Parker, J.N. & E. Hackett (2012). "Hot Spots and Hot Moments in Scientific Collaborations and Social Movements." *American Sociological Review*, 77(1): 21–44; Penders, B. (2010). *The Diversification of Health. Politics of large-scale cooperation in nutrition science*. Bielefeld (D): Transcript Verlag; Penders, B., Horstman, K. & Vos, R. (2008). "Walking the line between lab and computation: the 'moist' zone". *BioScience*, 58 (8): 747–755; Vermeulen, N. (2009). *Supersizing Science. On Building Large-scale Research Projects in Biology*. Maastricht: University Press Maastricht; Vermeulen, N., Parker, J.N. & B. Penders. (2010). "Big, Small or Mezzo?: Lessons from Science Studies for the ongoing debate about 'Big' versus 'Little' Science". *EMBO Reports*, 11, 420–423; Spruit, S., Schuurbiers, D. & Penders, B. (2012). *Embedding Nutrigenomics into Nutrition Science. Addressing Epistemological and Social Challenges.* Valorisation Report. Nijmegen: Centre for Society and the Life Sciences (CSG), with Top Institute Food and Nutrition and the Pilot Plant.

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Grassle, a senior marine biologist collaborating in the decade long, international 'Census of Marine Life', witnessed and contributed to these changes. Grassle's interest in marine biology was triggered as an undergraduate when a biology teacher studying marine invertebrates invited him to study the mysteries of life at the sea bottom. He spent his early career at the Woods Hole Institute specialising in benthic ecology, and in 1989 founded the Institute of Marine and Coastal Sciences (IMCS) at Rutgers University. Believing that there was an insufficient focus on marine biodiversity, he also designed and initiated the Census of Marine Life–an ambitious, large-scale, international, interdisciplinary research project devoted to cataloguing all oceanic life. The Census has shown that the age of discovery is not yet over. It also created an international network of marine scientists, expanded the temporal range of marine research to include the past, present and future, and transformed research practice through the development of new technologies, databases, and new governance and communication strategies.[5] Grassle was awarded several prizes as a result for his contributions to ocean science and an enduring place as a research pioneer witnessing and participating in major transformations in scientific practice.

These scientific biographies evince in personal terms broad and enduring cultural, organisational and historical shifts in the ways in which biologists collaborate and relate to their study objects. This article focuses on these transformations in the orchestration, conduct and structure of contemporary collaborations in the life sciences. We consider factors related to the rise of large, complex, interdependent collaborations in the life sciences and how these contributed to the changes in 'doing biology' that Grassle, Watson and Sulston and their contemporaries witnessed over the course of a few decades. We do so by reviewing evidence of rising rates of collaboration in the life sciences while also showing that collaboration has been common throughout their history. On the basis of this historical overview we discuss differences in the developmental trajectories of collaboration in molecular biology and ecology, arguing that ancestral epistemological and organisational legacies continue to structure and inform contemporary research practice. Doing so provides a general understanding of the causes and consequences of changing patterns of collaboration in biology while specifying and analysing important differences in lab- and field-based research. This distinction is one of degree – research blending elements of lab and field biology have always existed – but different environments impart important consequences for the ways in which science is performed and the kinds of outcomes that are created. We conclude by reflecting on the overlap between field and lab research and the potential courses life science collaborations may take into the near future.

The growth of biology

Scientific collaboration is on the rise. Examinations of the 2.4 million scientific articles produced by the top 110 US universities between 1981 and 1999 reveals that research team size increased by 50% during this period. This trend accelerates over time from a 2.19% annual rate of growth in the 1980s to a 2.57% rate in the 1990s (an acceleration factor of 17%). Average distance between collaborators also increased, with the annual rate of growth of average miles between collaborators within US universities rising from 3.53% in the 1980s to 4.45% in the 1990s. During this same period rates of collaboration between US and foreign universities increased five-fold.[6] Similarly, analyses of 19.9 million articles collected by *Web of Science* (1955–2000) indicate that team size increased in 99.4% of science and engineering subfields.[7] Clearly, scientific collaborations are getting bigger and more international.

Collaboration in biology follows the same patterns. Considering all articles in the *Web of Science* database, the size of research teams in biology more than doubled from 1955 to 1990 – a trend slightly higher among molecular biologists (increasing 129%) and slightly lower among ecologists (increasing 83%).[8] Among the top 110 US universities average research team size in biology increased 52% from 1981 to 1990. With the single exception of medicine, biological collaborations also experienced the greatest growth in average distance between collaborators.[9] Within the European Union, during the period 1998–2003, the life sciences became the most collaborative field after physical, chemical and earth sciences.[10] Collaborations in the life sciences are most often intra-EU collaborations, but they also rank as the second field of extra-EU collaborations.[11]

Quantitative studies clearly indicate a rise in collaboration, but leave unexplored the reasons for this increase and the precise character of the collaborations, begging many questions. One study suggests that the acceleration of collaboration has been made possible by a sharp decline of the costs of collaboration,[12] but is that the only reason, or might the character of scientific questions, their subject matter or the technologies employed also be of influence? Moreover, is the increase driven by purely scientific motives, or do societal developments such as changing demographics increase the interest in human life and health, while issues such as climate change and biodiversity increase interest in non-human life? What can the tendency to collaborate within the European Union tell us? Are we witnessing cultural proximity at work, or can the preference for intra-European collaboration be explained by patterns of research funding? And are collaborations in the life sciences one big category, or can we also find differences within biology when looking into its subdisciplines?

[5] The National Ecological Observatory Network serves as an exemplar of similar shifts in collaborative arrangements in terrestrial ecology.

[6] Adams, JD, Black, GC, Clemmons, JR & Stephan, PE. (2005). "Scientific teams and institutional collaborations: Evidence from U.S. universities, 1981–1999". *Research Policy*, 34(3): 259–285. p. 260.

[7] Wutchy, S, Jones, BF & Uzzi, B. (2007). "The increasing dominance of teams in production of knowledge". *Science*, 316: 1036–1039, pp. 1037.

[8] Ibid. Supplementary Online Materials.

[9] Adams et al., pp. 272–273.

[10] Mattsson, P., Laget, P., Nilsson, A. & C. J. Sundberg (2008). "Intra-EU vs. extra-EU scientific co-publication patterns in EU". *Scientometrics*, 75 (3): 555–574, p 572.

[11] Ibid, p. 565.

[12] Adams, J.D., Black, G. C., Clemmons J. R. & P. E. Stephan (2004) "Scientific teams and institution collaborations: evidence from U.S. Universities, 1981–1999". *NBER Working Paper* 10640.